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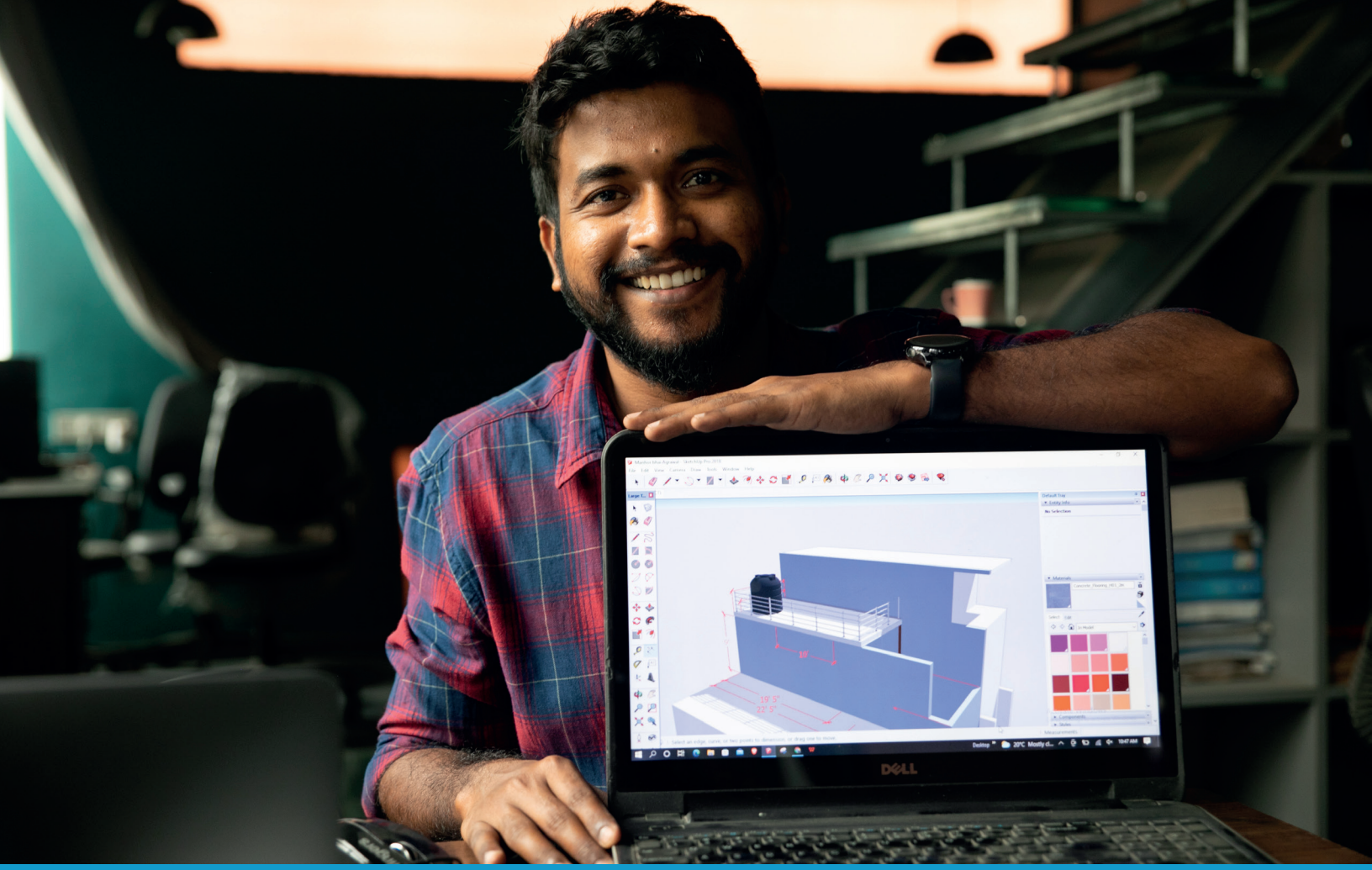
Terwilliger Center for Innovation in Shelter

Net-Zero Homes

How circular economy solutions to the housing crisis in low-income countries are key to achieving global climate targets

November 2022



Abinav Singh, an employee of ReMaterials, shows off new designs for the company's ModRoof product (Ahmedabad, India)

Table of Contents

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World Green Building Council

To learn more about the Terwilliger Center's work and opportunities to collaborate please reach out to TCIS@habitat.org.

Abbreviations

ADB	Asian Development Bank
CRDC	Center for Regenerative Design andCollaboration
CO_2	carbon dioxide
Gt	gigatonne (equal to 1 billion tonnes)
$GtCO_2eq$	gigatonnes CO_2 equivalent
EE	energy efficiency
IFC	International Finance Corporation
IGBC	Indian Green Building Council
IPCC	Intergovernmental Panel on Climate Change
KIRDI	Kenya Industrial Research and Development Institute
SDGs	Sustainable Development Goals

Close up of sand dust, which is seperated from manufactured sand during processing and quality control tests (Chennai, India)

Executive summary

Climate change and the global shortage of affordable housing are inextricably linked, and nowhere is this more so than in low-income countries, which face the biggest burdens of both a changing climate and the housing deficit.

Any commitment to addressing climate change-related loss and damage must recognize the social and environmental value of housing as a significant economic asset, and as a key component of adaptation to climate change. Efforts by governments and other agencies to support climate change mitigation and adaptation must take into account the centrality of housing in protecting the vulnerable and achieving net zero ambitions.

The significant contribution that the construction industry makes to global greenhouse gas emissions means that the sector, including housing, has a key role to play in climate change mitigation and adaptation, and the adoption of more sustainable inclusive practices.

The circular economy proves a helpful lens through which to see how housing is central to achieving both a net-zero future and to climate change mitigation and adaptation. Four circularity strategies – use less, use longer, make clean, use again – can all be applied to low-income housing construction in emerging markets.

In emerging markets achieving circularity in the house construction sector presents formidable challenges to all groups of stakeholders: governments and policymakers, the construction and materials industries, and individual low-income homebuilders, and the masons who work for them. However, this should not deter stakeholders from supporting circularity in affordable housing.

Low-income countries are home to many innovations and solutions for affordable housing, tailored to the specific needs of their contexts. These markets have demonstrated that there is the requisite motivation, creativity and drive towards the circular economy to ensure that such innovations can play a key part of the solution to address climate change.

Given that those who are most impacted by climate change are also those most affected by the

global housing shortage,

any measures to support

climate change

mitigation and adaptation must incorporate housing needs in order to succeed.

Introduction

The challenge of climate change do not exist in a vacuum. Rather, it intersects with multiple global trends, including growing urbanization, migration, rising systemic inequity and loss and damage from extreme events. The dual crises of climate change and the global affordable housing shortage are intertwined: in low-income countries, where the effects of the climate crisis on communities are felt the most, climate change is profoundly related to housing, which is where the bulk of unmet housing need is located. When the World Bank looked at housing need in 64 emerging economies, it found that the current deficit of 268 million housing units affects 1.26 billion people, and that more than a quarter of the current housing stock in these economies is classified as inadequate.[1] Affordable housing has a direct impact on numerous global calls to climate action, including Sustainable Development Goals (SDGs), notably SDG11: Sustainable Cities and Communities among other SDGs (see figure 3), and yet is often considered on the periphery of other priorities.

