In collaboration with
Boston Consulting Group

Towards Green Building Value Chains: China and Beyond

INSIGHT REPORT

JUNE 2024

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Foreword

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Every fraction of a degree counts in the response to the climate and nature emergency. To achieve speed and scale for climate action, a holistic approach across value chains is required. A comprehensive and effective net-zero transition plan seeks to understand the root causes of emissions, unlocks the catalytic points and opportunities for investment, and identifies partnership potential for breakthrough solutions and their scaling up.

The value chain for buildings includes material production, design, construction, operation, end-of-life demolition and recycling. Each stage offers immense potential for positive change and all actors can contribute to driving the momentum. Currently, the value chain for buildings accounts for approximately 37%[1] of global carbon emissions, involving more than 20 different types of public and private players, several of whom belong to hard-to-abate sectors such as steel and cement. The complexity of the value chain calls for a systems lens to map the key actions and roles of each player in the value chain to realize net-zero, nature-positive transitions.

As the largest building market in the world, and with more than half of the global production capacity for many building materials, China has an important role in decarbonizing the building industry. The green transition of China's building value chain will not only create value and new business opportunities for industry players in China, but could also help catalyse the development and adoption of green building products and services globally.

This insight report by the World Economic Forum, in close collaboration with Boston Consulting Group (BCG), explores opportunities for the green transition of the building value chain. Through a comprehensive analysis of the abatement potential, market opportunities and key barriers, the research outlines the enabling actions for public and private players to focus on. This report is a call to action for activities that will generate both positive environmental impact and significant economic gains. Our goal is to translate the vision for green and sustainable building value chains into strategy and delivery plans for the public and private sectors in China and beyond.

This report marks the first in a series of research reports on the business potential for green transitions of value chains, and identifies areas for priority action. We thank all community members and Forum initiative leaders for their dedication and invaluable inputs towards this report. We hope it will offer useful insights and perspectives to inform and support leaders in jointly creating a future with more sustainable buildings, improved health and well-being for communities, and better lives for all.

Executive summary

Buildings are responsible for 37%[1] of global carbon dioxide (CO_2) emissions, and 34%[2] of the earth's species are enduring habitat loss as a result of urban development. As the world continues to experience a surge in construction, the transition to buildings of the future will become increasingly important over the next decades.

It is critical to adopt a value chain perspective as the development of green buildings requires all upstream and downstream functions and players to take action. As a starting point, it is important to recognize that a building's environmental impact extends all through its life cycle. The day-to-day operations of an occupied building consume significant energy, and the processes involved in producing, transporting, installing and disposing of construction materials such as steel and cement generate substantial carbon emissions.

A comprehensive approach to the green transition must therefore consider the entire life cycle of buildings, including construction, use and end of life. Choices such as design and construction materials, which often involve various value-chain players, will set the baseline of a completed building's impact on nature for decades. Developing truly green and sustainable buildings requires a holistic approach that extends from initial planning to end of life, and mobilizes the entire value chain.

China is the largest building material and construction market. It produces more than 50%[3] of the world's steel and concrete, and also accounts for 50%[4] of the world's new construction each year. The green transition of China's building value chain can have a crucial impact on the world.

The future

Various solutions to green buildings already exist, but they often address singular areas – such as pollution reduction, net-zero goals or human-centric sustainability – in isolation. To achieve a comprehensive green transition in the building value chain, a holistic understanding that encompasses climate, environmental and people's needs must be developed so that all stakeholders can join hands and make united efforts towards a green future.

This report identifies four key characteristics of a holistic vision for green buildings:

Net zero
Minimizing whole-life emissions[5] through the use of innovative materials and technologies.

Nature positive
Enhancing buildings' environmental performance by integrating natural elements.

Resilient
Maximizing buildings' ability to withstand extreme weather and climate volatility.

Well-being oriented
Boosting the physical and mental well-being of their occupants, enhancing community development and ensuring access for all.

To realize this vision, several critical enabling factors need to be addressed. These include regulations and industry standards, data and advanced technologies such as artificial intelligence (AI) and biomaterials, and financing and upskilling support.

The levers

This report highlights 11 key levers that collectively offer abatement potential of approximately 80%[6] if properly implemented:

1. Green energy supply
2. Recirculation of materials and minerals
3. Decarbonization of traditional materials
4. Heating and cooling system upgrades
5. Integrated energy management
6. Building insulation retrofits and upgrades
7. Conversion to sustainable materials
8. Shared facilities and services
9. Self-sufficient facilities
10. Water recycling
11. Design for four key characteristics

These levers require collaboration between 25 distinct functions throughout the building value chain. Each player has their own role in promoting each lever.

Together, these levers are expected to generate $1.8 trillion in value by 2030[7] for a range of stakeholders, resulting from rent premiums vs. "brown discounts" (on less energy-efficient buildings), new market growth, differentiated value propositions and enhanced talent attraction for building sectors.

The barriers

The complexity of the buildings value chain makes the path to green buildings challenging. One obstacle is the lack of consistent standards for what makes a building net-zero, nature-positive, resilient and well-being oriented.

Another is the limited availability of flagship projects showcasing the buildings of tomorrow, which could mobilize value-chain collaboration and showcase leading solutions. A third issue is that near-zero carbon solutions and technologies currently impose a cost premium due to the immaturity of the technologies involved and the lack of economies of scale. Finally, the industry's relatively low growth in productivity slows adoption of new emissions-reduction technologies.

The solutions

To overcome the barriers to decarbonizing buildings, stakeholders must adopt various enabling actions across the value chain:

- Align global standards and methods of measurement for green and sustainable buildings.
- Identify flagship projects to enhance coordination among players.
- Develop effective policies and incentives to offset any cost disadvantages.
- Engage start-up communities and value-chain stakeholders to push for technological breakthroughs.

These solutions require players in the building value chain to form a unified community and work together to surmount obstacles and transform the vision of the buildings of tomorrow into a reality.

