



# Unlocking New Opportunities for Carbon Neutrality in China's Building Sector

Executive Summary





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RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut climate pollution at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; Abuja, Nigeria; and Beijing, People's Republic of China.

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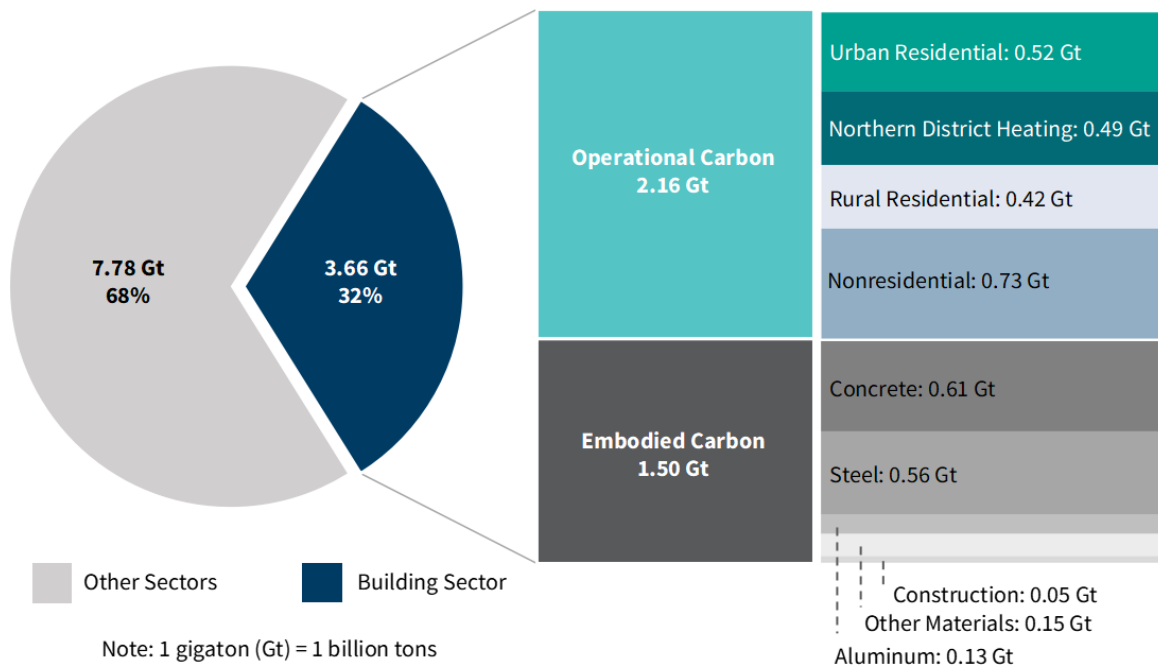
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# Toward a Systematic and Equitable Energy Transition: The Building Sector as a Pillar of China’s Carbon Neutrality Goals

Since China proposed its “dual carbon” goals in 2020, which aim to peak carbon emissions by 2030 and achieve carbon neutrality by 2060, the building sector has been a primary focus area. The sector’s total CO<sub>2</sub> emissions reached 3.7 billion tons in 2022, accounting for 32% of the nation’s total.<sup>1</sup> Of this, about 2.2 billion tons were emitted during building operations, whereas 1.5 billion tons were emitted during the production and transportation of building materials and during construction, which are referred to as embodied carbon (see Exhibit 1). Since 2014, total CO<sub>2</sub> emissions from China’s building sector have plateaued (see Exhibit 2). However, as living standards improve, China still has room for growth in building floor area and residential energy consumption on a per capita basis. Therefore, an urgent task is to decouple this growth from building emissions.