The unequal impact of climate change

The impacts of climate change are vastly unequal and felt the most by the world's poorest communities. The 46 least-developed countries only account for approximately 1.1% of total world carbon dioxide (CO_2) emissions from fossil-fuel combustion and industrial processes, despite being home to 1.1 billion people, approximately 14% of the world's population.[2] These countries were affected by less than a fifth of climate-related disasters, yet they have suffered 69% of deaths worldwide attributable to the same occurrences.[3] For those who live in coastal areas, climate change poses an existential threat due to rising sea levels. Approximately 10% of the world's population lives less than 10 meters above sea level, and around 40% live within 100 km of the sea.[4]

Global housing shortage

Worldwide, 1.6 billion people lack adequate housing, including 1 billion living in slums and informal settlements, a situation that severely undermines efforts to address and eradicate all facets of poverty.[5] The situation is not getting better: UN-Habitat estimates that 3 billion people – 40% of the global population – will need access to adequate housing by 2030, equivalent to 96,000 new affordable and accessible housing units every day. Moreover, an estimated 100 million people worldwide are unhoused, and a quarter of those who are housed live in conditions that are harmful to their health, safety and prosperity.[6]

The construction industry and carbon emission

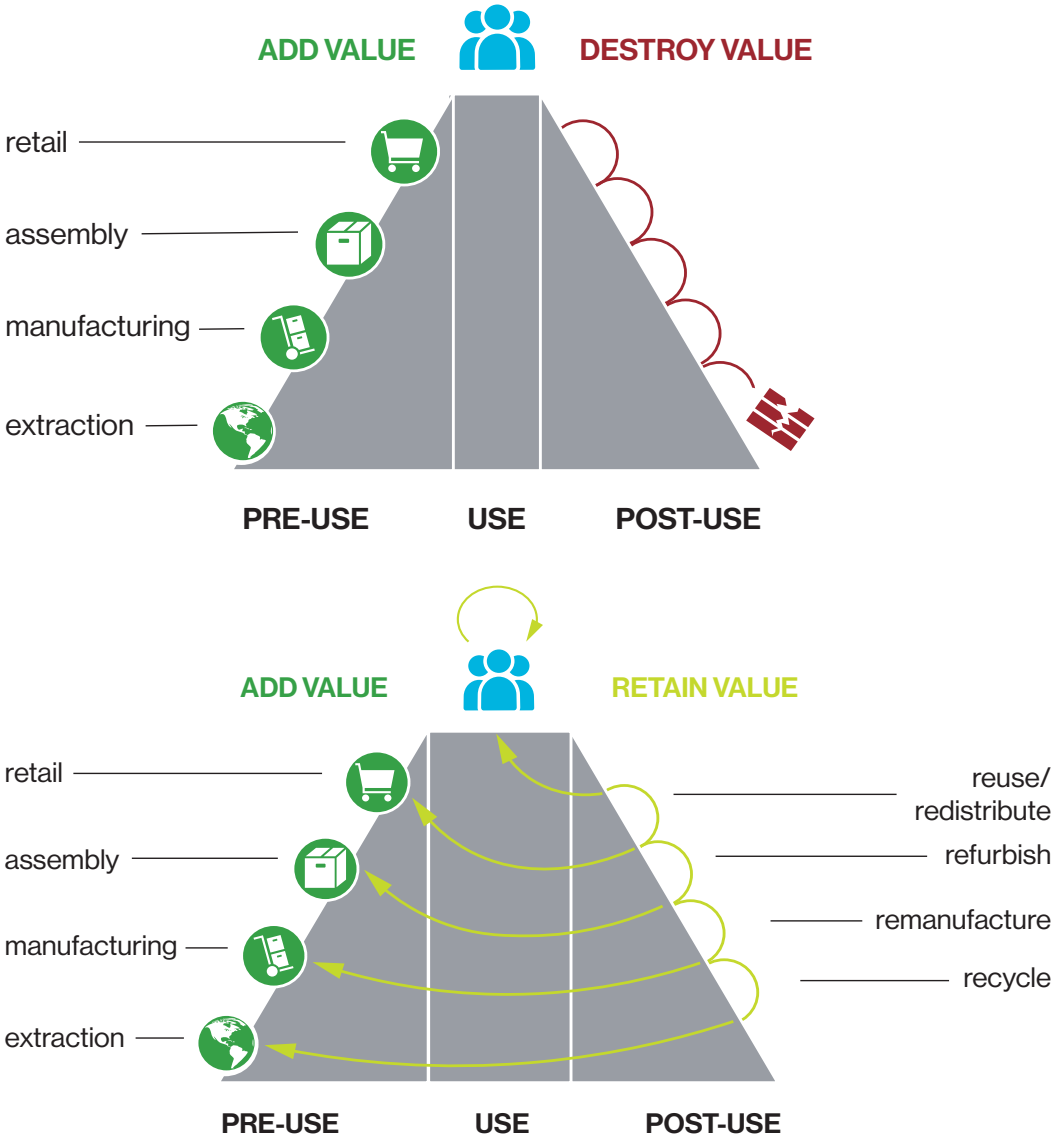
The construction industry is a major contributor to greenhouse gas emissions, especially in the production of certain foundational materials including cement, concrete and steel. The use of these materials is also set to increase, especially in low-income countries where new infrastructure and housing growth is anticipated to accelerate most, due largely to rapid urbanization and the quality limitations of existing housing stock.[7]

1 Introducing the Adequate Housing Index : A New Approach to Estimate the Adequate Housing Deficit within and across Emerging Economies. World Bank, 2021. https://openknowledge.worldbank.org/handle/10986/36481.
2 Smallest footprints, largest impacts: Least developed countries need a just sustainable transition. United Nations Conference on Trade and Development, 2021.
3 CH More, GSA Swaby, SP Wangdi. Time to redress the globally unjust cost of climate change. International Institute for Environment and Development, 202. https://pubs.iied.org/17726iied.
4 Factsheet: People and Oceans. The United Nations Ocean Conference, 2017. https://www.un.org/sustainabledevelopment/wp-content/uploads/2017/05/Ocean-fact-sheet-package.pdf.
5 World Cities Report 2022. UN Habitat, 2022. https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf.
6 Housing. UN-Habitat. https://unhabitat.org/topic/housing.
7 Oomen J. Building for the Future: What Does Net Zero Building Look Like in the Global South? Engineering for Change, 2022.