1 The importance of a green value chain for buildings

Buildings are the leading contributor of global emissions and making them sustainable requires a value-chain approach.

The United Nations (UN) Intergovernmental Panel on Climate Change's *Synthesis Report for the Sixth Assessment Report* noted that the Paris Agreement's goal of limiting warming to 1.5°C will be difficult to achieve at the current speed and scope of decarbonization actions. As the impacts of climate change escalate, the importance of green built environment becomes increasingly apparent. Buildings are the leading contributor to global emissions and therefore play a crucial role in stressing the natural environment. In fact, 37%[1] of CO_2 emissions globally are attributable to buildings.

To address these challenges and to meet the 1.5°C goal, a value-chain approach is imperative. It entails adopting strong abatement measures to dramatically decrease emissions in existing buildings. About 80%[8] of the world's building stock will still be in place by 2050. Therefore, global renovation rates must double by 2030 to align with the 1.5°C pathway, rising to at least 2% per year from the current rate of less than 1% (many of which do not feature green retrofits).[8]

As for new buildings, the other part of the equation, the International Energy Agency (IEA) projects that building floor space will nearly double globally by 2050.[9] This calls for accelerated adoption of innovative technologies and approaches that enable green and sustainable building solutions.

Significant environmental impacts occur all through a building's value chain. Life-cycle emissions[6] from buildings are spread out over whole value-chain steps, from material production to demolition. Building operations consume large amounts of energy for heating, cooling, lighting and other functions. Building materials come from industry sectors (such as steel and cement) where emissions that occur during the production, transportation, installation and demolition processes (termed "embodied carbon") are large and difficult to abate.

Planning for a fully green transition of buildings must therefore take the whole value chain into account, which includes emissions related to production, construction, operation, end of life and beyond asset life. Decisions made at each stage of the building value chain can have long-lasting effects. Building design and materials choice sets the baseline of a building's environmental impact for decades. A further complication is that steps towards achieving green transition of buildings often depend on coordinated action by more than one participant in the value chain. For example, building a waste management system involves onsite and end-of-life waste and requires contributions from construction companies, site owners, recyclers and material suppliers. Full mobilization of the value chain is a necessity.

China plays a vital role in the global building value chain. China is the country with the largest building material production and consumption, with more than 50%[3] of the global market share in steel, concrete, aluminium, etc. China is also the largest construction market in the world. Its annual new construction area accounts for 50% of the global total. The green transition of China's building value chain will not only make a sizeable contribution to China's carbon neutrality goals but will also bring significant impact for the world.

2 Four key characteristics

The buildings of tomorrow must embody four key characteristics: net zero, nature positive, resilient and well-being oriented.

Today, there are many sustainable building concepts. Some take a piecemeal approach, focusing first on operational energy, and later addressing wider issues of nature and biodiversity. Others primarily emphasize human sustainability rather than environmental sustainability more broadly. However, achieving a complete green transition of the building value chain requires a comprehensive approach that considers all of these factors – decarbonization, nature and human beings. Such a vision is critical to aligning stakeholders and harmonizing their efforts in the journey to a green future.

This report adopts a holistic vision in which the buildings of tomorrow have four key characteristics (see Figure 1):

– **Net zero.** The cornerstone of the green transition of buildings is a net-zero life cycle that minimizes carbon emissions. This consideration encompasses circularity in material use, transition to renewable energy sources, and enhanced energy efficiency. Levers and innovations along the entire value chain – ranging from materials to construction to operation to demolition – are essential to achieving this goal. The *Green Building Principles*[10] introduced by the World Economic Forum illustrate all the steps to deliver net zero-carbon buildings.

– **Nature positive.** A critical aspect of the green building transformation involves integrating nature-based elements and solutions, such as green roofs, rainwater harvesting and stormwater management. These initiatives can enhance environmental quality, protect biodiversity and contribute to the aesthetic and recreational appeal of buildings and cities.

– **Resilient.** Building designs must prioritize adaptability to and mitigation of physical climate risks. This shift entails proactive assessment of risks, durable and flexible construction specifications to withstand both extreme weather and more chronic climate impacts, and reduced dependence on external utilities.

– **Well-being oriented.** An adjacent component of green buildings is promoting physical and mental well-being, community development and access for all. This calls for, from an early planning stage, developing facilities for leisure, physical activities and community events, and ensuring flexible, inclusive use by providing access to shared facilities and public transport.

Three key enablers are essential for implementing green approaches and achieving substantial and sustainable impact:

Regulations and industry standards. Clear, comprehensive and standardized regulations can play a pivotal role in driving the development of the buildings of tomorrow. Holistic standards that cover net-zero, nature-positive, resilient and well-being oriented perspectives of buildings, along with requirements and guidelines on building energy and carbon performance, technology adoption, etc., can accelerate the adoption of sustainable practices. They can encourage innovation and ensure consistency in green-building initiatives.

Data and technology. A robust system for tracking, evaluating and sharing data throughout the building value chain is imperative for collaboration and evaluating progress of decarbonization efforts. Technologies are rapidly developing to offer more solutions for the buildings of tomorrow. These include digitalization such as the use of artificial intelligence (AI) to support building operation, and innovative materials and techniques on green and efficient material production, construction and demolition, such as biogenic materials and three-dimensional (3D) production.

Financing and upskilling. Adequate financing from corporates, investors and public sectors – in the form of project investment, green bonds and funds – is vital to support research and development (R&D) into green building solutions, for the development of green buildings and for the retrofitting of existing buildings to enhance their green attributes. In addition, to drive the green transition effectively, professionals in the building value chain must have access to the requisite skills and training.

