Better Buildings

Key Drivers for Constructing a Circular Built Environment in the U.S.

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CENTER FOR THE CIRCULAR ECONOMY

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About Us

The Closed Loop Foundation

Based in New York City, the Closed Loop Foundation (CLF) aims to further the research and development needed to build a more circular economy. Since its founding, the Foundation has supported numerous organizations, companies and communities working to reduce food, packaging and plastic waste.

CLF received a grant from 3M to fund and release this body of work, which was prepared by the Center for the Circular Economy. The Center for the Circular Economy ("The Center") is the innovation arm of Closed Loop Partners, a firm focused on building the circular economy. The Center executes research and analytics, unites organizations to tackle complex material challenges and implements systemic change that advances the circular economy.

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Acknowledgements

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In particular, we would like to extend our gratitude to 3M for funding this body of work, helping to fill a current knowledge gap around the built environment and circularity within the U.S., to connect stakeholders and to showcase leading case studies to inspire the acceleration of circularity in the built environment in the U.S. and the spread of equitable economic, social and environmental outcomes.

Disclaimer

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Overview

Constructing Change: Why U.S. Buildings Need a Circular Makeover

The built environment—those man-made structures where we live, work and play—casts a profound impact on our quality of life and well-being.

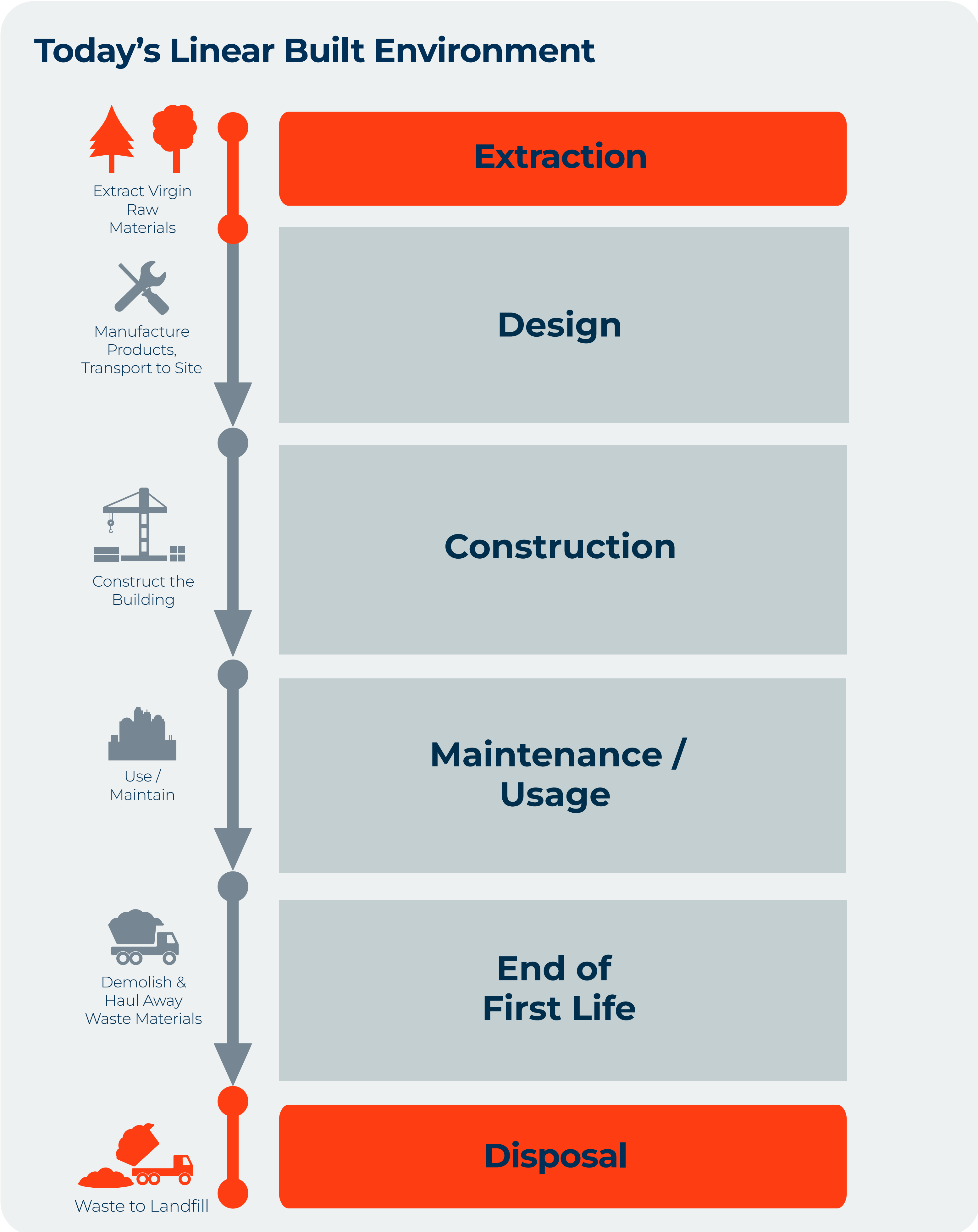
From the air we breathe within office buildings, to the urban heat islands trapping warmth in dense cities, to a community's resilience against extreme weather—the materials composing our buildings shape our surroundings in myriad ways. Yet in our current linear "take-make-waste" economy, these same materials bear a tremendous environmental cost, responsible for 39% of global energy related carbon emissions—28% from operational emissions and 11% specifically tied to materials and construction.[1] Understandably, a strong focus persists in prioritizing Heating, Ventilation and Air Conditioning (HVAC) systems and insulation as key means of curbing emissions from building operations. This report, however, focuses on the materiality of buildings and their lifecycles—a crucial issue, as construction and demolition waste constitute a staggering 30-40%[2] of all globally generated solid waste, with a shocking 30%[3] of materials that are delivered to building sites ultimately ending up discarded as waste.

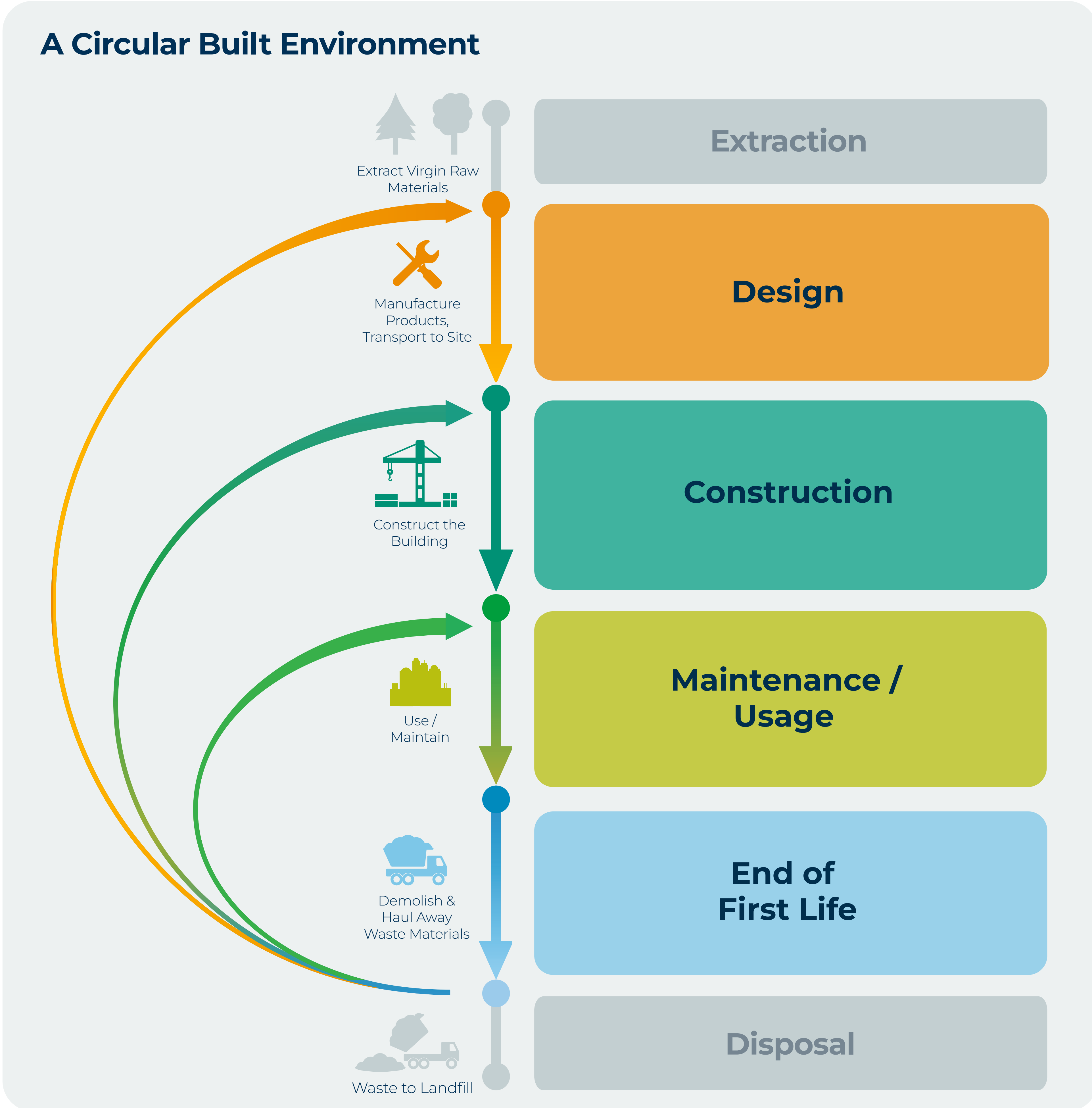
This report puts a spotlight on the U.S., where the magnitude proves equally stark, with the Environmental Protection Agency (EPA) reporting a colossal 600 million tons of construction and demolition debris generated in 2018—over 90% stemming from demolition.[4] In New York City alone, building materials represent 70% of embodied carbon emissions in the built environment and construction and demolition debris makes up over 60% of the city's entire solid waste stream.[5] In North America, it's estimated that the service lives of most buildings are shorter than their theoretical maximum lifespan—meaning that they are destroyed well before their "time is up."[6] This paradigm of treating materials as disposable and the high volume of resulting waste makes clear the urgency of aligning the industry to circular economy principles in the U.S. This begs the question: what needs to be true for this sector to identify a path forward that incorporates circularity while still meeting all the mandates of building functionality, safety and profitability?

The circular economy redefines "waste" as an asset to be kept in use at its highest value for as long as possible through innovative repair, reuse, remanufacturing and recycling strategies. It represents a fundamental overhaul of our prevailing linear economic model, aimed at diminishing our dependence on resource extraction and landfill disposal, thus fostering a more resilient and enduring system. Circularity is not a quick fix, but rather a comprehensive, materials-focused strategy rooted in an economic framework.

At Closed Loop Partners, we believe that there are significant untapped opportunities to keep building structures and components in use through circular principles. Given that the U.S. is still in the nascent stages of this journey, we present this report to elevate examples of the transition specific to the U.S., as well as to spotlight strategies, trends and tools that are helping move the nation in the right direction. To that end, **in this report, we delve into innovation, policy, partnership—with a spotlight on investment—as the essential pillars that can propel circularity in the U.S.** While it is still early days in terms of aligning incentives within this industry to motivate key stakeholders to participate in circular design and implementation, these examples are bright spots in the national landscape, and demonstrate efforts underway that could be built upon if theory, policy and profit coalesce.

Overview


Today's Linear Built Environment
Extract Virgin Raw Materials
Extraction
Manufacture Products, Transport to Site
Design
Construct the Building
Construction
Use / Maintain
Maintenance / Usage
Demolish & Haul Away Waste Materials
End of First Life
Waste to Landfill
Disposal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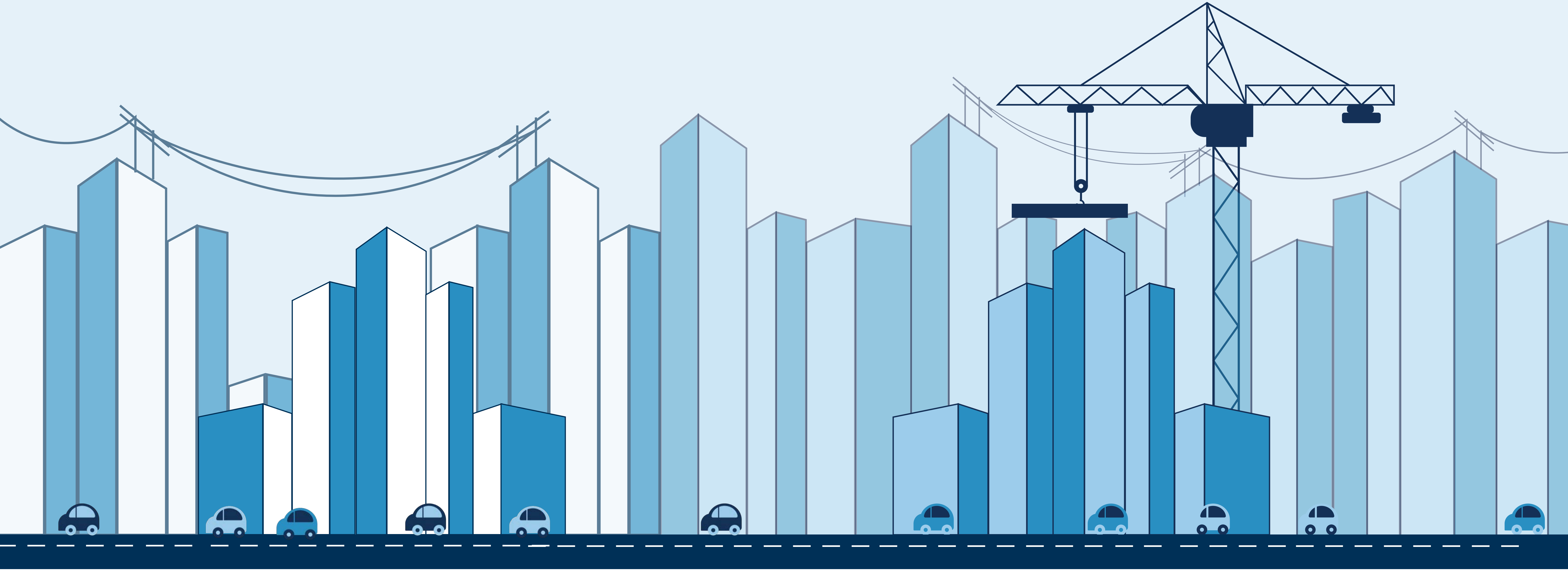
What is the Built Environment?