The circular economy, sustainability, and green housing

In the global discourse on climate change, terms such as circularity and sustainability are often used loosely and interchangeably, and there is some ambiguity around the two concepts.[8] The most commonly accepted definition of sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[9] Thus, sustainability is a more over-arching concept than circularity, which is concerned with resource cycles that add and retain value rather than add and then destroy it (figure 1). In terms of practical application, in manufacturing for example, the difference between circularity and sustainability may become an academic one.[10]

Figure 1. Value in the linear economy and the circular economy



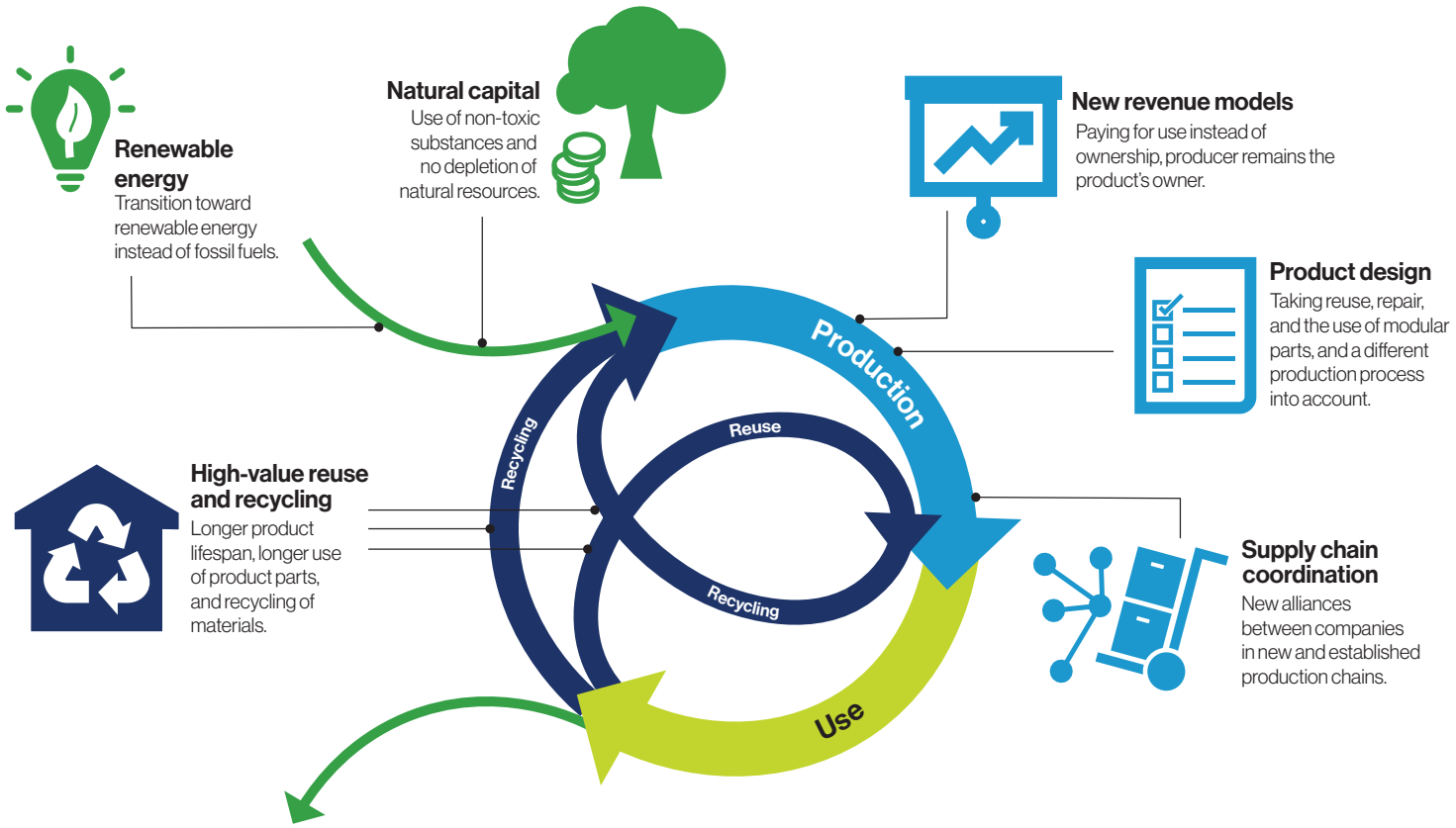
8 M Geissdoerfer, P Savaget, Nancy MP Bocken, EJ Hultink. (2017). The Circular Economy – A new sustainability paradigm?. Journal of Cleaner Production. 143. 757–768. 10.1016/j.jclepro.2016.12.048.
9 GH Brundtland. Our common future: Report of the 1987 World Commission on Environment and Development. United Nations, 1987.
10 AM Walker, K Opferkuch, E Roos Lindgreen et al. What Is the Relation between Circular Economy and Sustainability? Answers from Frontrunner Companies Engaged with Circular Economy.

In the housing sector, circularity's application is complex and requires systemic approaches from the initial design stage to reduce the amount of materials that are used, extend their life, and act on the assumption that a dwelling is in effect a library of physical resources that will at the end of the building's life be repurposed (table 1) . In a circular economic system, manufacturing occurs in closed loops in which the value of raw materials, components and products is retained as much as possible, using renewable energy sources, and based on systems thinking (figure 2).[11] Circular uses of resources are not inherently sustainable, but the circularity lens is a useful one for conceptualizing how materials can be best used to minimize usage, reduce wastage and increase reusability.

The circular economy stands in contrast to the linear economy, which is predominant in the current construction sector. In the latter, the model of production is "take-make-use-dispose" and is heavily reliant on fossil fuels.[12] Value is added prior to use and destroyed post-use, whereas in a circular economy modality, value is retained post-use through reuse, redistribution, refurbishing, remanufacture and recycling (figure 2).[13]

How can we build a circular economy for affordable housing's delivery? Solutions across the housing value chain and innovation enablers can amplify where and how circularity can be applied in the affordable housing sector.

Figure 2. Elements of a circular economy



11 What is the definition of a circular economy? Het Groene Brein.
12 NMP Bocken, I de Pauw, C Bakker et al. Product design and business model strategies for a circular economy, Journal of Industrial and Production Engineering, 2016;33:5, 308-320, DOI: 10.1080/21681015.2016.1172124.
13 E Achterberg, J Hinfelaar, N Bocken. Master Circular Business with the Value Hill. Circle Economy, 2016. https://publish.circle-economy.com/financing-circular-business.

Table 1. What does the circular economy look like for housing?

	Design	Material	Services
Core functions	Heat resilient design and cool roof solutions	Biodegradable materials, renewable energy, clean processes	Energy retrofitting to keep a building in use rather than demoloishing
	Reducing raw material requirements	Incorporating agricultural, industrial or other waste into materials	Green financing
	3D printing or modular designs	Material recovery and processing facilities	SME financing to small scale developers of new materials
	Leverage digital technology to deliver housing	Proper recycling of demolition waste	Rental housing or co-housing schemes
Enabling environment	Performance-based green building codes	Product standards and testing facilities	Green financing subsidies
	Circular economy increntives	Funding for material research and development	Regulations supporting green financing
	Tools to measure and understand impacts	Implementation of waste management protocols	Zoning flexibility for reuse or repurpose of commercial space
	Regular review and upgrade of existing building codes		

About this paper

This paper looks at how housing is key to achieving both a net-zero future–whereby the greenhouse gases going into the atmosphere are balanced by removal out of the atmosphere – and to achieving climate change mitigation and adaptation goals.[14] This paper takes the concept of the circular economy as a lens through which to examine this issue. Circularity is concerned with resource cycles.[15] Circular economic practices offer a toolbox for sustainability and have important implications for achieving a significant number of the SDG targets.[16] This paper examines the challenges to promoting circular economy thinking in the housing construction sector in low-income countries, but also lays out how a vision of the circular economy is already emerging for housing construction and suggests what might be needed to amplify these trends.