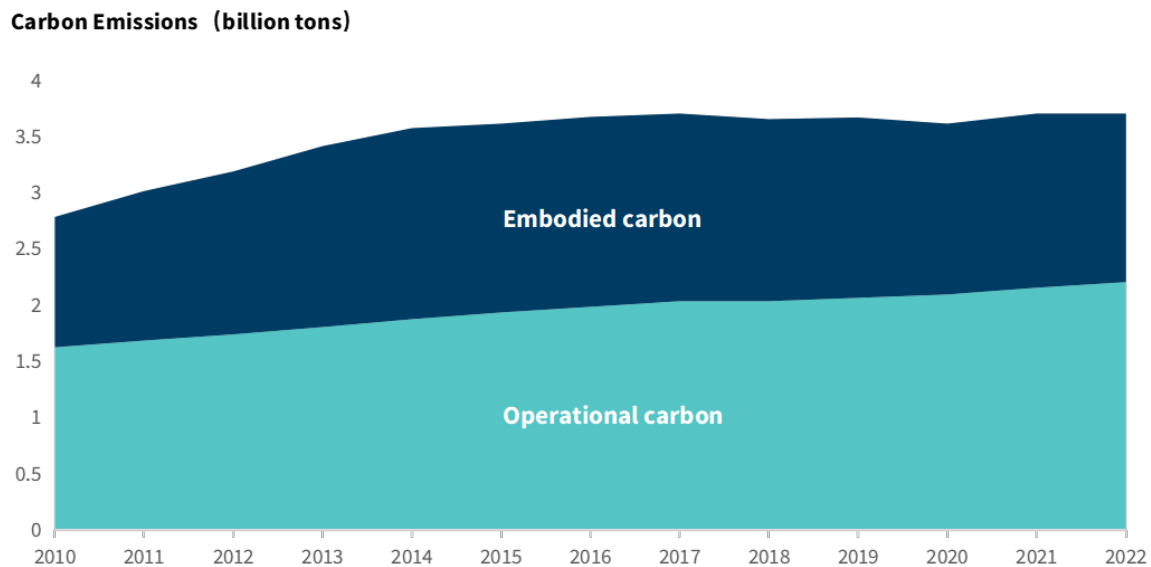
**Exhibit 1 CO<sub>2</sub> emissions breakdown from China’s building sector in 2022**



RMI Graphic. Source: International Energy Agency (IEA), <https://www.iea.org/reports/co2-emissions-in-2023/>; Building Energy Research Center Tsinghua University, *Annual Report on Building Energy Efficiency Development in China 2024*; Building Energy Research Center Tsinghua University, China Association of Building Energy Efficiency, *2023 China Building and Urban Infrastructure Carbon Emissions Report*

<sup>1</sup> In 2022, China’s national CO<sub>2</sub> emissions totaled 11.48 billion tons, according to data from the International Energy Agency (IEA) <https://www.iea.org/reports/co2-emissions-in-2023/>.

## Exhibit 2 CO<sub>2</sub> emissions from China's building sector from 2010 to 2022



RMI Graphic. Source: Building Energy Research Center Tsinghua University, *Annual Report on Building Energy Efficiency Development in China 2024*

Because buildings demand significant energy, a net-zero building sector is critical to China's energy transition. On one hand, buildings account for 21% of total final energy consumption and a quarter of electricity consumption in China. Moreover, the building sector's electrification rate has reached 44.9%, the highest among energy-using sectors. This means buildings can serve as an important flexible resource in the new energy system. On the other hand, buildings are the biggest user of industrial raw materials, accounting for 37% of total steel consumption and 55% of total cement consumption in China. Reducing embodied carbon in the building sector will lead to emissions reductions in upstream industrial sectors and nurture a market for low-carbon products.

A net-zero building sector is also critical to people's quality of life and an equitable energy transition. Decarbonization measures in this sector can bring more efficient, smarter, and healthier living environments to a broader population. China already has a large affordable housing program, the largest stock of existing buildings of any country in the world, and a significant number of rural buildings, totaling nearly 35 billion square meters (m<sup>2</sup>) and housing approximately 750 million people. Implementing carbon-neutral technologies in these buildings will improve energy access and quality of life for vulnerable populations and promote social equity.

The next 5–10 years will be critical for guiding China's building sector toward carbon neutrality. The building sector must realize high-quality carbon peaking and control and stabilize its current emissions plateau even as more buildings are built. At the same time, it is necessary to lay the foundation for a net-zero building sector by promoting the application and integration of carbon-neutral technologies as soon as possible and solving key issues related to the supply chain, cost, and market acceptance.