FIGURE 1 | **The buildings of tomorrow have four key characteristics**

Net zero

Minimizing life-cycle emissions through innovative materials and technologies such as:

- Use of green building materials
- Adoption of recycling and circularity
- Incorporation of high-efficiency equipment and renewable energy
- Upgrade of building insulation
- Deployment of advanced smart building technologies

Nature positive

Enhancing environmental performance by integrating natural elements:

- Embedding natural elements in design (e.g. green roofs and walls)
- Utilizing natural resource management (e.g. rainwater harvesting and biodiversity protection)

Resilient

Building-in adaptability to manage risks related to extreme weather and climate volatility through:

- Proactive assessment of risks
- Use of durable and flexible structures against extreme weather
- Reduced dependence on external utilities (e.g. natural ventilation and onsite power generation)

Well-being oriented

Promoting physical and mental well-being, community development and accessibility for all with:

- Affordability
- Mixed-use development
- Accessibility to shared facilities
- Community livelihood services

Enablement

- Regulations and industry standards
- Data and technology (AI, biomaterials, etc.)
- Financing and upskilling

Source: BCG

BOX 1 | **BEEAH group headquarters: Net-zero building in the desert with clean energy source and recycled materials**

Net-zero emissions with self-sufficient green energy system: Solar farm and battery packs will meet the building's energy demand throughout each day and night.

Recirculation of materials: High percentage of locally procured materials including construction waste.

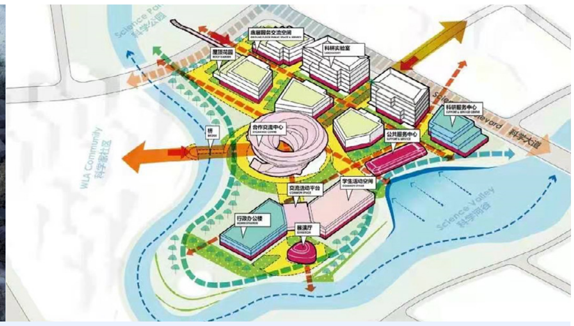
Nature-based design to save energy: Interconnected "dunes" design to optimize orientation and shade in local climate, ensuring ample daylight and natural ventilation while limiting exposure to the harsh sun.

Owner: BEEAH Group
Architect: Zaha Hadid Architects
Location: Sharjah, United Arab Emirates

Source: BCG

BOX 2

Shanghai Scientist Community: High-efficiency equipment, nature-based solutions on a large scale



High-efficiency heating and cooling system: Heat pumps, smart home-control system, etc. reduce carbon emissions

Water and waste recycling: Water recycling system to supply clean water and reduce negative impacts on nature; Smart collecting and separation system for residential waste to achieve 100% separation

All facilities – including hospitals, art centres, green parks, sports grounds, schools and commercial facilities – are within 15 minutes' walking distance to improve well-being

Constructor: China State Construction Engineering Company (CSCEC)
Architect: China Shanghai Architectural Design & Research Institute of CSCEC
Location: Shanghai, China
Scale: 204,000 square metres

Source: China State Construction Engineering Corporation (CSCEC) contribution to the World Economic Forum study

BOX 3

Zuckerburg San Francisco General Hospital and Trauma Center: Resilient design to save material consumption

Resilient base-isolated structures and the most advanced seismic designs available, allowing it to glide 30 inches in every direction during a seismic event, save 3,000-ton steel consumption

Sustainable design providing natural daylight and ventilation and open green spaces, to create a humanistic and healing environment and address the well-being of patients, family and staff

Owner: San Francisco City Department of Public Health
Architect: Fong and Chan Architects, ARUP
Location: San Francisco, United States

Source: Desktop research, BCG

BOX 4 **Unicorn Island: Nature-positive and well-being oriented design with self-sufficient facilities**

Nature-positive design: Embeds natural elements into design, such as green roofs, wetland parks, urban gardens and farming.	Self-sufficient facilities: Flexibly integrated rain garden and urban run-off treatment leverages sponge-city principle to manage stormwater smartly	Well-being oriented design: Creates a green environment for citizens with aesthetic landscape, urban farms providing food, public transport and all facilities within 8 minutes' walk

Owner: Tianfu Group
Architect: Zaha Hadid Architects
Location: Chengdu, China
Scale: 670,000 square metre

Source: Zaha Hadid Architects contribution to the World Economic Forum study

3 Key levers for the buildings of tomorrow

Prioritizing 11 key levers available to various value-chain players is critical to achieving impact.

Realizing a broader green-building vision is contingent on attaining a value-chain transformation that goes beyond narrow, single-factor efforts. These typically focus on redesigning operations, engaging tier-one and -two suppliers, and meeting customer demands. Although these actions contribute to carbon abatement, a more comprehensive approach is crucial to large-scale success. Such an approach would take a systems lens to identify gaps in the value chain that require innovation and financing, and use collective actions to solve key challenges by leveraging enablers such as regulation, technology and financing.

Considered end to end, the building value chain ranges across five main stages: planning and design, procurement of building materials, construction, operation and end-of-life treatment. More than 25 types of players – including building owners, investors, designers, contractors, suppliers, regulators and industry groups – are involved at various points along the chain (see Figure 2).

These stakeholders can play vital roles in shaping sustainable practices, implementing environmentally friendly technologies, and promoting the adoption of green-building standards. Their collective efforts are crucial to achieving a successful transition to a more sustainable and environmentally conscious building industry.

FIGURE 2 **The building value chain involves more than 25 types of players**

Source: IEA, China Energy Conservation Association, BCG

This report has identified nearly 30 levers that drive green buildings across the four key characteristics – net zero, nature positive, resilient and well-being oriented – and identifies 11 as having the highest priority. Each lever engages multiple players within the value chain and requires collaboration among them (see Figure 3).