According to the U.S. Environmental Protection Agency (EPA), the built environment is defined as "the buildings we live in, the distribution systems that provide us with water and electricity, and the roads, bridges and transportation systems we use to get from place to place."[7] For the purposes of this report, we focus solely on the portion of the EPA definition that covers **the buildings that we live, work and play in.**



Key Highlights for a More Circular Built Environment

Prioritizing Adaptive Reuse

When buildings do reach the end of their first use, the greenest path is often adaptive reuse—repurposing, retrofitting or renovating existing, often historic, buildings for new uses instead of tearing them down and constructing new buildings. This approach also aligns with the fundamental waste hierarchy principle of reuse before recycling.[8] A report by the National Trust for Historic Preservation found that new energy-efficient buildings can still take 10 to 80 years to offset the greenhouse gas emissions from their construction through more efficient operations.[9] This highlights the importance of preserving and adaptively reusing existing buildings as a crucial strategy in combating climate change and reducing the environmental impact of the built environment.

Two examples we profile, among others, are **Google's transformation of a 1930s rail terminal structure in New York City** into a corporate office and the conversion of a Sears, Roebuck & Company distribution center into **Ponce City Market in Atlanta**. While the Federal Historic Preservation Tax Incentives program offers a welcome incentive to building owners to adaptively reuse their historic structures, and local and state historic preservation ordinances have a tremendous impact on conserving structures and resources, work still remains to link these conservation practices to the design principles of circularity.

Spotlighting Design Tools

From the initial stages of design and material selection, through the utilization of materials in construction, a wealth of innovative strategies exist to ensure that materials remain actively utilized and in circulation. Design strategies such as Design for Deconstruction play a crucial role in waste prevention by prioritizing materials and construction methods that facilitate easy dismantling or disassembling at the end of a building's useful life. This approach necessitates the use of durable, easily recyclable and non-toxic materials as well as replaceable components while avoiding complex material combinations that hinder separation and recovery processes. **The R.W. Kern Center at Hampshire College** exemplifies many of these principles. It is a mixed-use facility designed for simplicity, accessibility and future deconstruction and reuse, utilizing long-lasting materials like stone and minimizing complex connections, among other strategies.

Innovations like material passports offer detailed information about materials and components used in buildings, infrastructure and products, facilitating their easier disassembly, reuse, recovery or recycling. Although material passports have gained some traction in the European built environment and are being explored in the U.S. textile industry, their adoption in the U.S. construction sector is in its infancy, presenting an opportunity for further expansion. Other technologies like Building Information Modeling (BIM) support the maintenance, use and management of buildings within our built environment, and have been used in applications like the new **Louis Armstrong New Orleans International Airport**. BIM generates virtual models that precisely replicate a building or infrastructure's physical and functional characteristics, aiding in estimating impact and performance assessment and scheduling preventative maintenance through data collected from sensors and simulations.

Key Highlights for a More Circular Built Environment

Deconstruction Over Demolition

When all viable uses for a structure have been exhausted, and destruction of the building is planned, a circular approach affords opportunities for deconstruction rather than demolition. However, most of the existing built environment in the U.S. today was not designed for deconstruction, making economically viable deconstruction challenging. There are growing but limited end markets for salvaged materials marketplaces that connect suppliers of used building materials with architects, designers and contractors seeking more sustainable sourcing options. If a building was not designed for deconstruction or reuse, its components are often too complex and multi-layered to isolate the most valuable raw materials, or the materials are unknown or unidentifiable, risking the integrity and safety of the structure in a next life. A third-party certification or warranty of materials could go a long way in providing professionals who are sourcing materials with the assurance they need of quality and provenance. Ultimately, those harvested materials should be seamlessly integrated into standard supply chains, much as remanufactured parts are an integral part of the automotive industry supply chain.

Modular construction—manufacturing of building components off-site in controlled warehouse environments—may also allow for easier deconstruction, reuse or refurbishment of specific modular formats for renovation or retrofit. In the U.S., there are a growing number of examples of modular construction, from Marriott promoting numerous modular hotels—notably the 26-story, 168-room **AC Hotel New York NoMad**, currently considered the world's tallest modular hotel—to firms like **Factory_OS** leveraging the approach to boost affordable housing supplies.

Policy Matters

Policy is a key catalyst and lever for transitioning toward a more circular built environment across federal, state and city levels in the U.S. On a federal level, the Bipartisan Infrastructure Law (BIL), the CHIPS Act and the Inflation Reduction Act (IRA) will fund nearly half a trillion dollars toward climate technologies and energy infrastructure over the next decade.[10] In particular, **Section 60503 of the IRA** marks a bright spot, making a $2.15 billion investment for the U.S. General Services Administration (GSA) to acquire and install low-carbon construction materials and products with substantially lower levels of embodied carbon.[11] This investment coincides with the Biden-Harris Administration's **Federal Buy Clean Initiative** to leverage federal purchasing power to spur markets for products with reduced embodied emissions.[12]

In March 2023, the Biden-Harris Administration announced the official launch of the **Federal-State Buy Clean Partnership** with 12 leading states—California, Colorado, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, New Jersey, New York, Oregon and Washington—and later welcomed Minnesota into the partnership.[13] However, cities such as **Portland, Oregon** continue to lead the way, showcasing best practices related to circular design principles, including ordinances mandating deconstruction versus demolition of certain buildings.[14]

As part of the U.S. policies influencing circularity in the built environment, green building standards present a significant opportunity—particularly at the corporate policy level—to drive the adoption of circular design principles and low-carbon materials. Certification programs and standards such as **LEED (Leadership in Energy and Environmental Design)** and the **Living Building Challenge** are already incentivizing market adoption of more sustainable building principles.

Key Highlights for a More Circular Built Environment

Aligning Incentives Through Partnerships

A pivotal challenge in fostering circularity within the built environment is the need to **align diverse stakeholder interests**. Fragmentation among stakeholders at various stages of the value chain, such as designers, material suppliers, developers, building managers and demolition crews, presents a significant hurdle, with each entity operating under different incentives and time frames. For example, some interests include: building designers prioritize aesthetics and durability, developers focus on cost and timelines, and building managers aim to maximize occupancy. This discrepancy leads to a split incentive problem, exacerbated by the multitude of stakeholders involved in decision-making processes. Achieving true circularity requires aligning incentives and engaging diverse stakeholders in a collaborative effort, underscoring the importance of partnerships in advancing long-term, systems-based solutions.

Investing Capital

Given the vast size and diversity of needs within the built environment, there is room for every stage of the capital stack, including: **venture capital, growth equity, buyout, real estate investments and project finance, among others**. Unlocking the sector's financing potential involves aligning appropriate financing mechanisms with specific opportunities.

For example, real estate investors historically invest in the buildings themselves and look to have stable dividend-like payouts from rental income on their properties. Managers of real estate investment firms and long-term institutional building owners like universities often bring a longer-term mindset that makes the implementation of best-in-class circular economy principles a possibility at their buildings. Some universities house architecture and design programs that teach their students about the concepts of the circular economy. Can we collectively envision a future in which this theory becomes practice, and the principles taught within campus buildings are applied to new construction on

Key Highlights for a More Circular Built Environment

Inspiring Change

While the U.S. shows promising developments in innovation, policy and partnerships within the built environment sector, much work is still needed. The rapid pace of climate change and the depletion of finite resources lends urgency to the need to prioritize resilient, circular solutions that promote equitable economic, social and environmental outcomes. Achieving true circularity entails keeping materials and products in circulation at their highest value, prioritizing retrofitting, renovating and preserving existing buildings over new construction.

Transitioning from a linear economic model to a circular one involves overcoming financial incentives aligned with the former. While imperfect solutions may arise during this transition, the tools and strategies are available to build a future focused on longevity and reuse, where waste in one context becomes a resource in another. ***This report spotlights where circularity is already underway in the U.S. as a first step to identifying what is possible for the next generation of circular buildings.***

Circular Innovation Spotlight

Calling for Submissions

Have you or your organization developed and implemented a circular solution for the built environment in the U.S.?

Submit your solutions **HERE** for a chance to be highlighted in the innovation series on our website.

Key Highlights for a More Circular Built Environment

In the following chapters, we delve deeper into strategies across key circular economy drivers—**innovation, policy, partnerships**—with a **spotlight on investment**, which stakeholders can utilize to help realize the benefits of circularity in the built environment.

Innovation

This chapter delves into innovative concepts and approaches related to design, materials, data management and end-of-life strategies for the built environment championing circular economy principles within the U.S.

Policy

This chapter provides an overview of federal, state and city regulations in the U.S. that are advancing circularity through mandated emissions reductions, deconstruction ordinances and waste diversion targets. It also examines the roles of government agencies, corporations and other stakeholders in transforming the regulatory landscape of the built environment in the U.S.

Partnerships

This chapter discusses various cross-sector collaboration models such as public-private partnerships, industry alliances and community initiatives that enable systems-level transformation by aligning interests, pooling resources and overcoming fragmentation in America's built environment.

Innovation:

Bedrock Breakthroughs

CHAPTER ONE

Innovation: Bedrock Breakthroughs

Design Out Waste From the Outset

There are significant opportunities for innovation throughout the built environment sector—from the early design stage to the long-term management and maintenance of assets in the built environment. This chapter explores innovative concepts and approaches to reimagine the lifecycle of buildings, highlighting select frameworks and examples that illustrate a path forward for developing a more circular built environment in the U.S.

Circular economy principles aim to design out waste from the very beginning, by making the most of materials already in play. There are many complementary but distinct design philosophies influencing this transformation across different design strategies, such as:

- **Cradle-to-Cradle (C2C) design** prioritizes a biomimetic approach, viewing materials as nutrients circulating in healthy, safe metabolisms.[15]
- **Passive design** minimizes the use of mechanical heating or cooling, taking advantage of the climate to maintain a comfortable temperature range in the home.[16] Key elements include thermal mass, insulation and natural ventilation. Passive design-focused architecture firm, OPAL estimates that a single-family home built with passive design "can be heated on the coldest winter day with the energy equivalent of using a hairdryer."[17]
- **Biophilic design** connects building occupants more closely to nature by incorporating natural elements and patterns into the built environment, promoting sustainability while benefiting human health and productivity.[18]

Each of these design approaches contributes to the principles of the circular economy in the built environment, focusing on resource efficiency and the well-being of occupants.

In this subsection, we see these principles come to life as we explore one example: design for deconstruction.

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- Design Out Waste From the Outset

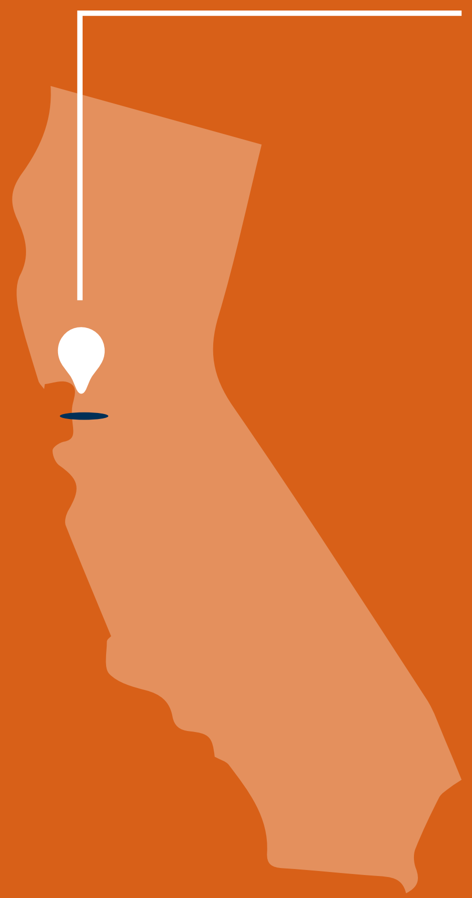
Design for Deconstruction (DfD) involves choosing materials and construction methods in the design process that allow buildings to be more easily dismantled or disassembled—rather than demolished.

This ensures their components can be reused, incorporated into future projects and recycled at the end of their useful life. It requires utilizing materials that are durable, easily recyclable and non-toxic, and avoids combining different materials in a way that makes them difficult to separate and recover at end-of-life. For example, DfD leverages demountable and mechanical connections such as bolts and screws instead of permanent methods like welding and gluing. This design strategy prevents waste creation by enabling reuse of components and facilitates deconstruction, rather than demolition where most materials end up wasted in landfills. This approach is planning-heavy and involves considering the environmental impact of materials, from extraction to recovery and recycling.