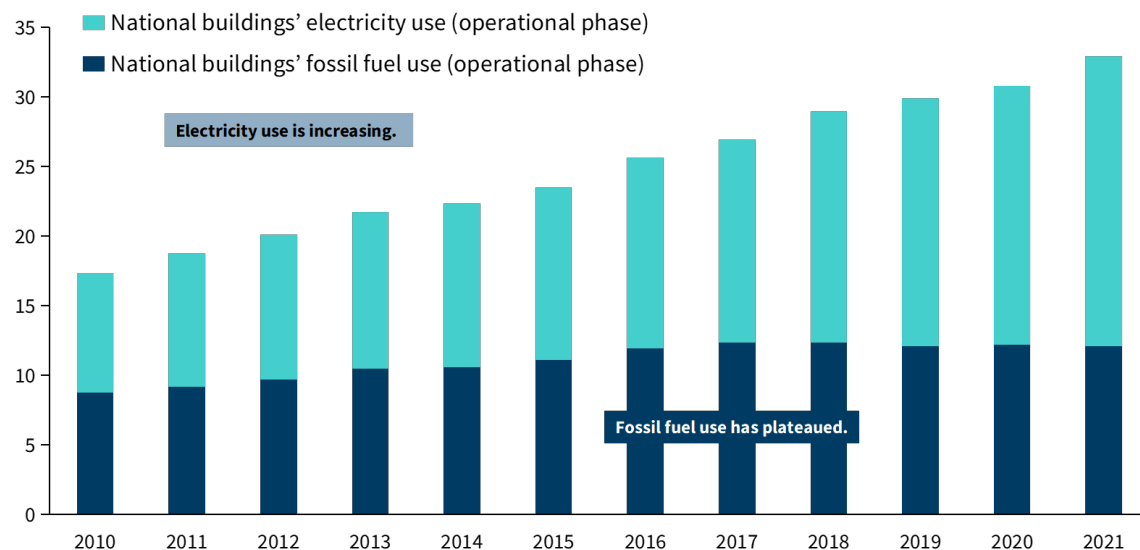
## Decarbonizing Building Operations: Energy Flexibility and Zero-Carbon Heating

Building operations account for approximately 59% of the life-cycle CO<sub>2</sub> emissions of buildings in China. These emissions come from two main sources: direct emissions from burning fossil fuels for heating, hot water, and cooking, and indirect emissions from electricity use and district heating. In 2022, China's buildings consumed 34.25 exajoules (EJ), accounting for 21% of the country's total energy consumption and 19.1% of China's total CO<sub>2</sub> emissions.

With continued economic development and improving living standards, the demand for building energy is expected to continue to rise. Electricity consumption in buildings has been increasing rapidly, with the 2021 level being nearly 2.5 times the 2010 level (see Exhibit 3). Meanwhile, the share of building electricity load during peak demand has been increasing, with air-conditioning loads accounting for 40% to 50% of the peak electricity demand in certain provinces, including Zhejiang, Hubei, and Sichuan. Although building fossil energy consumption has peaked,<sup>ii</sup> direct fossil fuel use in urban residential buildings and district heating continues to grow.

### Exhibit 3 Building electricity and fossil energy consumption during the operational phase

#### Buildings' operational energy use (EJ)



RMI Graphic. Source: China Association of Building Energy Efficiency, China Building Energy and Emissions Database, <https://www.cbeed.cn/#/database>

<sup>ii</sup> "Building fossil energy consumption" does not include the fossil energy consumption associated with electricity used in buildings.

## Challenges to Decarbonizing Building Operations

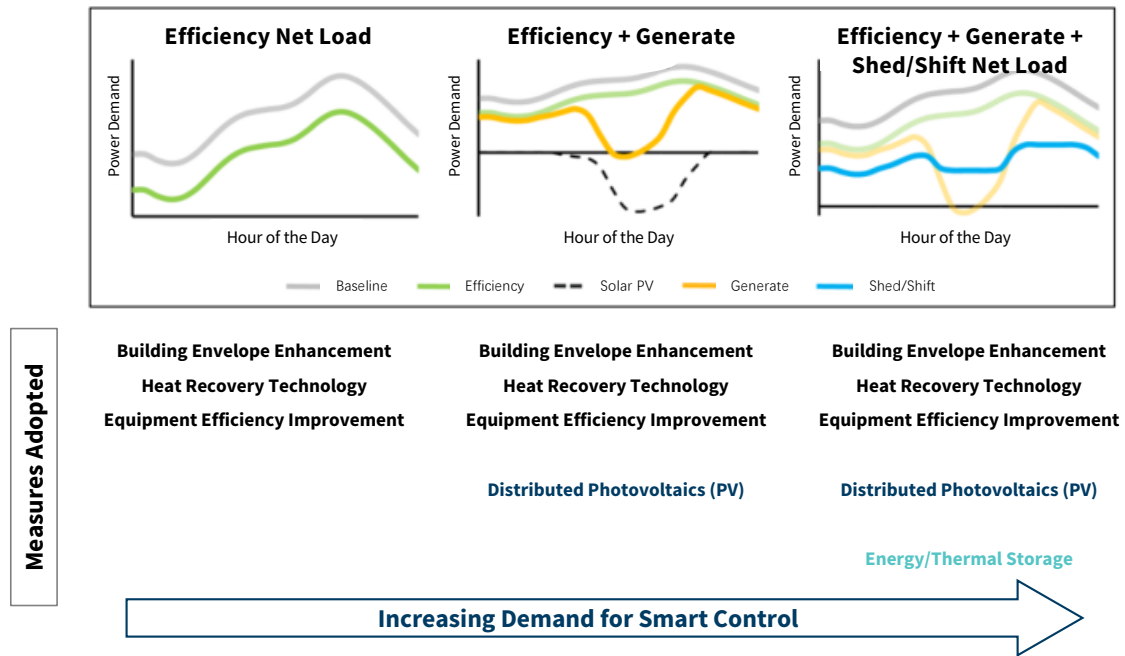
The increasing electricity consumption and peak loads of buildings are putting pressure on the power system supply and peak shaving, but buildings' potential as flexible resources has not yet been fully tapped. Most buildings have limited flexibility to manage their energy demand and generation. During peak demand periods, power generation still resorts to fossil fuels, delaying the decarbonization of the power system. This also affects industrial activities, leading to certain economic losses.