This paper is rooted in the working experience of Habitat for Humanity International's Terwilliger Center for Innovation in Shelter and its support to startups and other construction sector players in low-income countries and emerging markets. Over the past five years,

14 What is net zero? Net Zero Climate. https://netzeroclimate.org/what-is-net-zero/.
15 What is the definition of a circular economy? Het Groene Brein. https://kenniskaarten.hetgroenebrein.nl/en/knowledge-map-circular-economy/what-is-the-definition-a-circular-economy/.
16 P Schroeder, K Anggraeni, K. and U Weber. (2019), The Relevance of Circular Economy Practices to the Sustainable Development Goals. Journal of Industrial Ecology, 23: 77-95. https://doi.org/10.1111/jiec.12732.

Terwilliger Center staff have noticed a curious trend: an increasing number of start-ups in low-income countries are focused on sustainable materials and construction practices, or circular economic practices, but many are struggling to scale and gain traction. The innovation enablers that would needed to support these solutions' growth are absent. This paper draws on this experience to provide insights into the challenges that innovations face and the opportunities to take to scale solutions emanating from emerging markets. In addition to innovation examples, this paper also highlights examples of emerging public policies and policy frameworks that support the transformation of the sector into a contributor to climate change solutions, rather than remaining a major contributor to climate change.

Housing is central to action on climate change and achieving a net-zero future

Because of the scale of the global housing deficit and the resource intensity of current building practices in most parts of the world, addressing the housing crisis can be seen as either a threat to climate change mitigation and adaptation, or an opportunity to boost its chances of success. Given that those who are most impacted by climate change are also those who are most affected by the global housing shortage, any measures to support climate change mitigation and adaptation must incorporate housing needs in order to succeed.

As we address the impacts of the construction sector on climate, housing affordability must be taken into account when addressing climate change mitigation to ensure that the poorest and most vulnerable to climate change are not the most burdened by carbon mitigation efforts. In rapidly urbanizing places, climate change mitigation must be done in a way that does not drive up housing costs and exacerbate the housing shortage.

Figure 3. How housing supports the SDGs

Global calls to climate action

Sustainable, climate-resilient and green housing also support the Paris Climate Accord's goals of "enhancing adaptive capacity and resilience; and reducing vulnerability, with a view to contributing to sustainable development targets,"[17] as well as the Accord's principles of investing now to save on costs later, and giving priority to communities most vulnerable to climate change.[18] Similarly, such housing initiatives also align with other global climate change initiatives, including the UN's Race To Zero Campaign to rally leadership and support from businesses, cities, regions, and investors for a healthy, resilient, zero carbon recovery.[19] Within this campaign, the Cities Race to Zero track specifically focuses on fostering unity among cities that support climate action toward the Paris Agreement goals.[20] The call for sustainable housing also aligns with action by the private sector, such as Climate Action 100+, an investor-led initiative to ensure the world's largest corporate greenhouse gas emitters take necessary action on climate change. It reflects the growing trend within the construction industry specifically, to set and attain climate action targets. For example, the World Green Building Council Net Zero Carbon Buildings Commitment calls on the building and construction sector to "take action to decarbonise the built environment, inspire others to take similar action, and to remove barriers to implementation."[21]

Linking housing and climate change

According to UN Environment Programme, buildings contribute 30% of global greenhouse gas emissions, use approximately 40% of global resources in their entire life cycle, and produce 40% of the world's waste.[22] Housing is a significant part of this, accounting for an estimated 13.5 billion tonnes of emissions, attributable to resource extraction, transport and construction activities, and energy required for domestic heating, cooling and lighting.[23] Residential buildings accounted for 22% of all energy use associated with buildings and 17% of emissions, based on 2019 estimates.[24] Global energy consumption for cooling is lowest for low-income homebuilders in emerging markets, but with the increasing frequency of heat stress events and rising incomes in emerging markets, consumption is likely to increase in years to come. These heatwaves are some of the most visible manifestations of climate change around the world.

As the building construction industry is such a big contributor to carbon emissions, it follows that it also has to be part of the solution. Arguably, addressing the housing shortage in a sustainable way can only be achieved through measures to increase the circular economic aspects of housing – from materials sourcing, to construction through the life cycle of the home.

In 2022, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) highlighted the opportunity to deliver action through cities and human settlements,[25] noting that making affordable housing a priority – and upgrading informal and precarious settlements – holds a promise of breaking concentrated inequalities in climate risk. Moreover, "continuing rapid growth in urban populations and unmet needs for healthy, decent, affordable and sustainable housing and infrastructure are a global opportunity to integrate inclusive and adaptation strategies into development," the report states. However, finance remains a significant barrier. Policy innovations have not been backed by funding. What finance there has been, has too often been focused on the wealthiest rather than the poorest settlements, and solely focused on large-scale engineering projects rather than on social innovations and maintenance. Places with fragile or under-resourced local government fare the worst in terms of resources for climate change measures. Historically, the arc of affordability for innovation has been long, making it unaffordable for many. However, now there is more consideration for, and focus on, finance mechanisms and incentives that can be deployed to shorten that arc. By looking to, and learning from, local technologies and solutions developed in low-income countries, it is possible to demonstrate that green does not have to mean expensive.

17 New elements and dimensions of adaptation under the Paris Agreement (Article 7). UN Framework Convention on Climate Change. https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/new-elements-and-dimensions-of-adaptation-under-the-paris-agreement-article-7.
18 Climate Action. United Nations. https://www.un.org/en/climatechange/climate-adaptation?gclid=Cj0KCQjw94WZBhDtARIsAKxWG-8YEdUApD0xefmr33A77tsOAKDnEN-aiOTLlrF-NepCng6Z9s7_fP84aAsxrEALw_wcB.
19 Race To Zero Campaign https://unfccc.int/climate-action/race-to-zero-campaign.
20 Cities Race to Zero. https://www.c40.org/what-we-do/building-a-movement/cities-race-to-zero/.
21 The Net Zero Carbon Buildings Commitment. World Green Building Council. https://www.worldgbc.org/thecommitment.
22 Circular Economy and Affordable Housing. Engineering for Change, 2021. https://www.engineeringforchange.org/research/circular-economy-affordable-housing.
23 The Circularity Gap Report 2022. Platform for Accelerating the Circular Economy. https://www.circularity-gap.world/2022
24 United Nations Environment Programme (2020). 2020 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. Nairobi.
25 Fact sheet - Human Settlements Climate Change Impacts and Risks. Intergovernmental Panel on Climate Change Sixth Assessment Report, 2022. https://www.ipcc.ch/report/ar6/wg2/downloads/outreach/IPCC_AR6_WGII_FactSheet_HumanSettlements.pdf.