The uneven distribution of construction and demolition recovery infrastructure across different regions, coupled with a lack of specialization and widespread buy-in from architects, builders and clients due to nascent market demand, pose significant challenges for mainstream adoption of designing for deconstruction practices in the U.S.

Case Study

Chartwell School, Seaside, California



Chartwell School in Seaside, California is known for educating children with dyslexia and related language learning disabilities. In the early 2000s, the school board embarked on a mission to build a new campus that was deliberately designed for deconstruction. Beams, roof joists and other framing components were also left exposed for students to see how the materials were put together, and to highlight how their design allows for eventual dismantling and reuse.[19]

Case Study

R.W. Kern Center in Amherst, Massachusetts

The R.W. Kern Center is a mixed-use building—home to Admissions, Financial Aid, the Kern café, and student and classroom spaces—on the Hampshire College campus in Amherst, Massachusetts, and is the 17th certified Living Building in the world.[20] The building prioritizes simplicity and accessibility, designed explicitly to enable future deconstruction, reuse or redesign.[21] For example, it leverages long-lasting materials like stone and was also detailed to minimize complex connections to make it easier for construction, reuse or re-design.[22]

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Innovation: Bedrock Breakthroughs

Select Healthy Materials & Extend Material Lifecycles

Scientists have found that there are more human-made materials than biomass, and most of these human-made materials are made up of building materials.[23] At 1,100 gigatonnes, buildings and infrastructure exceeded the mass of all tree and shrubs, which measured at 900 gigatonnes.[24]

At the 2023 U.S. Green Building Council conference and expo in Washington, DC—one of the largest gatherings of green building professionals—a central theme was embodied carbon.[25] Embodied carbon refers to the emissions produced by building materials during extraction, manufacturing and transport to a construction site. Embodied carbon of building materials accounts for approximately 11 percent of global carbon emissions.[26] This focus on embodied carbon spotlighted the growing need to evaluate the environmental footprint of materials. Material choice is therefore an essential consideration in the design process of the built environment because of its impact on environmental sustainability, functionality, health, aesthetics and cost, among other factors.

This subsection explores what opportunities exist to select healthier, more environmentally friendly materials.

Material Innovations

In September 2022, the Biden-Harris Administration launched the Federal Buy Clean Initiative, committing to purchase low-carbon steel, concrete, asphalt and flat glass, which account for 98 percent of purchased construction materials and nearly half of all U.S. manufacturing emissions.[27]

The summary matrix on the following page analyzes material innovations developing in the U.S. around these four materials: concrete, steel, flat glass and asphalt.

Material Innovations in Select Areas

Concrete

Concrete is one of the most widely used construction materials in circulation due to its strength and overall durability. In fact, it is the second-most-used material in the world after water.[28] Concrete production in particular is extremely energy intensive. Researchers estimate roughly 1,370 pounds of CO2 are produced for every metric ton of cement manufactured.[29] Moreover, cement—the main ingredient in concrete–accounts for roughly seven percent of the world's carbon dioxide emissions.[30] Though not a frequent occurrence, concrete can be crushed and reused as aggregate material in new concrete mixtures at the end of its useful life.[31]

Innovation Spotlight: Fortera is a materials technology company headquartered in Silicon Valley that engineers low-carbon dioxide cement by capturing carbon from kiln exhaust.[40]

Brimstone makes cement from carbon-free calcium silicate rock—which is abundant and voluminous at every surface of the world—instead of carbon-heavy limestone, which releases carbon dioxide when processed.[41] Calcium silicate is 100 times more abundant than limestone.[42]

Steel

Steel is mostly made in blast furnaces. The process requires two inputs: iron ore and coal which produce molten iron and carbon dioxide.[32] Like concrete, steel has a high embodied carbon content. For example, every ton of steel produced in 2018 emitted an average of 1.85 tons of carbon dioxide, equating to about eight percent of global carbon dioxide emissions.[33] Steel can be quickly recovered and recycled at the end of a building's life without losing its structural integrity. However, many steel reinforcing bars embedded in concrete structures are difficult to extract and are therefore not recovered. Recycled steel can be used to manufacture new construction materials. Using recycled steel scrap, rather than virgin-based production, reduces carbon dioxide emissions by 70 percent.[34]

Innovation Spotlight: Radius Recycling (formerly Schnitzer Steel), based in Portland, Oregon, has grown into a global leader in the steel industry. The company generates most of its revenues from recycling steel and other metals.[43] Finished steel products made from recycled ferrous metals have a number of applications including providing feedstock for new building development.[44]

Flat Glass

Flat glass is a general term that describes all glass produced in a flat form (i.e., float glass, sheet glass, plate glass and rolled glass) formulated from soda-lime silicates and metal-oxide materials.[35] Flat glass is manufactured by mixing raw materials at high temperatures and floating them onto the surface of a molten tin bath, which smooths the glass by gravity and surface tension.[36] Glass manufacturing is energy intensive and a significant source of greenhouse gas (GHG) emissions from the industrial sector. In 2019, 22 flat glass plants reported direct emissions of 2.95 million metric tons of carbon dioxide equivalents (CO2e) according to the U.S. EPA.[37]

Innovation Spotlight: Pennsylvania-based company, AeroAggregates has a low-emissions glass product called Ultra-Lightweight Foamed Glass, which is made from 99% recycled container glass and is 85% lighter than traditional aggregate.[45] This innovation reduces transportation costs, minimizes environmental impact and has strong insulation and drainage properties.[46]

Asphalt

Asphalt has been used for centuries—dating back to its use in Ancient Egypt to embalm mummies—and today, it is commonly used as a paving material for roads, parking lots and driveways. Asphalt, which is largely derived from crude oil has been shown to release semi-volatile organic compounds that contribute to air pollution, particularly in the form of particulate matter.[38] One study found that emissions from new asphalt paving and roofing in Southern California could lead to 1,000 to 2,500 tons of particulate air pollution annually.[39]

Innovation Spotlight: Green Asphalt is a New York City-based company that manufactures 100 percent recycled asphalt.[47] The company uses technology to convert old asphalt into high-quality, sustainable pavement material. It has paved over five million square feet of roadway in the tri-state area using its recycled asphalt mix.[48]

See 3M™ Cool Roofing Granules on page 20 for additional examples of circular solutions for asphalt.

Select examples of material innovation across the U.S.

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Innovation: Bedrock Breakthroughs

- Select Healthy Materials & Extend Material Lifecycles

Scaling the Use of Regenerative & Healthy Materials in the U.S. Built Environment

Beyond these four materials, an increasing number of circular economy-minded designers are exploring regenerative building materials, such as using timber structural supports as an alternative to steel beams.[49] Nonprofits like Mindful Materials, based in New York City, have also worked to create the **Common Materials Framework** to analyze and organize over 100 of the most common building products and material certifications and disclosures to help guide designers in selecting the most sustainable materials.[50]

While sourcing alternative materials that have a lower carbon footprint tied to their production and manufacturing is better than sourcing those with more energy intensive origins, it is important to look at the entire lifecycle of all materials to truly evaluate their circularity potential. Even if the feedstock for a material is sustainably sourced, if at the end of its useful life it cannot be recovered or re-circulated for another use, true circularity remains elusive.

Circularity aims to keep materials in play at their highest value and best use case. Some of the material innovations in the built environment today remain bridge solutions. They help lower the carbon impact of materials, yet are still not recovered and reused or are merely downcycled at the end of their useful lives.

Case Study

Kendeda Building in Atlanta, Georgia

The Kendeda Building at the Georgia Institute of Technology showcases the importance of selecting healthy materials in circular construction. To meet the Living Building Challenge standards, the project team carefully screened all building materials for hazardous chemicals, prioritizing salvaged and locally-sourced resources.[51] Innovative examples include staircase treads made from repurposed heart pine joists, use of salvaged wood from Tech Tower (one of the first buildings on campus), counters and benches crafted from campus storm-felled trees and flooring from dismantled movie sets.[52] By emphasizing material health and reuse, the Kendeda Building demonstrates how thoughtful selection can contribute to a more circular built environment.

Case Study

Mycocycle, Bolingbrook, Illinois

Mycocycle leverages fungal root structures (mycelium) to consume and eliminate toxins from construction waste, helping produce environmentally safe and sound raw building materials.[53] Bioinspired by fungi, Mycocycle is working to efficiently transform waste materials into valuable low-carbon biobased materials.[54] Their patent-pending products, MycoFILL, MycoFIBER and MycoFOAM can replace the need for virgin raw material extraction and plastic polymers, while offering a low embodied carbon alternative for the industry.[55]

CHAPTER ONE

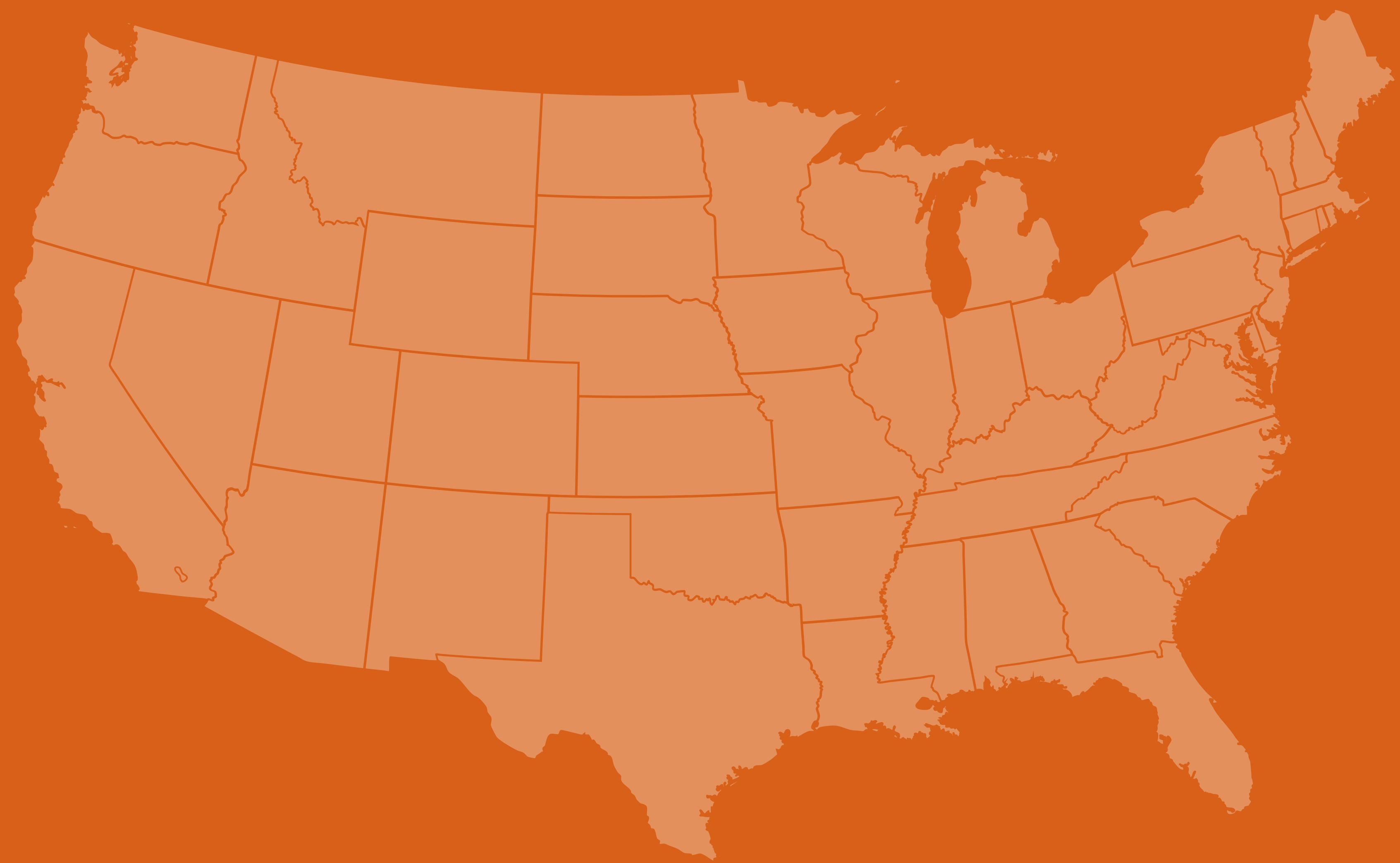
Innovation: Bedrock Breakthroughs

▶ **Select Healthy Materials & Extend Material Lifecycles**

Case Study

3M™ Cool Roofing Granules, U.S.

3M is a multinational company that manufactures thousands of products used in homes, businesses, schools and other industries around the world. Through science and innovation, they have created several products showcasing materials innovation in the built environment. For example, 3M created **3M™ Cool Roofing Granules** with a formulation that increases reflectivity and is designed for use in asphalt shingles.[56] By reflecting sunlight, these granules have a greater cooling effect than traditional shingles, helping reduce urban heating and lower energy consumption in climates with year-round cooling needs.[57] The application of 3M's cool roofing technology could be relevant to cities such as Los Angeles with its Cool Roof ordinance, which mandates cool roofs for new residential construction projects.[58] Los Angeles is the second-largest urban region in the U.S. with the highest heat island effect caused by the dense population of heat-absorbing buildings.[59]



This case study applies to multiple locations in the U.S.

CHAPTER ONE

Innovation: Bedrock Breakthroughs

Build With Innovative Techniques

Building with innovative techniques is crucial for creating a more efficient and resilient built environment. As the construction industry faces well-documented capacity constraints and labor shortages inhibiting growth,[60] the adoption of cutting-edge methods and materials is increasingly important. In fact, construction is one of the least digitalized industries globally.[61] Innovative techniques, such as modular construction, offer numerous benefits that can transform the way we construct our buildings while addressing some of these challenges.