FIGURE 3 **Levers across the value chain can help achieve the buildings of tomorrow**

Value chain step	Net zero	Nature positive	Resilient	Well-being oriented
Planning and design	- Design for full disassembly - Optimize structural design	- Design for full disassembly - Avoid habitat influence	Create durable and flexible structure against extreme weather	- Ensure mixed use for livelihoods - Ensure access to public facilities
	Maximize space utilization			
Building materials	- Reduce material use - Decarbonize traditional materials	Consider nature-related criteria in selecting materials		- Use non-toxic building materials - Promote local workforce and construction methods - Share facilities and services - Organize community service and events to promote well-being and sustainability
	Switch to sustainable materials			
Construction	- Use prefab/modular components - Optimize and digitize processes	- Minimize construction waste - Minimize water and energy use	Deploy "repair and rebuild" construction techniques	
	Upgrade building insulation			
Operations	- Integrate energy management - Maximize clean energy	Promote water harvesting and circularity	Depend less on external utilities	
	Upgrade heating/cooling system			
	Upgrade heat recovery ventilation system			
End of life	Recirculate materials and minerals			
	Ensure end-of-life repurposing			
Lifetime offsetting	Plant biomass		Proactively assess risks	
	Plan for carbon capture, utilization and storage	Address climate change and nature simultaneously		

Cross-pillar Net zero Nature positive Resilient Well-being oriented

Source: BCG

These 11 levers for prioritization have been selected after assessing each lever's cost-effectiveness, technological maturity, potential positive impact on carbon abatement and the natural environment, resilience, and effects on human well-being (see Figure 4).

Green energy supply. Switching to clean energy sources is crucial to reducing buildings' carbon emissions. Buildings can accomplish this by adopting onsite renewable solutions such as rooftop solar panels and building-integrated photovoltaics, as well as by using external clean-energy sources such as heat recovery and renewable power. Innovative clean energy solutions such as energy storage, microgrids and direct current systems can help maximize clean-energy integration.

Recirculation of materials and minerals. Recycling and reuse of construction materials and minerals enables stakeholders to tap into the transformative benefits of a circular economy. Key opportunities lie in formalizing recycling processes and maximizing the use of recycled materials such as metal scrap, concrete aggregate and plastics. The World Economic Forum's Centre for Nature and Climate and Centre for Energy and Materials have conducted a thorough analysis of the circulation loops for the built environment in the report, *Circularity in the Built Environment: Maximizing CO_2 Abatement and Business Opportunities.*[11]

Decarbonization of traditional building materials. Using zero-carbon steel, concrete, aluminium and other materials is critical because these materials significantly reduce embodied carbon, which is responsible for more than 50% of total life-cycle carbon emissions. Advancing this lever involves process optimization, use of renewables for production, and achievement of a zero-carbon breakthrough such as hydrogen-direct reduced iron steelmaking and carbon-curing concrete.

Heating and cooling system upgrades. One way to reduce energy consumption is by installing more efficient heating, ventilation and air-conditioning (HVAC) equipment. For example, heat pumps can yield energy savings of 30% to 40% in comparison to traditional air-conditioners.

Integrated energy management. Building owners and operators can integrate various systems and technologies to monitor, control and optimize energy consumption and building efficiency while also ensuring occupants' comfort and productivity. By leveraging advanced energy management strategies, such as data analytics, internet of things (IoT) and AI, these stakeholders can make informed decisions on all aspects of a building's energy use to reduce energy waste, lower operating costs and minimize adverse environmental impacts.

Building insulation retrofits and upgrades. Enhancing the thermal efficiency and overall energy performance of buildings by installing or improving insulation materials, such as low-emissivity glass and spray foam, can help mitigate heat loss, minimize air leakage and enhance the overall building envelope, leading to substantial energy savings and long-term environmental benefits.

Conversion to sustainable materials. Shifting to sustainable building materials, including biogenic materials and other environmentally friendly alternatives, can pay valuable dividends in the form of reduced costs and a smaller carbon footprint. These materials come from renewable resources such as trees, and their environmental impact is significantly less than that of traditional construction materials. In addition, many sustainable building materials are non-toxic and possess excellent thermal and acoustic insulation properties, enhancing occupant comfort and improving human well-being.

Creation of shared facilities and services. Shared gardens, bike-sharing programmes and shared workspaces foster a sense of community and promote efficient use of resources. By encouraging building occupants to share spaces, utilities and amenities, these initiatives lead to reduced energy consumption, minimized waste generation and enhanced social interaction.

Creation of self-sufficient facilities. These enhance resilience to external disruptions and contribute to a more sustainable and environmentally conscious future in which buildings can operate autonomously and minimize their impact on natural resources. This endeavour involves the use of onsite power generation facilities, efficient water management systems and even urban farms to produce food onsite.

Water-recycling systems. This lever involves the capture, treatment and reuse of water from various sources within the building and outside, such as sinks, showers and rainwater. Recycled and treated water is suitable for non-potable uses, such as toilet flushing, irrigation and cooling systems. A sustainable water-recycling system can minimize water waste, conserve resources, lower bills and reduce the strain on municipal water supplies.

Design for net-zero, nature-positive, resilient and well-being oriented use. The design of a building can have a large and lasting impact on emissions, from construction to operation to end of life. By applying passive design, design for disassembly, structural design optimization and similar principles, and by integrating nature, clean-energy use and other green building elements into design, buildings can be made more sustainable.

FIGURE 4 | **The 11 prioritized levers involve various players and require multiple enabling actions**

Buildings of tomorrow

Key levers and players

Key levers	Owners and investors	Designers	Suppliers	Contractors	Utilities/operators
1 Green energy supply	✓	✓			✓
2 Recirculation of materials and minerals	✓	✓	✓	✓	
3 Decarbonization of traditional materials	✓		✓		
4 Heating and cooling system upgrades	✓	✓			✓
5 Integrated energy management	✓	✓			✓
6 Building insulation retrofits and upgrades	✓	✓			✓
7 Conversion to sustainable materials	✓	✓	✓		
8 Shared facilities and services	✓	✓			✓
9 Self-sufficient facilities	✓	✓			✓
10 Water recycling	✓	✓		✓	
11 Design for four key characteristics	✓	✓			

Enabling actions

A1
Align global standards and measurement for green buildings

A2
Identify flagship projects to enhance coordination among players

A3
Develop effective incentives and policies to offset any cost disadvantages

A4
Engage start-up communities and value-chain stakeholders to push for technological breakthroughs