Urbanization

An additional 397 million people were added to urban populations from 2015 to 2020, resulting in increased vulnerability to climate change in informal and unplanned settlements, according to IPCC. Global development actors are concerned about the impact of climate change that intersect with, and are compounded by, urbanization. Urban human settlements are vulnerable to cascading risks when disaster strikes. Coastal cities are especially at risk from climate change. Although many cities have developed climate change adaptation plans, few of these plans have been actioned, and the current rate of adaptation is insufficient to address the hazards associated with climate change, according to the IPCC. At the same time, actions addressing issues inherent to human settlements can make a significant contribution to delivering on climate action,[26] addressing both adaptation and mitigation.

Part of the solution

The housing sector can play a key part in the global effort to tackle climate change. Any efforts by governments and other agencies to support climate change mitigation and adaptation must take into account the centrality of housing in achieving a net-zero future and protecting the most vulnerable.

Firstly, commitment to addressing climate change-related loss and damage must recognize the social and environmental value of housing as a significant economic asset. Housing is typically a family's greatest asset – it unlocks other wealth creation opportunities for families. However, housing is more than just a roof over a family's head: it creates stability, results in better educational outcomes for families and improves health outcomes for the entire family. Loss of and damage to housing can arguably be one of the greatest destabilizing individual outcomes resulting from increasingly severe climate events, causing ripple effects on economic security, health, and livelihood. Additionally, as a key part of the construction industry, housebuilding is a significant employer, particularly of informal labor. Many of the same families in precarious housing earn their income in this sector. Research has shown that at least half to, in some countries, almost all of the construction workforce is employed informally.[27]

Secondly, housing is a key component of adaptation to climate change. The construction of new housing and the upgrading of the existing housing stock to adapt to climate change play a key role in supporting communities to be more resilient to and to deal with a warming climate. However, low-income countries are least equipped to withstand the increasingly extreme shocks driven by climate change and lack the resources for mitigation that developed countries have at their disposal.

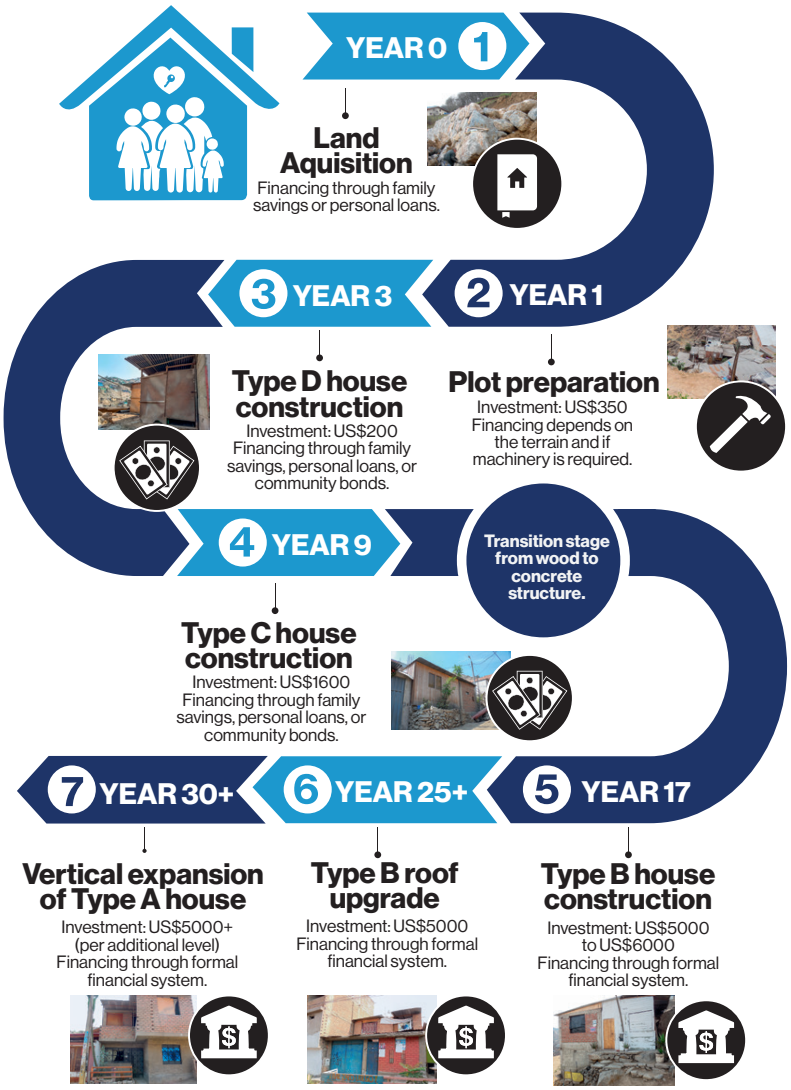
Thirdly, and the focus of the remainder of this paper, the housing sector can be a driving force of climate change mitigation. There is an imperative for the industry to seize the moment to shift mindsets, change practices and adopt the policies and standards needed to achieve net zero.

26 Fact sheet - Human Settlements Climate Change Impacts and Risks. Intergovernmental Panel on Climate Change Sixth Assessment Report, 2022.
27 A Acolin, R Green & M Hoek-Smit. A Ladder Up. Terwilliger Center for Innovation in Shelter, 2021. https://www.habitat.org/sites/default/files/documents/A-Ladder-Up_Report.pdf.

Challenges to promoting circular economy thinking in the housing construction sector

Worldwide, circularity is not trending in the right direction. In 2020, only 8.6% of what was used globally got cycled, down from the also meagre 9.1% recycled in 2018.[28] In housing, there are formidable challenges to embracing circular construction practices because of the complexity of the systems and competing priorities of its various stakeholders, including governments, developers, and materials manufacturers and suppliers. Moreover, much of the sector – an estimated 70% in low- and middle-income countries – is informal and fragmented.[29]

Figure 4. Incremental housing and the housing lifecycle for low-income families, as modeled in Peru



28 The Circularity Gap Report 2022. Platform for Accelerating the Circular Economy. https://www.circularity-gap.world/2022.
29 R Goethert. Incremental Housing. A proactive urban strategy. School of Architecture and Planning, Massachusetts Institute of Technology.

Low-income homebuilders

For green building materials and circular construction practices to take off in these markets, homeowners themselves must be convinced of their value. These materials and practices must also be made more readily available. Low-income homebuilding is not so much a purchase but a process, whereby families incrementally add to and improve their homes as finances allow over years or even decades (figure 4).[30] There is strong aspirational value to own a 'conventional' home. In the community discourse around what affordable housing means, alternative green materials often translate to cheaper, poor quality, and less aspirational.

Materials manufacturers and material suppliers

For materials manufacturers and suppliers, it is challenging to sell new products, especially if they are more expensive than what is commonly used. Success at introducing innovative materials depends on being able to push products into the supply chain and down to a level that reaches low-income homebuilders and the masons who work for them but balances making them aspirational.