This subsection explores one example of an innovative building method that can revolutionize the construction sector, contributing to a more circular future.

Modular Construction involves manufacturing building components off-site in controlled warehouse environments. These sections or modules can then be easily transported and assembled at the construction site. This method introduces efficiencies of scale, reduces delays and contains costs by eliminating the number of uncontrollable variables, such as weather. However, the widespread adoption of designing for deconstruction methods in the U.S. faces several obstacles. These include, among other challenges, logistical constraints around transporting large modular components, high upfront costs for factory equipment, and potential limitations on architectural creativity due to the prioritization of uniform, repetitive designs tailored for mass production.

Case Study

Carmel Place (formerly My Micro) in Manhattan, New York

In 2016, Brooklyn-based architecture firm **nArchitects** developed a nine-story modular micro-unit residential building on land previously used as a parking lot by the New York City Housing Authority in the Kips Bay neighborhood of Manhattan. The building aimed to serve as a paradigm for cities facing an affordable housing crisis.[62] Each modular unit was prefabricated off-site in Brooklyn and is made of steel frames and concrete slabs.[63] Prefabrication also sped up the construction process, lifting each piece into place by crane. This process could potentially help the team construct at a rate of an entire floor per day.[64]

Case Study

GO Logic in Belfast, Maine

GO Logic is an architecture and construction company which offers a line of predesigned, prefabricated homes.[65] Every home adheres to passive design standards and the building shell is designed to use 80 percent less energy than a conventional new house.[66] Exterior wall panels, interior walls and wooden flooring are all manufactured off-site in a climate controlled factory.[67] The material is then delivered to the building site and craned into place atop a slab-on-grade foundation.[68]

CHAPTER ONE

Innovation: Bedrock Breakthroughs

▶ **Build With Innovative Techniques**

Case Study

Modular AC Hotel New York City, New York

Since 2011, Marriott has seen the average time to build and open a hotel in North America increase by as much as 50 percent.[69] In fact, the average construction time for Marriott properties is twelve months, using traditional building techniques. With prefabrication, the same hotel could be built in seven months or less.[70] This creates a potential financial incentive with prefabricated hotels; reducing construction timelines and accelerating development cycles translate to economic gains.[71] Marriott has opened 31 modular hotels and runs incentive programs to drive modular adoption. In 2018, Marriott broke ground to construct the **AC Hotel New York NoMad**—a 26-story, 168-room hotel—the world's tallest modular hotel.[72] The hotel's design features prefabricated hotel room units that arrive fully complete at the hotel site before being lifted into place by crane.[73]

Case Study

Factory_OS in San Francisco Bay Area, California

Factory_OS is a construction company based in California's Bay Area that transformed a former Naval submarine plant into a modular apartment factory, where units are put together on an assembly line before being transported to building sites.[74] This model allows Factory_OS to construct apartment buildings in nearly half the time of conventional methods, with a more streamlined process.[75]

Factory_OS is primarily focused on affordable housing. So far, they have completed 10 buildings with roughly 1,200 units in Northern California.[76] Driven by strong demand, Factory_OS has expanded with a second production facility handling 24 upcoming projects and is planning to open a third factory in Los Angeles in the next two years.[77]

CHAPTER ONE

Innovation: Bedrock Breakthroughs

Harness the Power of Data to Maximize Access & Usability of Materials

Data plays a critical role in a more circular built environment by enabling more informed decision-making. By monitoring and measuring performance, data helps optimize resource use and energy use, and reduce waste. It also enables effective material reuse and recycling. The use of buildings as material banks (BAMBs) is a concept that views buildings as repositories of valuable resources from which all stakeholders along the building value chain can recover, reuse or upcycle value. BAMB solutions enable circularity in the construction industry along the entire building lifecycle on three levels: materials, components and buildings. Combining digital tools like building information modeling, material passports and platforms with circular design and deconstruction enables the shift to reuse.

In this subsection, we will explore how data can play a more significant role in tracking material locations and properties. This can maximize access to previously used materials through Building Information Modeling (BIM) and Material Passports.

CHAPTER ONE

Innovation: Bedrock Breakthroughs

- Harness the Power of Data to Maximize Access & Usability of Materials

Building Information Modeling

Building Information Modeling (BIM) can support the maintenance, use and management of buildings in our built environment. BIM creates virtual models that precisely represent a building or infrastructure's physical and functional characteristics.[78] These representations are created using data collected from sensors and simulations, among other sources, and they mimic the behavior, characteristics and interactions of the built environment in a digital environment, which helps assess performance and schedule preventative maintenance.[79]

Material Passports

Material passports are emerging as a critical tool for enabling circular economy principles in the building and construction industry. These digital documents contain detailed information about the materials and components used in buildings, infrastructure and products—including data on their origin, properties, installation, use and maintenance. Material passports aim to preserve information about materials so that at the end of their useful life, they can be more easily disassembled, reused, recovered or recycled.[80] This transparency around material composition supports better decision-making regarding the recovery, repurposing and recycling of materials after deconstruction or demolition, including helping architects more easily select building materials that are, for example, non-toxic.[81]

Although material passports have gained some traction in the European built environment and are being explored in the U.S. textile industry, their adoption in the U.S. construction sector remains limited, presenting an opportunity for expansion.

However, it is essential to recognize that many of these innovations in data and transparency, which bolster circularity, also come with an associated carbon footprint. There is a carbon cost and footprint to data generation and storage that warrants further exploration for better comprehension.[82]

Case Study

New Orleans International Airport, New Orleans, Louisiana

BIM technology implemented by Pinnacle Infotech helped streamline construction of **New Orleans' International Airport** through collaborative digital processes. In this project, the airport's overall BIM model was organized into different sections or zones based on location within the terminal.[83] Breaking down the model helped specialized teams such as architects, engineers and contractors focus their efforts and skillsets on areas and reduced the likelihood of errors or rework. By minimizing the need for costly and time-consuming changes during construction, the zoned BIM model helped conserve materials and prevent waste. Dividing up the building information into more manageable file sizes also aided with handling and sharing of data among team members.[84] This efficient data management reduced the risk of technical issues and data loss, which could have led to unnecessary material waste and duplication of efforts. Overall, taking a zoned approach to the BIM model enabled a smoother, glitch-free construction process for the airport modernization project.

Case Study

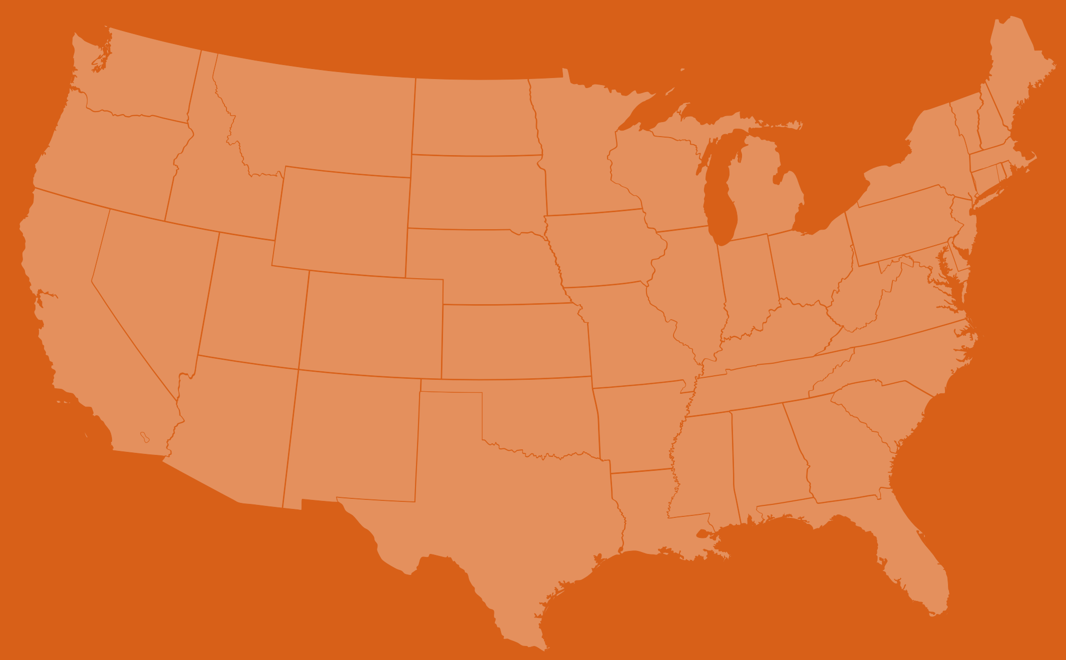
Building Transparency's Embodied Carbon Construction Calculator, U.S.

Building Transparency is a Washington State nonprofit dedicated to sustainability in construction. Their **Embodied Carbon in Construction (EC3)** tool exemplifies the power of data in driving circularity in the built environment. By providing open access to a comprehensive database of construction Environmental Product Declarations (EPDs), EC3 enables architects, engineers and contractors to make informed decisions about material selection and procurement, optimizing resource use and reducing embodied carbon emissions.[85] The tool allows users to compare product-specific EPD data, set material category targets and track progress towards climate goals. EC3's digital EPD platform and automation capabilities streamline the process of verifying and standardizing EPD data, supporting accuracy and transparency.[86]

Case Study

PCL Construction's Job Site Insights, U.S.

PCL, a construction company with U.S. head offices in Denver, Colorado, has been utilizing modular construction for over 30 years. PCL's modular construction services leverage BIM technologies through their bespoke platform, **Job Site Insights (JSI)**, which collects and analyzes data to provide real-time monitoring, threshold alerting and insights to make more data-driven decisions.[87] JSI uses embedded sensors—which are strategically located throughout buildings under construction—that collect actionable data such as moisture levels, temperature, concrete curing time, localized job-site weather, sound, vibration, water leaks, volatile organic compounds and frost levels in the ground.[88] PCL also continues to explore how to leverage advanced technology in construction such as the procurement of robots for its project sites.[89]



These case studies apply to multiple locations in the U.S.

Grow Alternative Service Models

The traditional approach to building ownership and operation often prioritizes short-term cost savings over long-term sustainability and resilience. However, the emergence of alternative service models, such as rental, presents new opportunities for the built environment to embrace circular principles, starting with the furnishing of buildings. These innovative business models challenge the conventional notion of single-use, disposable materials and instead promote the idea of maintaining, repairing and extending the lifespan of building components to maximize their value. By shifting focus from ownership and replacement to retrofit and access, these alternative service models can significantly reduce waste, conserve resources and create more adaptable, resilient buildings.

Research suggests that younger generations, such as millennials, are more inclined to rent, lease or share items such as clothes, cars or houses compared to previous generations.[90]

The popularity of rental models among these demographics highlights a cultural shift toward valuing sustainable functionality over possession. These models present opportunities for companies to rethink existing business models. When it comes to the built environment, how buildings are furnished is also evolving, with rental models developing for different items, from furniture to lighting.

This subsection explores alternative circular business models that are gaining traction in the built environment such as product-as-a-service and rental models applied to furnishings as a starting point.

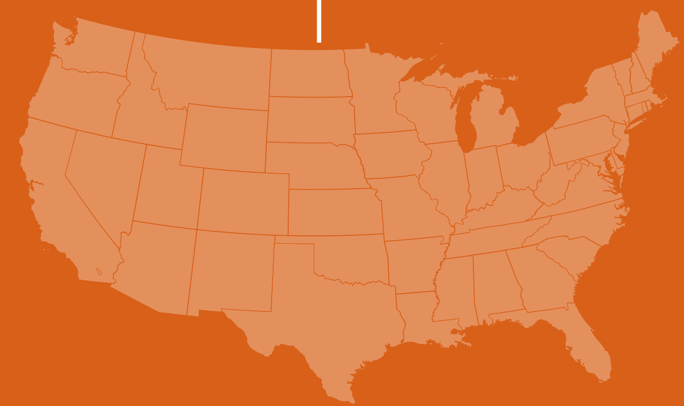
Case Study

Feather in New York City, New York

Launched in 2017, **Feather** is a subscription service for furniture, decor and commercial office applications. Members can subscribe to individual pieces such as sofas, beds or desks, especially useful for those who move to cities for shorter term stays.[91] As more people, particularly in cities, move away from traditional ownership, flexible subscriptions could disrupt existing housing and office norms.

Case Study

U.S. Light Emitting Diode (LED) National, U.S.



This case study applies to multiple locations in the U.S.

U.S. LED's "Lighting as a Service" (LaaS) offering installs, maintains and upgrades LED lighting systems for clients who pay a monthly subscription fee.[92] LaaS eliminates upfront capital investments by tenants or building owners to own the luminaires, making the initial decision to retrofit to energy-efficient technology more attractive while also extending the life of the luminaires avoiding them going to landfill. By retaining ownership of the equipment, U.S. LED ensures proper maintenance, repair and disposal throughout the product lifecycle, enabling effective recycling and refurbishment. The model incentivizes the design and manufacture of durable, long-lasting and easily repairable lighting solutions that align with circular economy principles.

CHAPTER ONE

Innovation: Bedrock Breakthroughs

Retain & Extend Material Value Through Reuse & Preservation

In the current linear "take-make-waste" model that defines our built environment, buildings are typically demolished at the end of their life, with valuable construction materials sent to landfills. This wasteful approach not only contributes to environmental degradation but also squanders the embodied energy and materials invested in the original construction. Circular principles turn this notion upside down by offering alternative approaches to waste reduction and resource conservation.

This subsection explores how reuse marketplaces and adaptive reuse can help retain and extend material value. Reuse marketplaces provide a platform for salvaged building materials to find new life in other projects, while adaptive reuse breathes new life into existing structures by repurposing them for different functions.