Cross-pillar | Net zero | Nature positive | Resilient | Well-being oriented

Source: BCG

BOX 5 Examples of key levers in building value chains

Taikoo Hui Guangzhou

Green energy supply

100% renewable energy use with about 30,000 kilowatt-hour generated by onsite solar and over 30 gigawatt-hour purchased from the grid

Vanke Star City

Decarbonization of traditional building materials

Low-carbon adhesives for cement and tiles using fly-ash and slag, which have 25-75% less carbon emissions than traditional alternatives

Siemens BSCE factory

Integrated energy management

Digital energy management system includes automated control sensors, AI-based and cloud-enabled optimization platform and energy/emission data visualization system. Realized 12% carbon emission reduction

Yangzheng Library

Heating and cooling system upgrades

- 41.2% energy saving ratio of building operation by improving energy efficiency of equipment such as lighting system and electrical appliances, increasing heat recovery efficiency of the fresh air system to 70%
- 100% renewable use

IBR Future Complex

Design for all four characteristics

- First large-scale direct-current building with onsite solar, energy storage and equipment designed to fit the direct-current system
- Integrated sponge-city design with green roofs, rainwater utilization and stormwater management

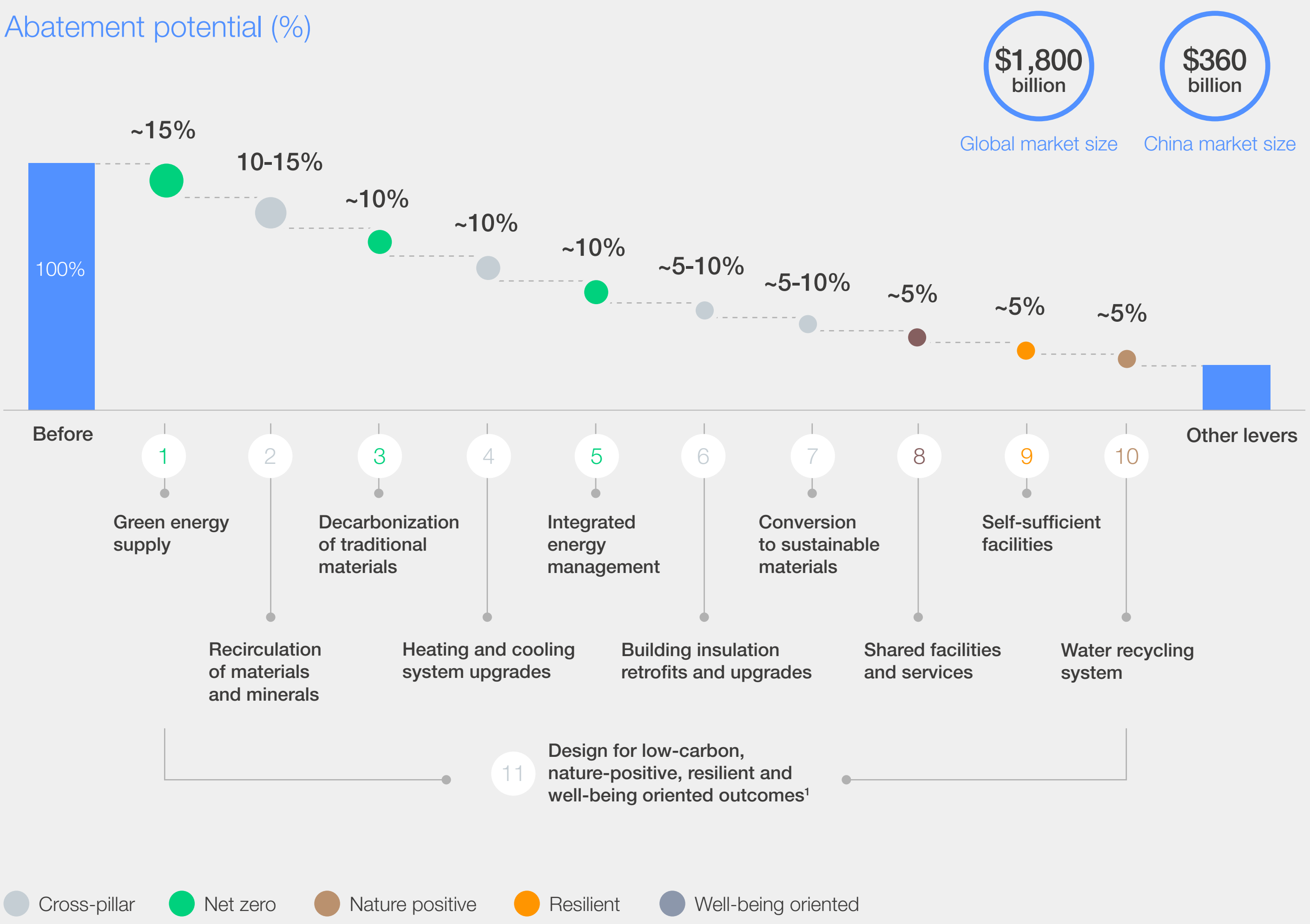
Source: Public reports and contribution to the World Economic Forum study from Swire Properties, Vanke, Siemens and China Association of Building Energy Efficiency

Together, these 11 high-priority levers carry over 80% abatement potential and substantial nature-positive, resilient and well-being impact. By 2030, they could generate a global market worth $1.8 trillion, of which the China market represents $0.4 trillion[12] (see Figure 5).

These levers will unlock numerous green opportunities for stakeholders throughout the value chain. The opportunities include rent premiums, new market growth, differentiated value propositions, enhanced talent attraction and improved environmental, social and governance (ESG) performance.

FIGURE 5

The 11 key levers have 80% abatement potential and represent a $1.8 trillion global market opportunity



Note: 1. Although it has limited direct carbon impact, applying advanced tech in design optimization can trigger large-scale abatement over the value chain
Source: BCG

Notably, implementing each of these levers requires collaboration among various players along the value chain. No player acting alone can fully address any of these levers, and stakeholders have to play their roles to realize each lever's potential (see Figure 6).