Small-scale construction services providers

It is challenging to shift the mentality of small-scale contractors, who may lack skills and knowledge in using alternative materials, and are not positioned to absorb higher front-end costs for more sustainable materials and practices. There is also a need to address information asymmetries on alternative construction materials or circular practices, and how they can be incorporated into incremental home construction. In many settings there is a stubbornly enduring perception that construction practices using traditional materials, such as bamboo, which are often inherently circular in nature, are backward and undesirable.

Governments and policymakers

Governments must grapple with maintaining a fine balance between competing responsibilities, including addressing the affordable housing deficits through new construction and refurbishment, while reducing greenhouse gas emissions. While countries have committed to CO_2 reduction targets under the Paris Climate Accord in their Nationally Determined Contributions, committing to this shift to net zero is complex, and requires significant investments and rethinking across all sectors. Acting on these commitments may in the short term run counter to immediate societal needs, such as employment, livelihoods and affordable housing. An illustration of this is the hard-to-reconcile fact that the construction sector is a significant contributor to greenhouse gas emissions, and at the same time is also a major driver of the economy, a major employer of low skilled labor, typically one of the largest employment sectors after agriculture, and represents between 4% and 11% of the workforce in emerging markets.[31] This makes it challenging to mandate climate change measures that may rely more on technology and less on labor and which may adversely affect the sector's ability to absorb labor, especially youth, in the short term.

Developers

Continuing rapid urbanization is fuelling increasingly high demand for urban accommodations, even of poor quality. In the absence of enforced legislation mandating developers to adopt zero carbon targets or sustainability, they have few incentives to adopt more circular practices, and face short-term challenges of appealing to the end market. In the absence of enabling codes and standards, innovation may not necessarily be inhibited, but it is certainly not encouraged. Sticking to what they know makes it easier for developers to more confidently predict that they can sell their developments in mid- to low-end markets.

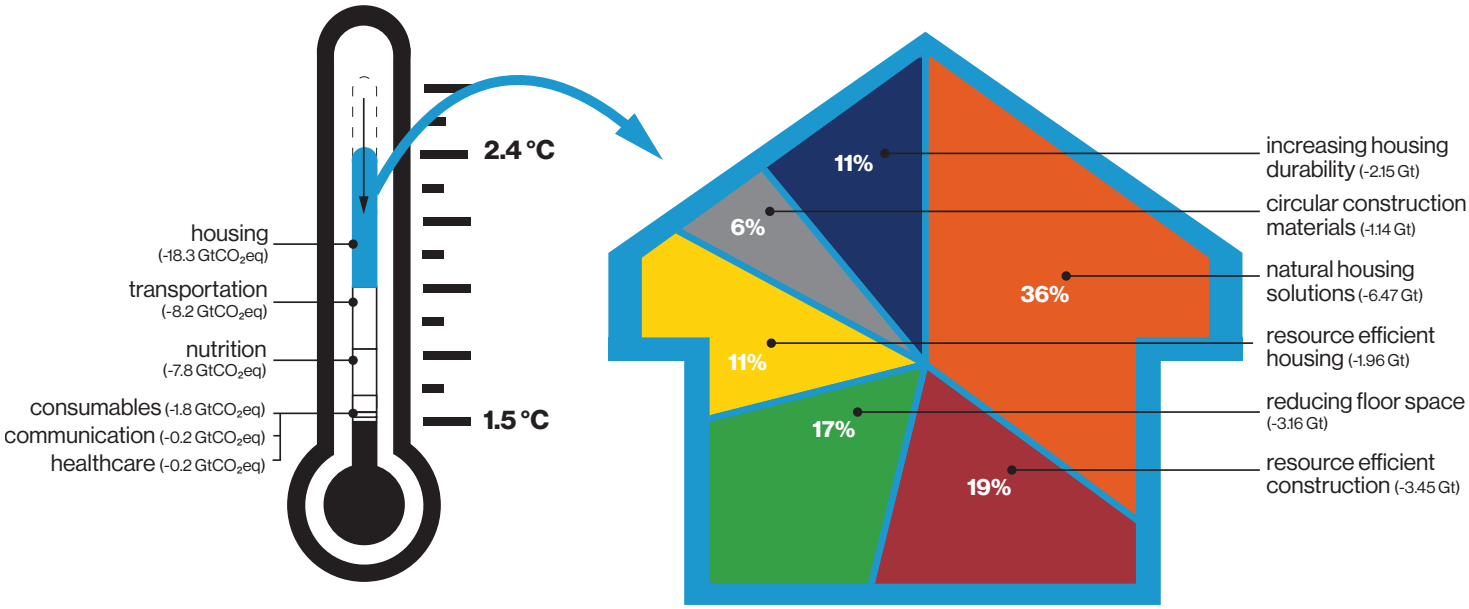
30 Hábitat en Perú "Estudio cualitativo de sistemas de mercado de vivienda" Nov. 2019.
31 A Acolin, R Green & M Hoek-Smit. A Ladder Up. Terwilliger Center for Innovation in Shelter, 2021. https://www.habitat.org/sites/default/files/documents/A-Ladder-Up_Report.pdf.

A vision of the circular economy in the affordable housing context

Despite the challenges, there are circular economy initiatives ralated to housing happening all over the world. Models of circularity and frameworks that are appropriate to local conditions and potentially less-resourced settings are needed to take them to scale and encourage more players to join forces. However, these existing innovations show that there is already the motivation, creativity and drive toward the circular economy in low-income housing construction.

These innovations have value, and entrepreneur-support organizations such as Plug and Play, Villgro, Village Capital, Reall, Engineering for Change, and Habitat's Terwilliger Center for Innovation in Shelter[32] support sustainability, circularity, and affordable housing innovations. However, for this support to entrepreneurs to be truly transformative, their innovations need a clear pathway to scale. That requires both a supportive ecosystem of players and partners and an innovation-enabling environment including policies, legal standards and frameworks that supports this shift.

Figure 5. Contributions of circular economy solutions to reducing global greenhouse gas emissions in order to meet the targets sent by the Paris Climate Agreement



PACE's Circularity Gap Report (2022) proposes a roadmap of 21 solutions across six categories (housing, transportation, nutrition, consumables, communication, healthcare) to mitigate climate change by curbing greenhouse gas emissions. Together, these solutions would reduce global emissions by an additional 22.8 billion tonnes beyond what is projected under the global community's current climate commitments, thereby meeting the Paris Agreement's goal of limiting global warming to a maximum of 1.5 degrees Celsius by 2030. Housing (5 of 21 solutions) would contribute 50% of the projected emissions reductions ($GtCO_2eq$) laid out in the roadmap.

32 Circular Economy and Affordable Housing. Engineering for Change, 2021. https://www.engineeringforchange.org/research/circular-economy-affordable-housing.

Scholars of the circular economy have developed a framework for product design and manufacturing that can be applied to, and adopted by, the housing construction sector, including governments, material suppliers, and construction professionals.[33] This framework comprises two objectives: to minimize resource extraction, and to minimize dispersion and loss of materials. There are four strategies to achieve these objectives and meet the emissions targets of the Paris Accords, each describing a way to change the flow of materials by narrowing flows (using less), slowing flows (using longer), regenerating flows (making cleaner) and cycling flows (using again).[34]

Narrow flows (use less). This requires circular design and manufacturing processes that reduce materials usage rates. Practical applications include models of usage based on rental or sharing rather than ownership, products and buildings with multiple uses, and digitization. In housing construction, narrowing flows includes climate resilient building practices and introduction of prefabricated and modular housing components.