Reuse materials marketplaces are paving the way toward more robust end markets for recovered materials. These markets help create the demand to incentivize increased materials recovery in the built environment. The growth of new strategies like design for deconstruction move the sector away from demolition and landfilling. Instead, it creates opportunities to salvage, reuse and resell materials from buildings and infrastructure that would otherwise be destined for demolition and their materials sent to landfill. However, most of the built environment in the U.S. today was not designed for deconstruction or reuse, and therefore, economically viable deconstruction remains challenging.[93] Typically, buildings from the 1960s onward contain more composite materials that are difficult to disassemble and reuse.[94] There are budding but limited end markets for salvaged materials marketplaces that connect suppliers of used building materials with architects, designers and contractors looking for more sustainable sourcing options.

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One of the significant challenges of material reuse in construction today is the increased labor required, as the process involves additional steps such as load testing, cleaning, processing, and transportation between building sites and facilities to ensure components can be safely re-installed in different buildings; however, this challenge also presents an opportunity to create more jobs and foster a thriving labor economy within the material reuse sector.

Another significant challenge in material reuse is the storage of materials, as demolition and construction sites rarely operate in sync, necessitating the need for dedicated spaces to house components once they are deconstructed. This storage issue must be carefully considered and integrated into the economic ecosystem of a circular built environment, presenting an opportunity for innovation and creative solutions, as well as the potential to create accessible marketplaces for used materials that have been deconstructed and are awaiting reuse.

Case Study

ReBuilding Center, Portland, Oregon

ReBuilding Center is a nonprofit organization founded in 1997 and operating in Portland, Oregon with the mission to make building material reuse and home repair skills more accessible.[95] Their 30,000 square foot store is stocked with salvaged building materials from deconstructed and renovated homes in the area and new materials from partnerships with the construction and development industry.[96] Since inception, they have provided supplies to over one million community members and diverted 35,000 tons of reusable building materials from landfills.[97] Their wide selection of items, from doors to lighting to lumber, is sold at affordable prices to ensure people can equitably access the materials they need to safely repair their homes.[98] ReBuilding Center also offers classes to teach repair skills like carpentry, empowering homeowners to maintain their most valuable asset.[99]

CHAPTER ONE

Innovation: Bedrock Breakthroughs

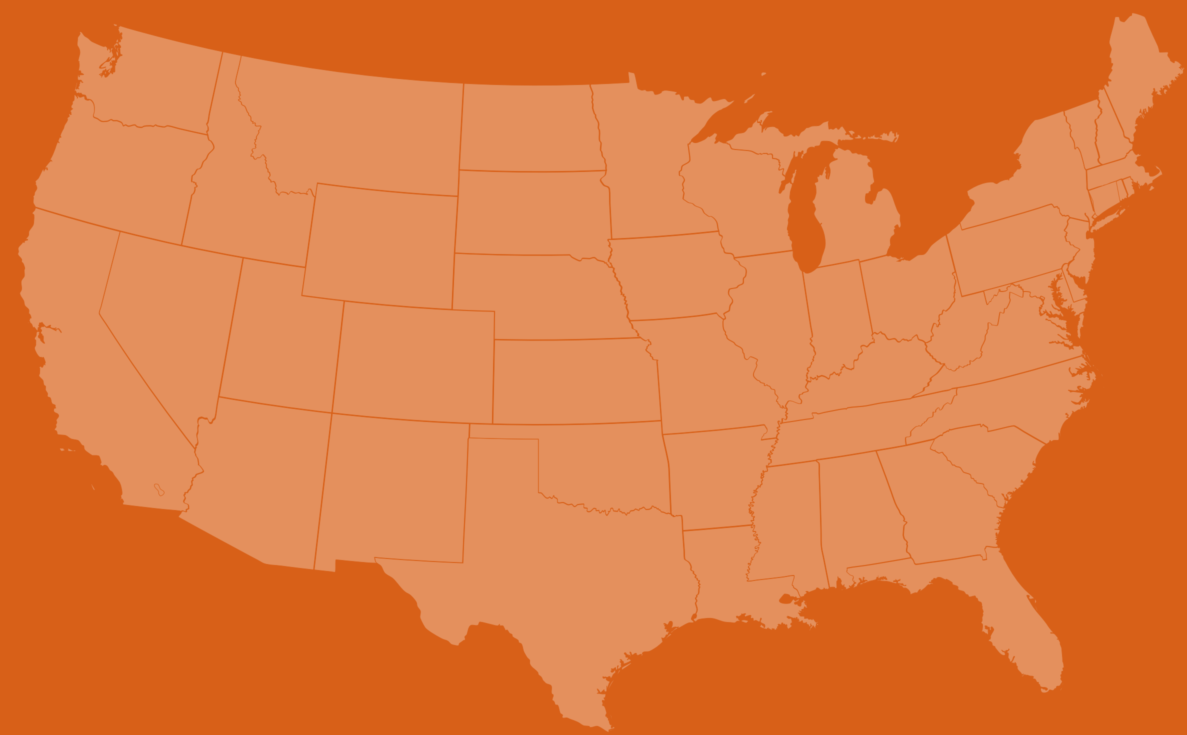
▶ **Retain & Extend Material Value Through Reuse & Preservation**

Case Study

Rheaply

Rheaply, headquarted in Chicago, provides an online platform and asset management technology to enable the reuse of furniture, fixtures, equipment and building materials.[100] Rheaply's exchange platform helps individual users, on behalf of their organizations, list and redistribute their surplus assets on their Rheaply storefront.[101] The digital exchange and inventory system streamlines the reuse process, providing visibility, tracking and analytics. For large clear-outs and decommissions, organizations can leverage the company's reuse services, including boots-on-the-ground support.[102]

In 2023, Google sponsored the launch of Rheaply's free-to-join New York City Reuse Marketplace in the tri-state Area, which includes New York, New Jersey and Connecticut.[103] This is a significant initiative for the region given that New York City alone produces an estimated 14 million tons of trash annually.[104] The initiative also aligns with the city's climate goals, which include reducing greenhouse gas emissions by 80% by 2050 and achieving carbon neutrality by the same year.[105] By adopting a circular economy, businesses in the area can reduce costs and landfill waste while simultaneously keeping valuable products and materials in use.



This case study applies to multiple locations in the U.S.

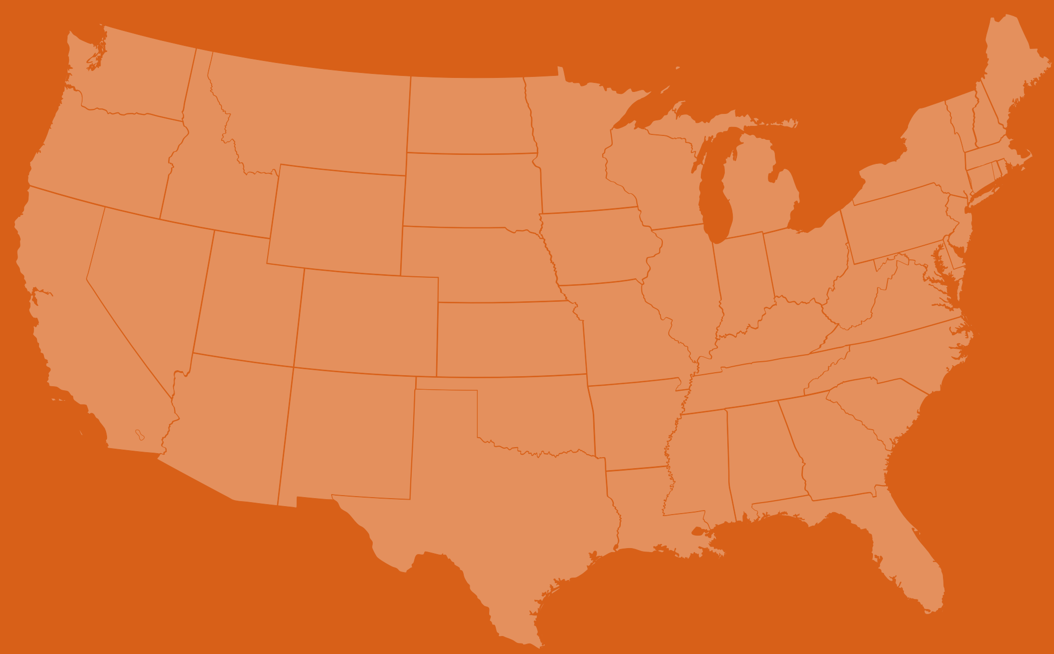
Case Study
Habitat ReStores, U.S.

Habitat ReStores are independently owned reuse stores operated by local Habitat for Humanity organizations, which sell new and gently used furniture, appliances, home goods, building materials and more—keeping valuable items and materials out of landfills and redirecting them to low-income families.[106] ReStores also help fund the work of local Habitat for Humanity affiliates by selling donated goods to the public at a fraction of the retail price. Profits then go towards building affordable housing in local communities for families in need.[107]

Case Study
Doors Unhinged & All for Reuse, U.S.

In 2018, Andrew Ellsworth founded **Doors Unhinged**, which sells reclaimed commercial door systems providing a zero-carbon door option in the U.S for new builds and renovations serving industries like retail, medical, education and multifamily residential.[108] During his time as an architect, green building consultant and environmental health advisor in the early 2000's, Ellsworth had seen firsthand the level of demolition waste and the potential opportunity for recovery of valuable materials and products, such as doors.[109]

Ellsworth, in partnership with Arup, also launched the **All for Reuse** initiative, which "aims to develop a network of building professionals committed to the reuse of commercial building materials."[110] This initiative and convening of professionals helps stimulate demand for reclaimed materials and fosters the creation of new commercial reuse enterprises across the nation.



These case studies apply to multiple locations in the U.S.

CHAPTER ONE

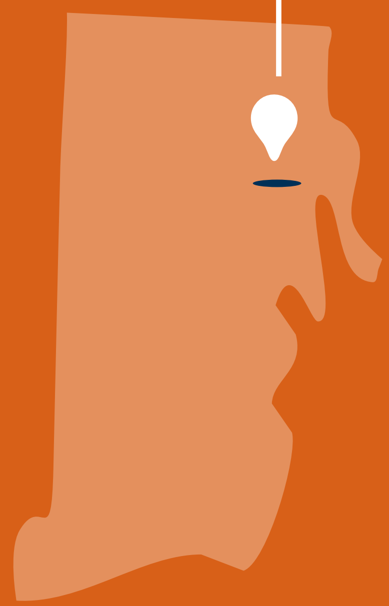
Innovation: Bedrock Breakthroughs

- Retain & Extend Material Value Through Reuse & Preservation

Adaptive Reuse involves repurposing, retrofitting or renovating existing, often historic, buildings for new uses rather than tearing them down and constructing a new building. This process requires evaluating the existing building's structural integrity, mechanical systems and layout to understand the feasibility and scope of adaptation. Retaining some of the building's existing materials eliminates the need to extract new materials and avoids the carbon emissions associated with the extraction. By repurposing historic buildings, cities can maintain their cultural identity, connect with their past and promote a sense of belonging. The significant structural and system upgrades that are often required for adaptive reuse projects, along with strict regulations governing modifications—especially for historically designated buildings—can make obtaining necessary approvals, permits and documentation challenging and costly.

Case Study

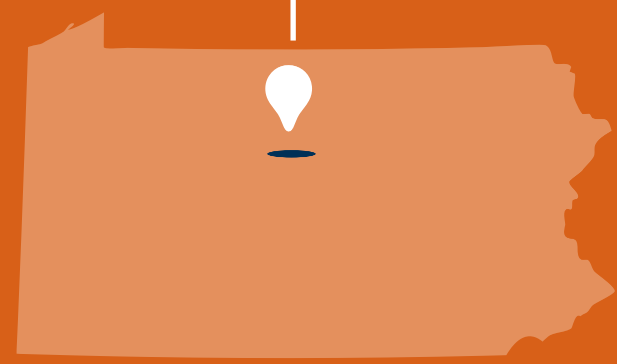
The Steel Yard in Providence, Rhode Island



In 2002, the owners of the **Steel Yard and Klopfer Martin Design Group** embarked on a collaborative project to revamp a vacant steel fabrication facility in Providence, Rhode Island into an arts-based, non-profit center.[111] Instead of demolishing the industrial space, they renovated the existing structures to create a communal space for artists. The process involved peeling away the existing structures, exposing the steel frame and installing workspaces for artists and makers. The team also collaborated with local artists to make creative furniture from existing sources, such as tracks and trashcans.[112] Today, the Steel Yard is "a reclaimed urban landscape that represents the neighborhood's industrial history while also offering a campus for industrial arts education, workforce training and small-scale manufacturing."[113]