Collaboration among stakeholders is essential to implement each lever effectively and to drive the transition towards a greener future.

TABLE 1 | Key roles of value-chain stakeholders for each key lever

Lever	Key roles of value-chain stakeholders
Green energy supply	**Owners and investors:** Invest in clean energy installations to capture operational savings, potential rent premiums, access to green financing and the opportunity to establish green business lines. **Utility providers:** Expand production of clean energy solutions, to scale up the clean energy business, build sustainable competitive advantage and enhance access to green financing.
Recirculation of materials and minerals	**Waste collectors and processors:** Invest in demolishing and recycling capacity and in technology upgrades to boost business growth and to capture green financing. **Manufacturers:** Increase capacity to use recycled materials to offer differentiated green products, build stronger downstream relationships and expand into material recycling as a new business. **Contractors:** Provide sources of salvageable materials and increase their direct onsite use as a new revenue stream and cost-cutting measure.
Decarbonization of traditional materials	**Manufacturers**: Deploy net-zero processes and increase investment in advanced technology R&D to bypass capacity restrictions, reduce carbon-pricing costs and enhance green products' competitiveness. **Owners and investors:** Buy low-carbon traditional materials to gain potential rent premiums, attract green financing and save on carbon pricing.
Heating/cooling system upgrades	**Owners and investors:** Invest in equipment and system upgrades to capture operational cost savings and potential rent premiums. **Architects and engineers:** Deploy high-efficiency system designs to enhance sustainable design offerings and develop flagship projects. **Utilities and operators**: Provide technology and services that generate new revenue streams and build synergy with renewable development.
Integrated energy management	**Owners and investors:** Invest in digitalization to capture operational-cost savings and potential rent premiums. **Architects and engineers**: Deploy energy management systems, offer enhanced sustainable designs and develop flagship projects. **Utilities and operators:** Provide technology and services to generate new revenue streams and build synergy with renewable development.
Building insulation upgrade	**Owners and investors**: Invest in building insulation upgrades for new and existing buildings to capture operational cost savings and potential rent premiums. **Architects and engineers:** Provide designs for insulation upgrade and products to increase revenue from retrofit projects; develop flagship projects.
Transition to sustainable materials	**Owners and investors:** Capture green financing opportunities, carbon-price savings and carbon-sink assets by buying sustainable materials. **Architects and engineers:** Maximize sustainable material use in design to enhance sustainable design offerings and develop flagship projects. **Manufacturers:** Provide sustainable materials to foster business growth.
Creation of shared facilities and services **Creation of self-sufficient facilities** **Water recycling systems** **Design for net-zero, nature-positive, resilient and well-being oriented use**	**Owners and investors:** Approve and invest in design measures to capture capital and operational cost savings and rent premiums. **Architects and engineers:** Deploy design features to enhance green design offerings, develop flagship projects and potentially increase fees.

Source: BCG

4 Enabling actions to mobilize the whole value chain

To overcome key barriers and mobilize the value chain, enabling actions across steps and players are an imperative.

Key barriers to overcome

The building value chain is complex, and several significant barriers can hamper efforts to mobilize all participants towards a green transition.

First, current standards on green and sustainable buildings are not comprehensive enough to promote all four key characteristics. Many well-recognized global standards, such as LEED and Greenmark, primarily focus on net-zero criteria. Also, different standards define the nature-positive dimension inconsistently. For instance, LEED emphasizes water efficiency and the impact of materials, while Greenmark emphasizes greenery. Even within the net-zero dimension, Greenmark fully incorporates whole-life carbon criteria to cover embodied carbon, while other standards give greater weight to operational carbon emissions. The lack of balanced and harmonized standards across all four characteristics makes it harder for stakeholders to arrive at a comprehensive and unified approach to green building practices – and for architects and engineers to understand and apply different green building features to projects in different regions.

A second difficulty involves the absence of flagship projects that might effectively mobilize the entire supply chain in the green transition of buildings. The alignment and decision-making processes for these projects have become increasingly complicated due to discrepancies in the pace of net-zero commitments among different players and the misalignment of incentives and allocated risk. Although 10% of building material suppliers have announced targets that accord with the Science Based Targets initiative, only 3% of real-estate developers have done so.[13] The resulting slow growth of demand for net-zero building materials hinders overall progress towards sustainable construction practices. Addressing these discrepancies and fostering greater stakeholder collaboration in flagship projects are crucial to accelerating the adoption of green building solutions.

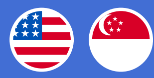
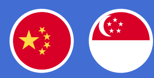
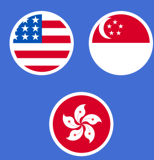
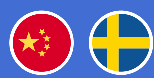
Third, many low-carbon solutions and technologies carry a cost premium – primarily because of high upfront costs, the still-developing maturity level of the technology, and the lack of economies of scale. For 60% of carbon emissions in the building value chain, the abatement cost exceeds $45 per ton of CO_2. The cost of hydrogen-based zero-carbon steel, for instance, can be 70%[14] higher than the cost of traditional steel in 2030 with no carbon pricing considered. The prevailing cost disadvantage of implementing green building solutions can thus be a major hindrance to their widespread adoption unless countervailing incentives are in place.

Four, the construction industry's relatively modest productivity growth is slowing the adoption of advanced green building technologies. The labour productivity growth in construction lags far behind that in manufacturing or the overall economy. The United States' Productivity Index of the construction industry has decreased by 19% from 1970 to 2020, in contrast to a 153% growth of the economy overall. This relatively low level of productivity in the building construction trade discourages owners, designers, construction companies and operators from adopting new technologies for sustainability.

Four enabling actions

To overcome these barriers and mobilize the entire building value chain, four enabling actions are crucial (see Figure 6). These actions, which need to be implemented throughout the value chain, require the active participation of all relevant players. By working collaboratively, stakeholders can foster a more sustainable and efficient transition to green building practices.