Precasting construction components can help homebuilders use more highly engineered materials. In the Philippines, for example, Cubo Modular uses engineered bamboo technology to produce highly customizable modular assembly building components that are then delivered to the construction site. The company also aims to increase market accessibility to their products by offering customers flexible financing options.

Because of its potential to reduce material waste and reduce construction times, 3D printing holds promise in the housing construction sector, and there has been traction in both India and Mexico. Indian firm Tvasta Construction, for example, has developed a concrete 3D printing technology that aims to increase efficiency during the construction process, transportation, and during the operation phase. In Mexico, NGO New Story is in alliance with the local partner Échale A Tu Casa to construct affordable housing using 3D printing in rural communities.

Slow flows (use longer). This entails extending the functional lifetime of goods through, for example, durable design-products that are designed for ease of repair, refurbishment and disassembly. Incrementally-built homes in informal settlements often suffer from substandard materials and poorly executed designs, that leave them vulnerable to weather and seismic shocks, and offer poor value for money over the long term. Access to end-user finance for low-income families to repair or refurbish their housing can extend the lifetime of the structure, while improving habitability and related outcomes, including health and education. Impact investment, risk sharing and technical assistance facilities – such as Habitat's MicroBuild Fund and ADB's Microfinance Risk Participation and Guarantee Program – can help financial institutions develop loan products tailored to helping low-income families improve the quality and resilience of their homes. Financial solutions with preferential rates can also be tailored to incentivize access to and use of green or circular building solutions.

Start Somewhere, a German-Kenyan nongovernmental organization, has brought a precast hollow concrete block to market in Kenya, tailored to the needs of low-income families. The main production facility for Start Somewhere's TwistBlocks is in Kibera – Kenya's largest informal settlement. The block technology was developed in response to the small, irregular plot sizes in these settlements, which make optimizing floorplans and construction quality challenging. TwistBlocks compare favorably pricewise with typical construction materials for informal settlements and are at the same time more durable and fire- and seismic-resistant. Because TwistBlocks require no mortar, walls can be dismantled to accommodate additional rooms, and the bricks can be reused for the new construction. Another good example is ModRoof, made by Indian start-up ReMaterials – a modular system of lightweight panels made from cardboard waste combined with natural binders and coated with a waterproof layer. Its structure provides insulation that helps keep heat out and significantly reduces the indoor temperature by as much as 18 degrees Fahrenheit, improving habitability and health in increasingly hot temperatures.

33 W Stahel. The circular economy. Nature 531, 435–438 (2016). https://doi.org/10.1038/531435a.
34 The Circularity Gap Report 2021. Platform for Accelerating the Circular Economy. https://www.circularity-gap.world/2021.

ReMaterials

Indian start-up ReMaterials turns cardboard waste into lightweight panels. The company's product, ModRoof, combines waste with natural binders and coats it with a waterproof layer. It then adds a strong metal structure to create a product with four strength options and a variety of finishes. ModRoof is designed to be an alternative to the asbestos cement sheets frequently used by low-income families, including those in informal settlements. ModRoof's structure provides insulation that helps keep heat out and significantly reduces the indoor temperature. Its light weight reduces construction costs, and its modular structure enables fast installation. The company has already installed 150,000 square feet of its product. As 90% of ModRoof is recyclable at the end of its life, with a 25% to 30% resale value, it supports circular economic practices in construction.

Employees of ReMaterials test the ModRoof assembly process (Ahmedabad, India)

Regenerate flows (make clean). Instead of relying on fossil fuels, pollutants and toxic materials, regenerative materials should be used, as well as renewable energy. In housing construction, there are many examples of repurposing what has previously been considered waste and using it either as an alternative to fossil fuels, or as a raw material in product manufacturing.

In India, for example, agricultural waste is being used as a raw material for bricks and other building materials. One product, Bio-Bricks, uses up to 85% agricultural waste combined with lime and cement. The bricks can be incorporated into traditional homebuilding practices and used as filler material for roofing and walls. Similarly, Indian firm Strawculture Eco uses 90% straw waste to produce fiber panels which can be used as a substitute for wood panels in house construction. In Kenya too, MycoTile's innovative mushroom mycelium insulation and roofing panels are produced from agro-waste materials, including coffee husks, sugarcane bagasse and sawdust, diverting these materials diverted from landfills.

Using natural materials such as adobe, rammed earth, bamboo and wood can also offer superior thermal insulation and energy efficiency, and better adaptivity to local conditions compared to non-local and synthetic materials. In addition, local materials have a smaller carbon footprint because of shorter transportation distances compared to imported materials. For example, EarthEnable's custom-developed earthen floors in Rwanda and Uganda are built with natural materials and green building techniques, utilizing clay that is often sourced often on site rather than being imported or trucked in from other sites across the country. Their earthen floors have 90% less embedded energy and are structurally strong, waterproof, and abrasion resistant. Bio-based materials such as bamboo and wood also serve as carbon capture as they grow, and this captured carbon is then, in effect, 'banked' in the house.

Mexican companies such as Adoblock , Ecoblock and Probarro are working with adobe and other natural materials. Bamboo, which is native to Mexico, has good mechanical properties and a low carbon footprint, and has been singled out by the Secretary of Environment and Natural Resources of Mexico as a material that should be promoted in home construction.

Kenya's Industrial Research and Development Institute companies, such as MycoTile, have benefited from state-owned industrial incubation infrastructure to develop innovative, low-carbon construction materials including ceiling panels and insulation made from mycelium tissue, which when dried is very strong, and resistant to water, mold, and fire. However, socializing such materials, and making them aspirational, can be challenging when 'progress' is associated with concrete and other industrialized materials.

Cycle flows (use again). Optimizing the reuse of materials at the end of a product's life cycle helps create a circular flow of resources. Products have to be designed for recyclability, and rely on adequate collection and reprocessing systems. In this way, houses can be conceptualized as materials banks, with the expectation of materials reuse considered at pre-construction phase. Finding ways to improve the recycling of construction and demolition waste and reuse of the material is an integral part of reducing the carbon footprint of construction industry.

The high CO_2 burden from plastic production and the scourge of plastics waste are worldwide problems. The ideal is for plastics production and use to decrease, and for plastics to be recycled into new plastic products of the same plastics type, so they can then potentially be recycled multiple times. However, where traditional recycling infrastructure and systems do not exist, plastics have begun to play an increasing role in the production of building materials. Using plastics as cement admixtures helps reduce the waste burden from plastics that cannot be locally recycled. CRDC Resin8, for example, adds 5% plastics to structural products and 25% plastics to non-structural product concrete mixes, at the same price and with an imperceptible difference to home builders.

Similarly, in Kenya, numerous companies including Gjenge Makers , EcoTiles, Corec , EcoPost and Green Pavers are producing building products such as paving blocks, roof tiles and faux wood from sand-based recycled plastic. In the Philippines, Green Antz and Plastic Flamingo both convert plastic waste to building products.