Case Study

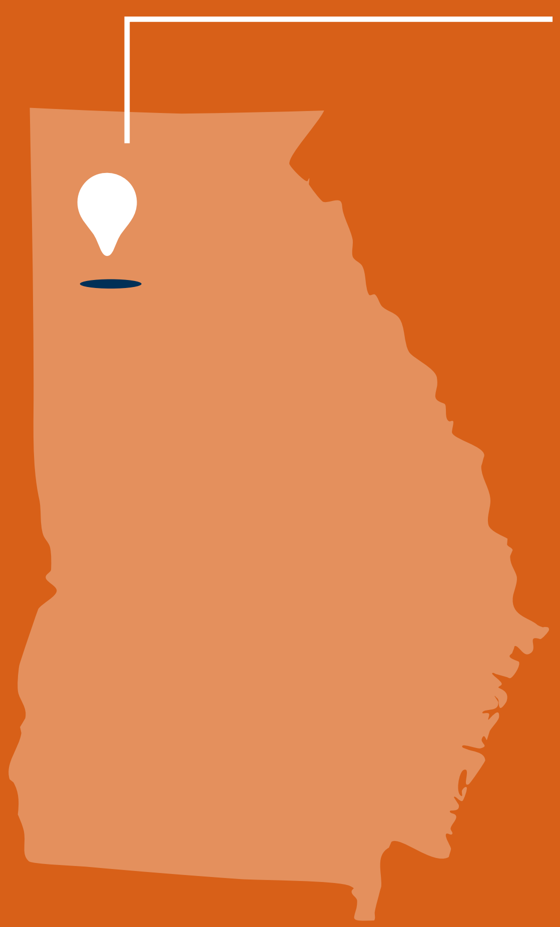
Swift Factory in North East Hartford, Connecticut



The **Swift Factory**, based in North East Hartford, Connecticut was a nineteenth-century factory that was redeveloped by the non-profit developer, Community Solutions, into a vibrant community hub and small business incubator.[114] The project is an example of adaptive reuse, as it transformed a historical factory into a sustainable mixed-use development that might have otherwise fallen into disuse or faced demolition. Features of the restored structure also foster economic and environmental resilience. For example, the main factory building has tall windows to let in natural light, without needing to rely on electric lighting and rain gardens on the site help manage stormwater, diverting the burden on municipal sewers.[115]

Case Study

Ponce City Market, Atlanta, Georgia



Ponce City Market in Atlanta demonstrates how historic preservation can unlock new value and circularity in aging urban properties. Initially built in the 1920s as a Sears distribution center, the 2.1 million square foot former warehouse fell into disrepair over several decades.[116] In 2011, real estate developer Jamestown Properties purchased the site and spearheaded a $300 million adaptive reuse initiative.[117] The project team retrofitted original features like concrete columns, hardwood floors and steel-frame windows while transforming the space for mixed use.[118] Circular best practices underpinned the reuse project, like recycling 98% of construction waste and integrating efficient water systems.[119] Today, Ponce City Market houses offices, residential units, restaurants, retail spaces and a food hall.[120]

Case Study

CO Adaptive Architecture in Brooklyn, New York

CO Adaptive Architecture is an architecture design firm focused on “retrofitting existing building stock to create energy efficient and climate-resilient environments, with the goal of extending the lifespans of these buildings for many decades to come.”[121] Part of this work includes a focus on adaptive reuse. One example of CO Adaptive’s work is the Mercury Store in Gowanus, Brooklyn, which repurposed an industrial warehouse building into a performing arts center where they also aimed to use less drywall and interior finishes to reduce embodied carbon of the project.[122]

Case Study

Google, St. John’s Terminal, New York City, New York

St. John’s Terminal, Google’s newest office in New York City, is a prime example of adaptive reuse. The project transformed the original rail terminal structure from the 1930s, reducing carbon emissions and enhancing the local ecology.[123] By adapting the existing structure and foundation, Google estimates that this project saved approximately 78,400 metric tons of CO2e emissions compared to creating a new structural foundation (equivalent to removing roughly 17,000 cars from the road for a year).[124] The building’s design incorporates 1.5 acres of vegetation at street level, in rail bed gardens and on terraces, redefining the concept of “green space” in commercial real estate.[125] Over 95% of the exterior plants are native to New York State, contributing to the local ecology and creating habitats for over 40 bird species, as observed by NYC Audubon.[126] St John’s Terminal also incorporates solar panels, rainwater retention and reclaimed wood from the Coney Island boardwalk after Hurricane Sandy, giving these materials a second life, reducing waste and preserving resources.[127] St. John’s Terminal showcases how circular economy principles through adaptive reuse can create a space that respects the site’s history and contributes to the local community and environment.

St. John’s Terminal represents just one example of Google’s circular building initiatives and adaptive reuse approach. Another notable project is Google’s Playa Vista office in Los Angeles, which is housed in an aircraft hangar built in 1943.[128]

Case Study

TenBerke, New York City, New York

TenBerke, formerly known as Deborah Berke Partners, is a New York-based architecture studio.[129] Founded by Deborah Berke, who has been serving as the Dean of the School of Architecture at Yale since 2016, the firm's early works focused on helping artists reinhabit industrial buildings for living and working.[130]

Known for their innovative renovations of older buildings, TenBerke has transformed structures such as a massive, long-abandoned psychiatric hospital in Buffalo, New York into a boutique hotel and revamped former industrial buildings into an arts and community incubator.[131] Berke views recycling existing buildings as an opportunity for cities to encourage cultural continuity and move beyond generic expectations of what older structures can become in a rapidly changing world.[132] In their whitepaper on Adaptive Reuse, TenBerke concludes that "adapted structures emit less carbon over their lifespan compared to new construction that accepts a carbon debt from preceding demolition."[133]

Policy:
Building Allied Agendas

CHAPTER TWO

Policy: Building Allied Agendas

Achieving a circular built environment necessitates strategic policy interventions across multiple levels of governance—federal, state and municipal—in addition to private sector leadership through corporate policies and green building standards.

In this chapter, we give a broad overview of federal and state mandates tackling the challenge of embodied carbon, dive into city-level policies, share an analysis of how corporate policies can integrate circularity through green building standards and conclude with a landscape of the key stakeholders who can help galvanize a shift to a more circular built environment.

Federal-State Partnerships to Combat Embodied Carbon

Combined, the Bipartisan Infrastructure Law (BIL), the CHIPS Act and the Inflation Reduction Act (IRA) will fund nearly half a trillion dollars toward climate technologies and energy infrastructure over the next decade.[134]

The IRA alone represents the single largest investment in climate and energy in American history.[135] IRA Section 60503 made a $2.15 billion investment for the U.S. General Services Administration (GSA) to acquire and install low-carbon construction materials and products with substantially lower levels of embodied carbon.[136] As previously mentioned, embodied carbon of building materials accounts for approximately 11 percent of global carbon emissions.[137] This investment coincides with the Biden-Harris Administration's **Federal Buy Clean Initiative** to use federal purchasing power to spur markets for products with reduced embodied emissions.[138] This aims to help the GSA purchase American-made products with lower greenhouse gas emissions associated with raw materials, transportation and manufacturing.

While federal standards lay the foundation, state governments emerge as critical players in crafting circular strategies tailored to their unique regional contexts, thereby acknowledging the diversity of conditions and demands across different localities. By championing building guidelines tailored to their local contexts, states can pilot sustainability models and demonstrate proof of concept for scaling at the national level. As significant purchasers of construction materials, state governments were early adopters of Buy Clean initiatives. Today, interest in adopting Buy Clean policies continues to grow among Governors' offices and state legislatures.[139] In March 2023, the Biden-Harris Administration announced the official launch of the **Federal-State Buy Clean Partnership** with 12 leading states—California, Colorado, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, New Jersey, New York, Oregon and Washington—and later welcomed Minnesota into the partnership.[140]

Case Study

New York State Buy Clean Concrete Guidelines

Starting January 1, 2025, **New York State (NYS) will require Environmental Product Declarations (EPD) for all concrete mixes on all state construction projects**.[141] The U.S. Department of Transportation's Federal Highway Administration defines an EPD as a "transparent, third-party verified report that communicates the impacts from resource use, energy and emissions."[142] EPDs, which function as part of the NYS Buy Clean Concrete guidelines, provide an opportunity to reduce negative environmental impacts by transforming the project delivery process.[143] The law is intended to increase the use and innovation of low-carbon concrete in state procurement projects.

Case Study

California Becomes First State to Mandate Reduction of Embodied Carbon

In October 2023, **California became the first state to mandate embodied carbon reduction** when the California Building Standards Commission and the Division of the State Architect voted unanimously in favor of two building code changes.[144] The two code changes, which will take effect on July 1, 2024, aim to reduce embodied carbon emissions in the construction, renovation or adaptive reuse of commercial buildings larger than 100,000 square feet and schools over 50,000 square feet.[145]

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Policy: Building Allied Agendas

Municipal-Level Initiatives Shaping Regional Circularity in the Built Environment

Municipal-level policies in the U.S. serve as laboratories for testing novel approaches to circularity before broader replication. These ordinances often act as incubators for innovative waste reduction strategies. This decentralization of policy implementation encourages dynamic strategies that can be scaled up or adapted in a broader context.

Case Study

Deconstruction Ordinance in Portland, Oregon

On October 31, 2016, the **Portland City Council adopted an ordinance,** including code language, which requires certain buildings built in 1916 or earlier to seek a demolition permit to be deconstructed instead of mechanically demolished.[146] The approval of this ordinance was unanimous and placed Portland as the first city in the U.S. to ensure that valuable materials are salvaged for reuse instead of landfilled. In 2020, after a successful first three years, the city expanded the ordinance's scope to include houses and duplexes built in 1940 or earlier.[147] The policy aims to address demolition waste, which represents nearly a quarter of local landfill disposal, salvaging reusable building assets like framing lumber for affordable housing projects. The successes of this policy have inspired multiple other cities to follow suit, including Milwaukee, WI; San Antonio, TX; Palo Alto and San Jose, CA.[148]

Case Study

San Francisco Construction and Demolition Debris Recovery Ordinance

Effective January 1, 2022, **San Francisco implemented strict new requirements to reduce waste from construction and demolition projects.**[149] Ordinance 144-21 mandates that all mixed construction and demolition debris be recycled or reused.[150] According to the ordinance, no construction and demolition debris can be transported to or disposed of in a landfill or incinerator or in a designated trash bin.[151] Impacted projects must also demonstrate a successful recovery rate of at least 75 percent of construction debris generated by that project.[152] Rigorous reporting and third-party audits help ensure programs stay on track. These robust diversion targets, paired with tight waste flow control through permitted operators, aim to drive San Francisco's ambitious goal of reaching "zero waste" by 2030.

Case Study

City of San Antonio Deconstruction & Circular Economy Program

Established to begin transitioning the city to a circular economy, **San Antonio's Deconstruction & Circular Economy Program** is a pioneering effort focused on reframing building material waste as a valuable social, cultural and environmental resource.[153] In their 2021 Treasure in the Walls report, they estimated that current policies in San Antonio supported a linear waste stream, sending over $1.4 million worth of salvageable materials to landfill annually since 2009.[154] In September 2022, the city council of San Antonio adopted a deconstruction ordinance requiring certain demolition projects to be deconstructed, ensuring materials are salvaged for reuse instead of being landfilled.[155] The program's website serves as an information hub from details on the deconstruction policy, to a list of trained deconstruction contractors, to tips for reusing building materials.[156] To further support circularity, San Antonio established the **Material Innovation Center (MIC)** at the former Kelly Airfield, which was originally constructed to house military officers.[157] The MIC serves as a "last stop before the landfill" by intaking reclaimed and surplus building materials donated by local contractors, businesses and individuals and redirecting them for free into three categories: (1) affordable housing repair and production, (2) trades and design education, (3) community impact projects.[158]

To date, the MIC has supplied materials to five affordable housing rehabs, more than twenty educational projects (including a groundbreaking research report on utilizing reclaimed building materials for the construction of accessory dwelling units, or ADUs), and numerous community impact projects, including public art and shade structures.[159]

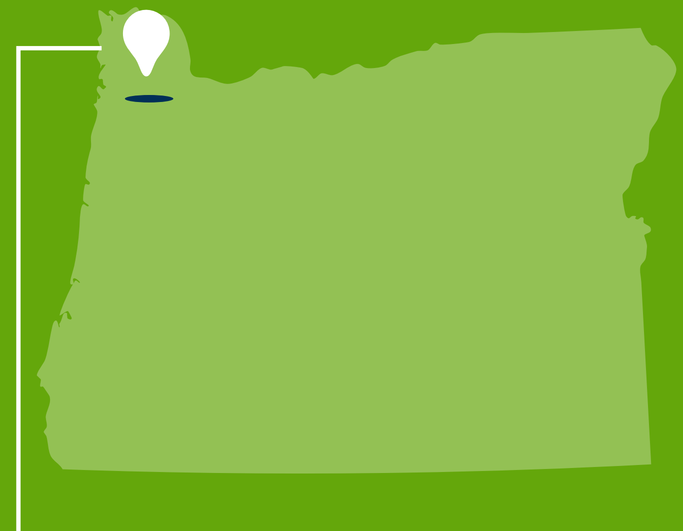
Case Study

City of Phoenix, Adaptive Reuse Incentive

The City of Phoenix's Adaptive Reuse Program began as a pilot program in April 2008, and today is one of the most comprehensive programs of its kind in the U.S.[160] An eligible adaptive reuse project may utilize up to $7,000 in financial incentives toward site plan and commercial construction plan review, and permit fees to establish new occupancy.[161] Eligible projects under 25,000 square feet can utilize the incentives for permitting and plans when establishing a new occupancy in a structure built before the year 2000.[162] The program aims to spur economic growth by making renovations more affordable and promoting small businesses, while also advocating for the sustainable reuse of existing buildings that preserve the city's history.[163]

Case Study

EcoDistrict in Seattle, Washington



Funded by the Bullit Foundation and led by Capitol Hill Housing, the **Capitol Hill EcoDistrict** in Seattle's Capitol Hill neighborhood sought to improve the sustainability of the community and equity of its constituents.[168] EcoDistricts provide a framework for advancing sustainability through behavior change, building design and infrastructure investments.[169] The EcoDistrict is now partnering with the Seattle 2030 District, a high-performance business district in downtown Seattle, that aims to reduce carbon emissions by 50 percent by 2030.[164] In 2015, Seattle's City Council formally passed a resolution recognizing the EcoDistrict.[165]

In cities across the U.S. and globally, EcoDistricts are being developed to improve environmental and social performance at a scale that extends beyond the building site alone.[166] The Capitol Hill EcoDistrict was the first EcoDistrict in the Pacific Northwest to become certified in 2021.[167]

Replicating and expanding upon these initiatives across some of the most populated metropolises in the U.S. offers immense potential to mainstream local decentralized solutions.