FIGURE 6 **To mobilize the entire value chain, enabling actions must be taken along multiple steps and players**

Barriers	Step-by-step enabling actions to overcome barriers	Key parties involved	Global best practices
Lack of comprehensiveness and alignment in standards	**Align global standards and measurement for green buildings** Multilateral entities to establish an evaluation framework from four perspectives: - Set holistic standards for world-recognized green buildings in terms of net-zero, nature-positive, resilient and well-being oriented attributes - Expand the coverage of existing green building codes from a micro (building) view to a macro (buildings/communities) horizon	- Governments and regulators (global multilateral entities) - Industry groups - Standard issuers	
Lack of flagship projects to mobilize supply chain	**Identify flagship projects to enhance coordination among players** Value-chain players to cooperate and implement flagship projects: - Identify opportunities to expand impact of green buildings - Strengthen cooperation, and align on the road to net zero - Boost economies of scale with targeted scenarios and solutions	- Governments - Developers - Suppliers - Thought leaders - Industry groups	
Cost disadvantage	**Develop effective incentives and policies to offset any cost disadvantages** Government to develop and deploy supportive policies: - Establish targets, standards, financial incentives, innovative funding and penalties to drive adoption - Offer value-chain players balanced risk-incentive policies to improve mobilization - Create an effective tiering mechanism to motivate deep decarbonization solutions	- Governments - Developers - Suppliers - Industry groups	
Low productivity growth and slow technology adoption	**Engage start-up communities and value-chain stakeholders to push for technological breakthroughs** - Create value-chain partnerships to share and test innovation to accelerate breakthroughs - Offer funding and capacity-building support to start-ups to activate broader technological innovation	- Start-up communities - Venture capital, private equity - Large corporations	

Source: BCG

Align global standards and measurement for buildings of tomorrow. To accelerate green building development, comprehensive, quantifiable, universally applicable green building standards are needed that provide a holistic framework encompassing the four key characteristics of the buildings of tomorrow: net zero, nature positive, resilient and well-being oriented.

To facilitate evaluation and improvement, measurable indicators need to be introduced for each aspect, allowing ongoing assessment of project performance and identification of areas for improvement. Establishing universal guidelines for standards and environmental impact measurement that are applicable across different regions can accelerate learning and understanding within the building profession and encourage global sharing of best practices to maximize the impact of networks (see Figure 7).

FIGURE 7 | A holistic and measurable standard for buildings is necessary to drive value-chain alignment

Holistic

Holistic framework covering major sustainability dimensions

Value- and result-driven standard that covers all four key characteristics: net zero, nature positive, resilient and well-being oriented

→

Measurable

Measurable KPIs[1] to evaluate performance and suggest areas for improvement

Result-driven and measurable evaluation framework and specific criteria to carry out quantifiable performance examinations

→

Universal

Universal standard to enable global best-practice sharing and maximize impact

Universal standard guidelines that are applicable to different regions across the world to expand impact and network

Note: 1. Key performance indicators
Source: BCG

To establish suitable holistic standards, an array of standard issuers, global institutions and thought leaders need to cooperatively develop and publish framework guidance in consultation with industry groups, leading companies and other key players. Building codes, policies and standards aligned with the framework are needed to facilitate widespread adoption. Also, the framework guidance needs regular updating to reflect emerging sustainability trends and to meet evolving development needs.

Identify flagship projects to enhance coordination among players. Establishing a network of flagship cases is crucial for setting standards and promoting collaboration throughout the value chain. Rigorous evaluation criteria that focus on delivering tangible, high-value outcomes need to be applied, thereby establishing ambitious targets for the market. By identifying global best practices, the network would provide benchmarks for the entire industry, encouraging others to strive for excellence.

To expand the network and foster collaboration, various stakeholders along the value chain need to come together. Key private players and proactive public entities with a strong commitment to developing flagship projects would logically be the initial participants in the network. Global institutions and thought leaders can provide support by identifying potential flagship cases and conducting comprehensive analyses, including measures of sustainability, roadmaps and financial/policy requirements. During flagship project development, all stakeholders – public and private – must align their goals and mobilize additional participants that can contribute products, funding, utility and policy incentives.

To ensure the success of the network, industry groups and global institutions need to regularly gather, exchange best practices and establish them as benchmarks for the value chain. Through its advocacy efforts, the network would gain wider acceptance and active participation from stakeholders across the industry.

Develop effective policies and incentives to offset any cost disadvantages. To promote the adoption of green solutions, effective policies and incentives are needed. Policies and incentives can not only guide operational change for building value-chain players, but also influence demand and supply in the market, so as to scale up technology adoption and drive down costs.

Five types of policy tools can be leveraged to promote green buildings: 1) a national master plan and target, e.g. on carbon emissions and energy performance of buildings; 2) standards and certification for green buildings; 3) government-led financial incentives such as grants, tax credits and public procurement; 4) innovative funding to support R&D and piloting; and 5) penalties including non-green tax such as tax on virgin material use.

These policy tools are widely used by globally leading countries, but the coverage of deep green-building solutions and market adoption need a boost (see Figure 9). For example, some public procurement programmes do not include green building materials or set the bar too low for deep green technology (such as recycled or decarbonized products) to be used. The cost competitiveness of these technologies cannot be effectively improved, hindering their scaling up.