Green Antz

Philippines social enterprise Green Antz Builders specializes in converting plastic waste into construction products. In the beginning, owner and founder Rommel Benig struggled to get the company's products accepted by the low-income households that he hoped to help. He later transitioned the company to a higher segment of the market and partnered with local conglomerate Ayala. More recently, the company has been able to pivot back to the low-income segment and has succeeded in partnering with 10 hardware stores and three social housing developers to stock and use the company's brick and paving products, particularly non-load bearing eco cast for the low-income market.

Green Antz empolyees at the company's warehouse (Cebu, Philippines)

Repurposing or upgrading unused existing buildings is another reuse innovation in the affordable housing space. For example, in Kenya's capital Nairobi, there are over 100 hectares of unoccupied commercial and residential space due to a mismatch between market supply and expected demand. While apartment-sharing models are prevalent in European and North American markets, companies such as The Vlage are pioneering these strategies in new markets. Vlage converts commercial space into residential property to turn surplus spaces into co-living spaces, matching young Nairobian working professionals who cannot yet purchase property. This conversion of space answers an affordable housing need among young professionals with a relatively small impact on the environment.

SUNRISE Mikrokreditna Fondacija

Building on the success of their housing loan product, SUNRISE launched a new energy efficiency (EE) loan product with the goals of helping clients reduce their home energy expenses, improving the resilience and habitability of their home and increasing the value of their home as an asset. A 2020 impact study of SUNRISE's EE loan product found that families that had taken out an EE loan had 5% lower energy bills and 8% higher household savings on average after 12 months, compared to a control group of similar clients who had taken other types of loans.

Goran, an entrepreneur and SUNRISE client, speaks with a loan officer in his home workshop.

Interrelated levers of change

These four strategies of circularity do not exist in isolation, and in fact – at the construction product and process levels – they intersect in many instances. They can be considered as levers, which can be applied both on their own and in combination, and together form a system of circularity. However, circular housing innovations, such as those described above, cannot go beyond the piloting and prototype stage without a supportive innovation-enabling environment, including regulatory frameworks that call on innovators to decarbonize the construction sector, and facilitate and reward them for doing so.

Enabling environment for circular construction practices

Strong state enabling environment action can drive change. In India, for example, life cycle assessment is encouraged in the National Building Code,[35] to analyze the environmental impact of each stage of a building's life cycle. The Indian Green Building Council (IGBC) rates buildings on their waste management, use of local and recycled materials, and use of appropriate technologies and alternative construction materials. A high IGBC star rating is a badge of honor in the construction industry. However, this is only for the formal construction sector, and such initiatives currently ignore the informal sector, which is a missed opportunity for more expansive inclusion of those involved in the construction industry, particularly in low-income housing.

The Philippines' National Building Code[36] is aligned with national development frameworks and climate action plans to promote climate change-resilient infrastructure, and this is also a priority agenda in the Philippine Development Plan. In addition, the Philippine Green Building Code is aimed at improving building performance through promotion of efficient resource management and site sustainability, and minimizing the negative environmental and human health impact of buildings on human health and the environment.[37] This is buttressed by participation in International Finance Corporation's EDGE certification of resource-efficient and zero carbon buildings.[38] However, the building code is not applicable to the lowest income housing projects and thus a missed opportunity to incentivize sustainable practices throughout the construction industry. Enabling financial regulations and the existence of green financing are both among the biggest barriers as well as essential solutions to scaling innovations and achieving net zero in the industry. International Finance Corporation (IFC) is one of the world's largest providers of climate investment in the housing sector. IFC supports green affordable housing finance via green bonds and equity investments addressing the needs of financial institutions to unlock further capital. At the same time, IFC created the EDGE tool, which provides green building certification tailored to the unique building needs of emerging markets, to help developers and financiers come together and merge and align incentives. Developers who use the EDGE tool can unlock working capital by receiving EDGE certification of resource-efficient and zero carbon buildings.[39]

Culture and social norms are also highly relevant to socialization of circular economy construction practices at bottom of the pyramid level and there is a role for communities, not just as producers of sustainable housing, but as active participants and partners with other stakeholders. Some of the barriers are due to norms and beliefs around housing and construction materials. At the same time, use of local materials can be seen (and framed) as a mark of respect for traditional building practices.

35 SP 7 : 2016 National Building Code of India 2016 (NBC 2016). https://www.bis.gov.in/index.php/standards/technical-department/national-building-code/.
36 Implementing Rules and Regulations of The National Building Code of the Philippines (PD 1096). http://www.iibh.org/kijun/pdf/Philippines_02_IRR_of_NBC_of_the_Philippines.pdf.
37 Philippine Green Building Code (P.D. 1096). Climate Change Laws of the World. Grantham Research Institute on Climate Change and the Environment.
38 Certify Green and Change Your World. EDGE. https://edgebuildings.com/.
39 Ibid.

Conclusion

Affordable housing construction is a significant part of the economic and social development of a country and is a major contributor to gross domestic product around the world, an estimated 13% on average.[40] It is also a significant contributor to CO_2 emissions, and this contradiction must be resolved. Efforts to introduce circularity into the affordable housing market are promising and inspiring, but to get to meaningful scale, systems change is needed, with regulatory frameworks, and investment and finance, the key drivers. There is a pressing need for more examples of policy that is supportive of circularity in the housing sector. The current financial and social barriers need to be unlocked for all stakeholders, including developers, materials manufacturers and distributors, and homebuilders and the masons who work for them.

For green materials to go from alternative to mainstream, the discourse around what is affordable housing needs to change and break away from conventional ideas about the relative merits of manufactured 'modern' materials and locally sourced traditional materials. This requires a concerted effort across the entire housing construction value chain, including big and established players. The onus to socialize new ideas and demonstrate value cannot be entirely on those who are the innovators.

There is an important role for the private sector to get involved, as pioneering entrepreneurs and investors already establishing the business case, not only in high-income countries, but to a significant degree in low-income countries as well. It is there that the challenge of innovation for sustainability that is also affordable is being met. There is also significant opportunity for governments to facilitate the creation of an enabling environment for access and adoption of green tools, materials and practices. Low-income countries have much to learn from each other in terms of supportive regulation and policy, as well as specific building practices, technologies and materials.

Efforts to address climate change must recognize the central role of housing, and ensure that the poorest, who are already most affected by both climate change and insufficiency, are not burdened with the cost of the climate change solutions in the form of even more unaffordable housing.

At a minimum, more sustainable practices in affordable housing construction can reduce the sector's impact on climate change. But, the potential of housing goes beyond this to something transformational, through the carbon sink function of sustainable housing. And as low-income countries, in particular, continue to grapple with the harshest impacts of climate change, providing adequate housing must go beyond putting roofs over families' heads, to help them mitigate the household impacts of climate change and adapt to what cannot be changed.

40 A Acolin, R Green & M Hoek-Smit. A Ladder Up. Terwilliger Center for Innovation in Shelter, 2021. https://www.habitat.org/sites/default/files/documents/A-Ladder-Up_Report.pdf.

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