Case Study

Decarbonization Efforts in New York City, New York

In 2019, New York City passed **Local Law 97 (LL97)**, which aims to mandate caps on greenhouse gas emissions of covered buildings that exceed 25,000 gross square feet to help New York City reach the goal of a 40 percent reduction in greenhouse gas emissions from buildings by 2030 and 80 percent reduction in citywide emissions by 2050.[170] The buildings covered by Local Law 97 will be required to file a report—certified by a registered design professional—with the Department of Buildings by May 1, 2025, detailing their annual greenhouse gas emissions by May 1 of every year after.[171] The law states: "*An owner of a covered building who submits a report indicating their building exceeded its annual building emissions limit will be liable for a civil penalty equal to the difference between the building emissions limit for that timeframe and the reported building emissions for that year. Building owners who fail to submit their report on their buildings' energy usage will face penalties and fines.*"[172]

In response to enforcement of LL97 and mounting requirements to decarbonize, Mayor Eric Adams, the New York City Economic Development Corporation (NYCEDC) and the Mayor's Office of Talent and Workforce Development (NYCTalent) announced the release of the Green Economy Action Plan that seeks to revolutionize a path forward for cleaner construction and low carbon buildings.[173]

To that end, NYCEDC released the ***Clean and Circular: Design and Construction Guidelines*** in March 2024 to offer an operational guide to reduce waste and embodied carbon in the city's built environment.[174] More specifically, the guidelines will "a) reduce embodied carbon and waste within NYCEDC capital projects, b) develop knowledge and capacity across industry stakeholders and c) drive demand for cleaner and more circular design and construction across NYC."[175] One application of these guidelines is the NYC Mass Timber Studio, a first-of-its-kind technical assistance program designed to support active mass timber development projects in the early phases of project planning and design.[176] Expanding the use of mass timber is critical as it is a natural, renewable and sustainable material with a lower carbon footprint than traditional building materials like concrete and steel, helping the city to achieve its decarbonization goals.[177]

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Policy: Building Allied Agendas

Accelerating Circularity in Corporate Policy Through Green Building Standards

As part of the U.S. policies influencing circularity in the built environment, green building standards present a significant opportunity—particularly at the corporate policy level—to drive the adoption of circular design principles and low-carbon materials. Certification programs and standards such as **LEED (Leadership in Energy and Environmental Design)** and the **Living Building Challenge** are already incentivizing market adoption of more sustainable building principles. These standards are significant in prioritizing waste reduction from construction and deconstruction in the U.S., while setting up a paper trail for materials used.

While LEED certifications are best known for their focus on energy efficiency, there are specific credits focused on reuse of materials, among other areas.[178] Compliance requires the use of lifecycle assessment tools, the selection of suppliers verified to follow responsible extraction standards and the adoption of construction waste diversion targets.[179] Complying with such standards drives the industry toward circular innovations necessary for market transformation.

The Living Building Challenge (LBC) is also a performance-based certification program that pushes designers and building owners to create self-sufficient buildings. It sets guidelines for the sustainable design, construction and operation of buildings. Specific requirements of the program include net positive energy and water supply and meeting thresholds related to energy, materials and equity.[180] Although few buildings have achieved full Living Building certification due to the ambitious benchmarks, the Challenge establishes progressive circularity goals for the built environment.

The U.S. EPA has compiled a **Green Building Standards matrix** comparing established programs, like LEED and the Living Building Challenge, with other frameworks.[181] This matrix helps building owners and regulators assess the strengths of each program against sustainability categories like site selection, energy / water use efficiency, materials and construction management.

Case Study

Gradient Canopy and Bayview Google Campus in Mountain View, California

After breaking ground in 2017, **Google opened its Bayview campus in 2022 and its Gradient Canopy project opened in 2023**.[182] Gradient Canopy, in particular, is one of the largest buildings to attain the International Living Future Institute (ILFI) Living Building Challenge (LBC) Materials Petal Certification.[183] To promote circular economy design principles, the space incorporates salvaged materials (including reclaimed wood, bike racks, lockers and carpet), and a closed-loop wallboard initiative enabled the project to recycle over 550,000 pounds of drywall waste from 2020 to 2022.[184]

Corporate-Level Building Guidelines

Corporate policies that integrate leading green building certification standards accelerate the achievement of a circular built environment by requiring thoughtful material selection and operational practices that reduce waste and environmental impact over the entire building lifecycle. Scaled across global corporate real estate portfolios, these corporate policies have the potential to achieve sustainability goals for individual companies and transform sector norms.

Case Study
AEGB, U.S.

In 1991, **Austin Energy Green Building (AEGB)** developed the first rating system in the U.S. to evaluate sustainability of buildings, inspiring many cities to follow suit.[185] The ratings are based on energy and water efficiency and environmental friendliness in design and construction.[186] AEGB's rating system has evolved over time to reflect new technologies, changing codes and a greater understanding of sustainable building practices. The ratings are flexible to recognize best practices at all scales, and help developments exceed local environmental codes. AEGB's rating systems are designed to work with LEED certification.[187]

Case Study
CALGreen, U.S.

The **California Green Building Standards Code (CALGreen)** was adopted in 2008 and has since been updated to further promote sustainable building practices.[188] CALGreen is a mandatory statewide green building code that requires covered projects to recycle and/or salvage for reuse a minimum of 65 percent of the non-hazardous construction and demolition waste or meet a local construction and demolition waste management ordinance, whichever is more stringent.[189] In August 2023, California took a significant step towards reducing the embodied carbon footprint of its buildings by amending the state's Green Building Standards Code with two new provisions that target 1) embodied carbon emissions from new construction projects and 2) major renovation work.[190]

These case studies apply to multiple locations in the U.S.

CHAPTER TWO

Policy: Building Allied Agendas

Driving Progress Through Multi-Stakeholder Collaboration

Transforming the built environment to embrace circularity requires the active participation and collaboration of diverse stakeholders across the entire value chain. Only through the concerted efforts and buy-in of these key players can impactful policies and standards be implemented to enable a circular built environment in the U.S.

Critical players include labor unions, specifically building and construction trade associations (BCTAs) such as the National Association of Home Builders, the Associated General Contractors of America, and their member organizations representing hundreds of thousands of building contractors, tradespeople and affiliated businesses, among others. Persuading BCTAs requires evidence of the benefits for their members, including economic opportunities and the environmental imperatives of the transition towards zero-waste buildings and infrastructure.

Whole building lifecycle assessments are one tool to help convince this stakeholder group. Lifecycle assessments help capture the upfront, operational and end-of-life impact of buildings. Typically, these are conducted when funding is available through local municipalities, state environmental agencies or federal agencies that want to drive change via policy to minimize the impacts of building materials. This type of assessment can help drive change within the building and construction trades to reduce waste, increase environmental benefits and provide a deeper understanding of the climate impacts of buildings. Ultimately, the greater the BCTAs' exposure to innovation, the more mainstream circularity approaches can become. Their buy-in and promotion of circular construction will be essential to scale new solutions.

Real estate associations, investment firms and corporate facility owners are other stakeholders who must also support more circular buildings. These groups can encourage circularity by incorporating appropriate metrics and facility standards, such as green building certification standards like LEED into their investment decisions.

Local housing authorities are another stakeholder in the built environment value chain who play a pivotal role in ensuring availability of affordable, sustainable housing in communities. These agencies have a deep understanding of local needs and oversee public and subsidized housing programs, approve development projects and set design standards for new affordable housing units.[191]

CHAPTER TWO

Policy: Building Allied Agendas

By integrating circular economy principles and leveraging standards like LEED, housing authorities can mandate best practices for waste and emissions reduction. For example, they may require renewable energy systems in new buildings or major renovations of existing stock. Tight, publicly-funded budgets often pose barriers, but assessing total lifecycle costs and highlighting long-term savings can help make the case for circular investments.

Finally, government agencies involved in building codes and standards, zoning policies, procurement programs and incentive structures either accelerate or impede the progress of the regulatory landscape. Local cities can also mandate innovative building standards that must be used when development permits are envisioned. Their early leadership in circular public projects and performance-based policies can drive market transformation. However, coordinated input from all stakeholders mentioned above is essential to develop feasible and scalable policy interventions.

Partnerships:

Collaborative Blueprints

CHAPTER THREE

Partnerships: Collaborative Blueprints

The fragmented built environment value chain encompasses a wide diversity of stakeholders, including developers, architects, engineers, contractors, trade workers, building owners, investors and occupants, among others. Aligning the distinct priorities of this vast ecosystem of participants can be challenging and time-consuming. That is why partnership models are pivotal to overcoming fragmentation and offer an influential mechanism for propelling circular economy initiatives forward in the built environment.

This chapter explores various partnership models that drive progress in the built environment, specifically focusing on public-private partnerships (P3s), cross-sectoral collaborations and community-led initiatives.

CHAPTER THREE

Partnerships: Collaborative Blueprints

Each of the three partnership categories described below brings unique advantages through combined expertise and resources. These approaches enable resource pooling and knowledge exchange, among other things, that would be challenging for individual entities to accomplish alone.

Public-private partnerships (P3s) integrate government bodies' regulatory capacities with private companies' innovation and resources to navigate the complexities of circular objectives. These partnerships represent collaborative efforts between public sector agencies, such as federal, state or municipal governments, and private sector entities like architecture and construction firms, real estate developers or technology providers. P3s have emerged as a fundamental mechanism for embedding circularity principles and practices into the built environment.

Cross-sectoral partnerships spanning academia, industry, government, NGOs and community organizations are vital for enabling the systems-level transformation required to transition towards circular buildings and infrastructure. These collaborations provide a framework for integrating diverse perspectives, priorities and capabilities to foster comprehensive, innovative sustainability solutions tailored to the unique needs and constraints of the built environment.

Community-led initiatives harness local insights and cultural considerations to develop solutions that resonate with residents' needs and aspirations. Today 90 percent of the world's architects serve only 10 percent of the global population,[192] which leaves many on the frontlines of pressing environmental issues underserved. Community-led initiatives play a crucial role in addressing this imbalance by empowering local residents to actively shape sustainability plans tailored for their neighborhoods. Community-led building projects are springing up in the U.S., challenging conventional architecture and introducing place-based change in locations where no professional architecture has ever had an impact.

Case Study

Rheaply & The City of San Antonio's Material Innovation Center in San Antonio, Texas

Launched in 2023, the **City of San Antonio is working with Rheaply** (an online platform and asset management technology to enable the reuse of furniture, fixtures, equipment and building materials) to turn salvageable construction materials into feedstock for low-waste construction projects.[193] The Material Innovation Center builds on the City's Deconstruction & Circular Economy Program by leveraging a platform-as-a-service to find and share supplies and equipment across the greater San Antonio area.[194] By reusing resources locally, the City can connect with members of community organizations, lower purchasing costs, speed up procurement times and help the City and its partners prevent waste from going to the landfill.

Case Study

Build Reuse in Atlanta, Georgia

Build Reuse is a nonprofit, all-volunteer organization established in 1994 that promotes the recovery, reuse and recycling of building materials in the U.S.[195]

In 2018, Build Reuse initiated a pilot program in Atlanta, Georgia, collaborating with local partner and member organization Lifecycle Building Center (LBC).[196] LBC is "a nonprofit dedicated to strengthening communities through building material reuse via their 70,000 square foot facility in Southwest Atlanta which distributes reclaimed materials back into the community through discounted resale to income-restricted residents and material donations to other nonprofits."[197] Support from Build Reuse led directly to a $50,000 grant from the EPA and helped LBC launch a new community-based coalition called ReBuildATL,[198] which joined together municipal, community and industry leaders to establish a local job market in deconstruction and reuse, creating new economic opportunities aligned with circularity.

The initiative also provided targeted training for individuals facing employment barriers through skills enhancement and employability, specifically for sustainability-focused careers such as deconstruction, construction, facilities management, weatherization, energy-efficiency and more. To promote the scalability and replicability of this training model, Build Reuse is actively tracking reuse-related initiatives and resources nationwide and worldwide, including policies and ordinances, industry research, grants and more through their *Reuse in Communities* toolkit, which will be released later in 2024. This resource will enable municipalities and organizations to share resources and learn from one another and facilitate the broader adoption of reuse practices more effectively.

President of Build Reuse and Executive Director at LBC, Shannon Goodman, states, "Although the building materials reuse industry is currently underinvested, the scalability and replicability of models like that in Atlanta give hope for the future. With the right investments and policies in place, combined with further research quantifying the reuse industry's potential, organizations like Build Reuse and Lifecycle can maximize their role in job creation and waste reduction nationwide. The path forward will rely on cross-sector collaboration to fully realize the environmental and economic promise of the building materials reuse industry."