FIGURE 8 **Five types of policy tools widely used by countries to drive green-building technology adoption**

Top 10 countries by GDP	United States	China	Japan	Germany	India	United Kingdom	France	Italy	Brazil	Canada
Master plan/target	✗	✓	✔	✔	✓	✔	✔	✔	✗	✓
Standards and certification	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Government financing incentives	✓	✓	✓	✔	✓	✔	✔	✔	✓	✓
Innovation funding	✔	✔	✔	✔	✓	✔	✔	✔	✓	✓
Penalty	✓	✓	✓	✔	✓	✔	✔	✔	✓	✓

Description	✔	✓	✗
Master plan/target	Deep-green transition plan for buildings (e.g. binding NZ[1] target)	National plan for buildings exists, but no deep transition (e.g. NZ) target	No specific national plan for buildings regarding carbon/energy
Standards and certification	Standards and certification holistically covering four aspects[2]	Standards and certification exist but do not fully cover the four aspects	No standard or certification for green buildings
Government financing incentives	Effective incentives for deep green solutions (e.g. recycled products)	Incentives exist, but do not favour/are not effective for deep green solutions	No financing incentives
Innovation funding	Innovation funds targeted at green building technology	Innovation fund available, but not specifically targeted at green building	No funding on building innovation
Penalty	Extra non-green tax, e.g. on use of virgin material, landfilling of building waste	Penalty on violation of environmental regulations	No penalty

Note: 1. Net zero; 2. Net zero, nature positive, resilient and well-being oriented
Source: Desktop research, BCG

Along with well-designed policies, purchasing coalitions are crucial to realizing incentives in tangible green-building projects and achieving economies of scale. Such coalitions send a powerful signal regarding collective demand, encouraging stakeholders throughout the value chain to take immediate action.

For instance, leading building developers and owners could form a coalition that focuses on green building materials, generating demand for zero-carbon steel, concrete and other materials that are essential for sustainable construction. By supporting the green transition of upstream manufacturing industries, the coalition can play a vital role in driving overall market transformation.

Within the coalition, each member would evaluate its asset portfolio, identify lighthouse projects, and publicly commit to demand for net-zero materials. This proactive approach enables coalition members to secure early access to zero-carbon materials, establish direct collaboration with suppliers, and accelerate progress towards net-zero carbon goals. Public institutes, financial institutions and other advisory parties can also actively participate in the coalition, providing essential support and guidance throughout the process.

BOX 6 **First Movers Coalition for Food**[15]

The World Economic Forum launched the First Movers Coalition for Food during the climate conference COP28 (the 28th Conference of Parties to the United Nations Framework Convention on Climate Change), in collaboration with more than 20 corporate and research partners in the food sector.

It aims to accelerate sustainable farming and production methods and technologies by leveraging collective demand for low-carbon agricultural commodities. It will do so through the power of aggregated demand, aiming for a combined procurement value for low-carbon commodities of $10-$20 billion from coalition members.

The World Economic Forum and participating companies and governments will work jointly to identify the demand commitments and pathways to support and mobilize the ecosystem to enable sustainable transformation.

Engage start-up communities and value-chain stakeholders to support R&D. Many green solutions are currently not scalable and need further development. For example, alternative production processes for cement that operate at low energy intensity or avoid use of fossil fuel-based kilns are still in the pilot phase and need further feasibility testing.[16]

To effectively drive green building technology breakthroughs, large companies and start-up communities need to be mobilized to work together on path selection, idea promotion and technology adoption.

First, leading players all through the value chain need to align on promising directions for technology breakthroughs so that start-ups can make progress on the route selected and provide feasibility feedback. For example, Baowu Steel, the largest steel-maker in the world, together with 24 steelmakers, 12 universities and other stakeholders has formed the Global Low-carbon Metallurgical Innovation Alliance to align on a decarbonization path and regularly exchange information on R&D progress and innovation.

Second, to promote innovation, public and private players including asset owners, investors, engineers and material suppliers can provide R&D support to start-up communities through accelerator programmes, venture funds and shared resources. For example, Vinci, a global leader in construction and infrastructure development, started Leonard Initiative, an incubation and acceleration programme for 185 start-ups in areas such as sustainable construction and materials, providing capacity building and venture capital.

In addition, leading players can bring innovative technology into flagship projects to enhance awareness and accelerate adoption. For example, Holcim collaborated with construction company Skanska on a net-zero concrete application to accelerate the transition to a greener built environment.

Conclusion: Time for collaboration

Achieving the goal of planning, building and operating green and sustainable buildings of tomorrow depends on stakeholders along the entire value chain. They must take collective and consistent action, starting now.

The building value chain has a pivotal role to play in reaching net-zero emissions and transitioning to a sustainable future, as it extends across such elements of the process as hard-to-abate materials, construction and real-estate development. Realizing a world in which buildings are net zero, nature positive, resilient and well-being oriented involves a plethora of actions. These include implementing energy-efficient designs, utilizing renewable energy and adopting sustainable materials. So far, the building value chain's pace of progress towards sustainability has been slow, owing to a lack of holistic standards and flagship projects to lead the market and showcase adoption of green building practices. The high cost-premium of sustainable technologies and the fragmented nature of the construction industry have also hindered progress.

Collaborative efforts by various stakeholders across the value chain are crucial both to align comprehensive global standards that encompass all aspects of the buildings of tomorrow and to pioneer flagship projects as examples of success. In addition, effective policies and incentives are needed to encourage widespread commitment to sustainability.

Finally, the engagement of start-up communities is essential to drive technological advances and push for breakthrough innovations in the industry. By working together and pursuing these strategies, it is possible to create a future where buildings actively contribute to a more sustainable, healthy and productive world.

The transition to the buildings of tomorrow will open up significant markets for upstream and downstream players. Greener and more sustainable buildings will offer enhanced attractiveness, higher rent premiums and advantages in sourcing green bonds and loan opportunities for asset owners and investors. Suppliers of materials and technology can enter a new market segment for growth, cut their carbon-pricing costs and achieve innovation breakthroughs. Architects, engineers and contractors can upgrade their talent and develop differentiated value propositions and competitive offerings. The transition can also contribute to robust economic growth and social well-being.

To capture these massive opportunities, early movers in the building value chain need to act now to advance towards a green and sustainable future – for their own benefit and for the collective net-zero future of humankind. Promoting the buildings of tomorrow in China, where most of the largest building material producers, constructors and real-estate developers are operating, will bring significant impact and experience to the domestic and global building market.

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Acknowledgements

The preparation of this insight report has drawn on the insights of many industry practitioners and experts, including leading businesses, academic and research institutes, industry associations and civil society members. Crucial support and suggestions also came from colleagues across teams. The authors thank all the organizations and experts who attended discussions and provided inputs for this report, with special acknowledgement for:

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