Today, Shannon Goodman and other industry colleagues are looking to fund a study that would quantify the economic and environmental effects of the reuse industry and demonstrate what their greater impact could be with the suitable strategic investments.[199]

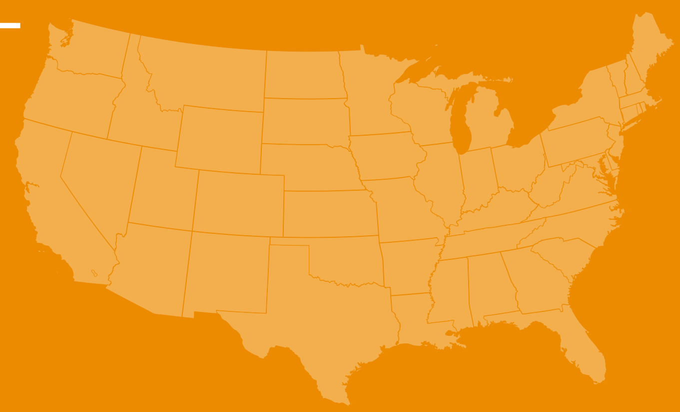
Case Study

Big Reuse in Queens, New York

Big Reuse is a Brooklyn-based nonprofit advancing sustainability in New York City through circular economy initiatives like its social enterprise, the Big Reuse Center.[200] Launched in 2015, the Big Reuse Center resells over 200,000 donated used and vintage items—ranging from building materials and furniture to clothing, books and music. Annually, it diverts one million pounds of goods from landfills, including 28,000 articles of clothing, 25,000 books, 87,000 home goods and 4,000 pieces of furniture.[201] The Big Reuse center symbolizes Big Reuse's mission to "divert waste from landfills and reduce greenhouse gas emissions in the atmosphere through reuse and transformation."[202]

Case Study

Build It Green, U.S.

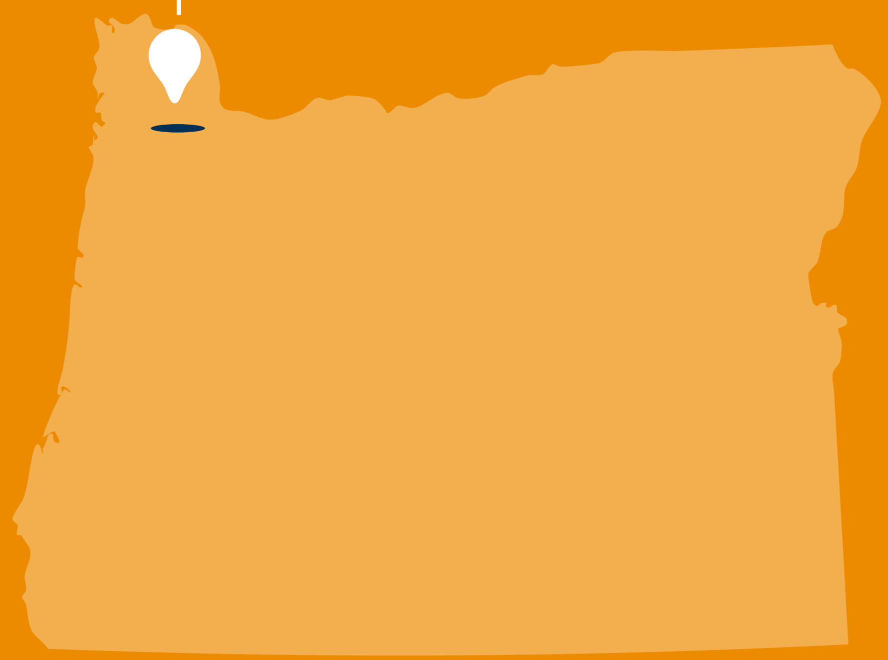


This case study applies to multiple locations in the U.S

Build It Green, a California-based nonprofit organization, exemplifies effective cross-sectoral partnership in the sustainable building sector. Through the California Housing System Innovators Network, Build It Green convenes over 350 cross-sectoral stakeholders from across the state to transform the state's housing ecosystem.[203] The organization "addresses issues of affordability, social equity and the environment to support thriving neighborhoods that exist in harmony with human and natural systems."[204] For example, Build It Green enables housing development in high-need Californian communities by targeting critical infrastructure needs (i.e., researching specific places and case studies where there is evidence that infrastructure is a barrier to housing development).[205] Through this research, Build It Green identifies neighborhoods to pilot precedent-setting projects that include innovative and regenerative solutions to current infrastructure problems in those areas. Another critical initiative by Build It Green is their bespoke GreenPoint Rated system, a comprehensive green building rating system for California. Third party sources recognize these standards and ratings are performed by a certified GreenPoint Rater, an independent professional trained and certified by Build It Green.[206] The rating process is a non-invasive physical examination of building systems, structures, materials and components to assess energy and water efficiency, indoor air quality, resource efficiency of materials and construction methods, and construction quality.[207]

Case Study

The M&M Marketplace Enhancement Project, in Hillsboro, Oregon



The **M&M Marketplace Enhancement Project** in Hillsboro, Oregon is an exemplary community-led initiative focused on transforming a parking lot into a green, urban plaza.[208] This collaborative project, funded in part by a $30,000 grant from Metro's 2016 Nature in Neighborhoods program, involved a steering committee of 20 community members and local leaders as well as local nonprofit Depave, to mitigate flooding and filter pollutants from stormwater.[209]

The Role Different Financing Mechanisms Can Play in Fostering a More Circular Built Environment in the U.S.

Advancing circularity in the built environment necessitates investment to catalyze solutions and facilitate scale across all value chain stages. The built environment encompasses a wide range of sub-sectors and project types, each with distinct risk-return profiles and financing needs. From early-stage material science startups to large-scale infrastructure projects, the financing landscape is complex and varied. However, the sector's vast financing potential can be unlocked by aligning appropriate types of financing with specific opportunities. These financing mechanisms include, among others, venture capital, growth equity, buyout, real estate investments and project finance—each representing its own unique value proposition.

Spotlight: Financing the Foundation

CLOSED LOOP partners
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Spotlight

Buyout investments

are a type of private equity transaction that seek to gain controlling or majority ownership of mature and profitable companies. In the built environment sector, private equity firms often attain exposure to the built environment by acquiring building service providers, ranging from HVAC providers to energy efficiency service providers. Some buyout funds also concentrate on materials management broadly. For instance, they focus on sourcing sustainable construction materials like recycled glass and evaluating environmentally friendly demolition practices. They also explore various geotechnical engineering techniques, as well as innovative methods such as precast concrete and modular construction. They invest in companies that sell technologically and commercially viable products for the built environment. These established companies play an essential role in decarbonizing buildings, and private equity firms contribute by providing capital to support their growth as demand for their services continues to increase. A popular strategy for private equity firms to create value across their portfolio companies is to seek to transform or positively influence the aspects of the business that are perceived more valuable by the broader market and command a premium multiple at exit. In the current environment, this often leads to a push for sustainable solutions within the built environment to meet the growing demand for green buildings and services. By injecting capital and strategic guidance into existing service providers and product companies, private equity firms enable the scale of proven solutions, thereby facilitating the transition towards a more sustainable built environment. Their ability to optimize operations, drive efficiencies and leverage economies of scale positions them as critical enablers in the decarbonization efforts of the built environment sector.

Venture capital and growth equity

focuses investments on new technologies with high-growth potential. In the built environment, this can include startups developing new circular materials, software platforms for building lifecycle management, or AI-powered tools for optimizing resource use and sourcing lower-carbon materials. However, the built environment sector currently attracts only a small share of venture capital dollars.[210] One reason for this gap is the slower pace of innovation in the built environment sector compared to other industries. Partially due to the safety risks associated with engineering for infrastructure where people live, work and commute, construction is one of the most risk-averse industries and is highly regulated.[211] Trialing new materials means that the products need to pass rigorous stress-tests before being implemented onsite. Connected to this, the typical rigidity of contracts and liabilities tied to the built environment further hinder opportunities for innovation. However, as the market demand and regulatory tailwinds pushing toward circular buildings strengthen (i.e., Local Law 97), so too does the opportunity for venture capital firms to back breakthrough emissions-reducing technologies and solutions.

Real estate investors

invest in the buildings themselves and look to have stable dividend-like payouts from rental income on their properties. Managers of real estate investment firms with a longer-term mindset can look at implementing best-in-class circular economy principles at their buildings, such as retrofitting to keep pace with changing demands. However, the built environment sector's fragmented value chain and slow pace of change can create challenges for these investors. This complexity can make it challenging to accurately assess the financial benefits and risks associated with implementing circular best practices as the long-term impacts may not be immediately apparent. Real estate owners and investors may struggle to quantify the potential cost savings, increased asset value and reduced environmental impact that circular practices can deliver over the lifecycle of a building. Circularity in the built environment involves a complex web of metrics around material use, waste and lifecycle impacts. The lack of standardized frameworks and robust data for measuring and valuing circular performance makes it challenging for investors to quantify risks and returns.

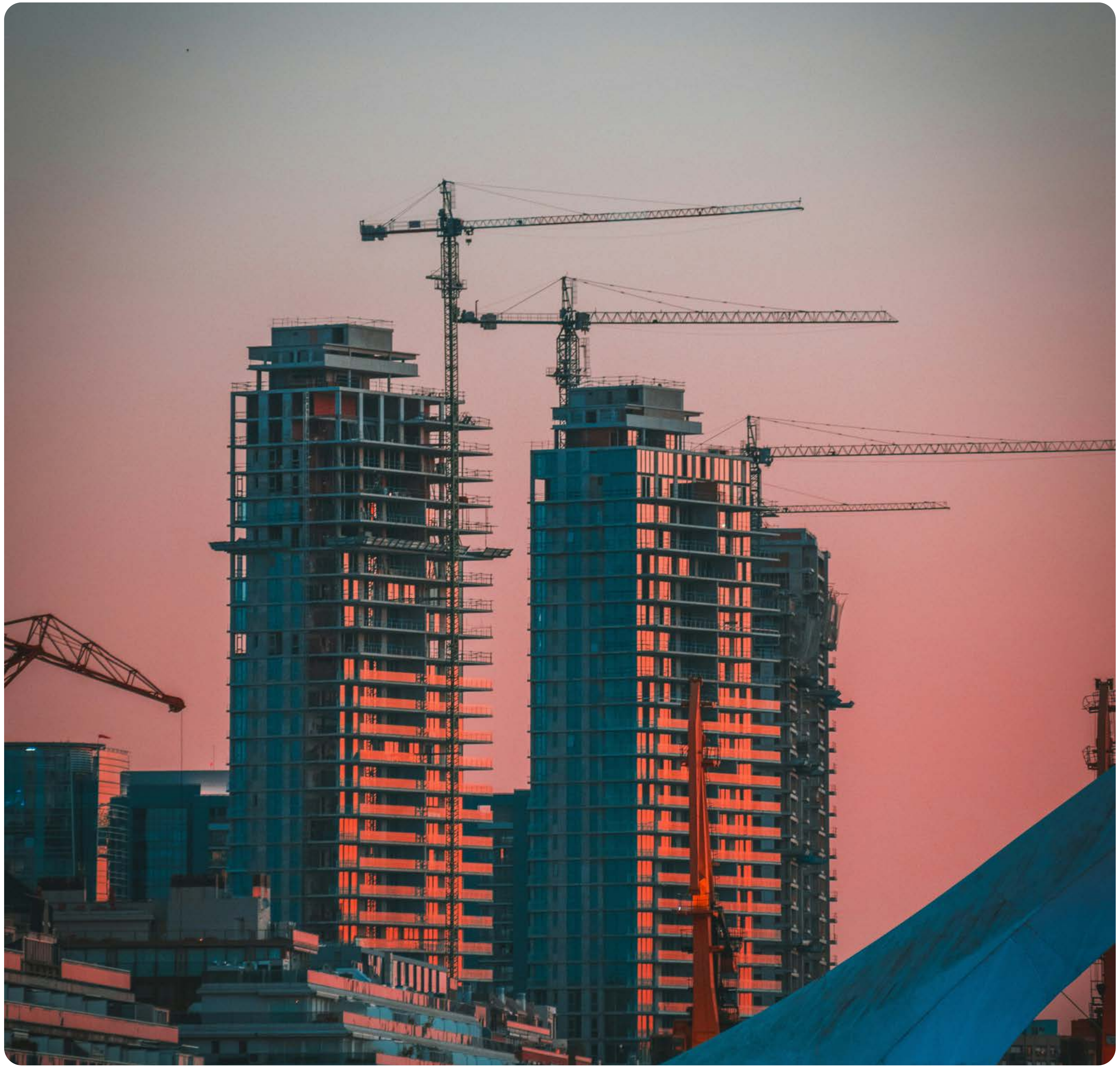
Project finance

is used to fund capital-intensive, large-scale, long-term project-based investments.[212] Project financing can be a mix of debt and equity, or a loan structure that relies primarily on the project's cash flow for repayment, with the project's assets, rights and interests held as secondary collateral.[213] As a result, project finance investors look for investments characterized by steady, predictable revenue streams from projects.[214] Project finance investors can play a crucial role in promoting green and circular building practices or new material production facilities by setting stringent criteria for the construction projects they fund. By only financing infrastructure that adhere to specific sustainability standards, these investors create a strong incentive for developers to adopt circular designs and construction methods.

Conclusion

The transition to a circular economy for the built environment in the U.S. holds immense potential for reducing the sector's environmental impact. While promising developments are emerging through innovation, policy, partnerships and investment, much work is still needed to adopt circular principles at scale. The urgency of addressing climate change and resource depletion calls for prioritizing resilient, circular solutions that keep materials in use at their highest value for as long as possible.

Achieving true circularity will require overcoming fragmented incentives across the value chain and aligning the interests of diverse stakeholders including designers, developers and building managers to develop collaborative, systems-based solutions. The strategies and tools already exist—from adaptive reuse and design for deconstruction, to material passports and modular construction, among other approaches. The path forward involves shifting away from new construction and demolition, toward retrofitting and renovating whenever feasible, to develop a built environment that is more dynamic, resilient and circular.



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