The heavy reliance on fossil fuel-based heating presents a decarbonization challenge due to the high cost of replacing existing systems. Northern district heating relies on coal/gas combined heat and power (CHP) plants and boilers. Thanks to its well-established infrastructure and cost efficiency, district heating lacks economically viable and technically mature heat source replacement solutions. In southern regions with hot summers and cold winters, demand for home heating has been increasing due to rising living standards. Many residents in regions such as the Yangtze River Delta use gas boilers for heating. Without additional economic incentives to replace existing heating equipment, the scale up of low-carbon heating alternatives such as heat pumps will continue to be delayed because of the so-called lock-in effect.

## Developing Buildings as Flexible Resources in the New Power System

The new power system requires more flexibility to ensure functioning grids with a high share of renewable energy. Given the limited availability of flexible resources on the generation side, the development of flexible resources on the demand side, especially in buildings, has become an imperative. Building loads offer high flexibility, economic efficiency, and ample space for distributed energy resources. Enhancing building energy flexibility involves improving efficiency, distributed generation, and shifting load. Effective combination of these measures with smart control can significantly boost building energy flexibility (see Exhibit 4). Improving building energy flexibility has significant potential for carbon reduction and economic benefits in China. RMI estimates that fully harnessing the potential of building loads' flexibility could reduce peak grid load by at least 10% nationwide. This would help China avoid approximately 500 billion yuan in additional investment in power system infrastructure and achieve at least 200 million tons of annual CO<sub>2</sub> reductions.

## Exhibit 4 Changes in building electrical load resulting from flexibility technologies



RMI Graphic. Source: US Department of Energy, *Grid-interactive Efficient Buildings Technical Report Series*, <https://www.energy.gov/eere/buildings/articles/grid-interactive-efficient-buildings-technical-report-series-overview>

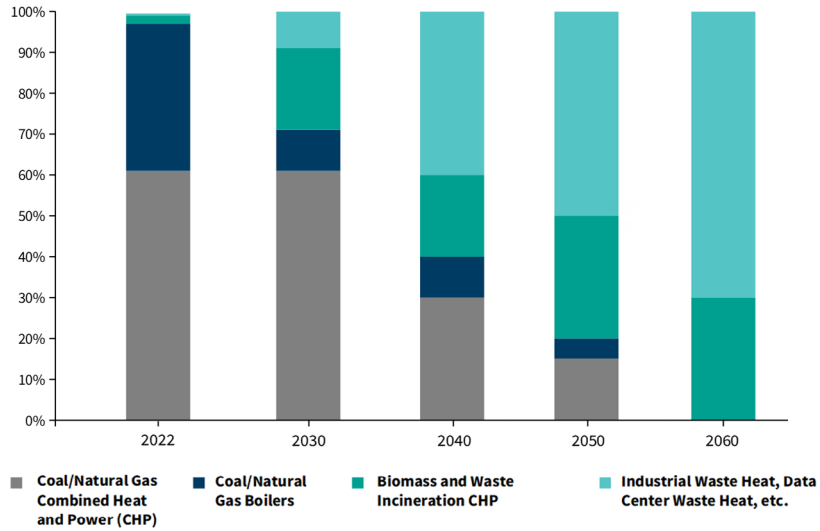
### Using Waste Heat + Heat Pumps to Achieve Zero-Carbon Heating

Decarbonizing district heating in northern China lies primarily in the use of waste heat resources. More than 200 EJ of usable waste heat is available from sources such as CHP plants, nuclear power, industrial processes, data centers, and wastewater treatment plants. The heating demand for urban buildings in northern China is about 54 EJ, and most northern Chinese cities already have well-developed district heating networks. The decarbonization strategy includes replacing coal-fired boilers with CHP in the short term and transitioning to biomass CHP and waste heat recovery in the long term, as well as deploying technologies such as seasonal thermal storage, long-distance heat transmission, and heat pumps to achieve a zero-carbon transition (see Exhibit 5).

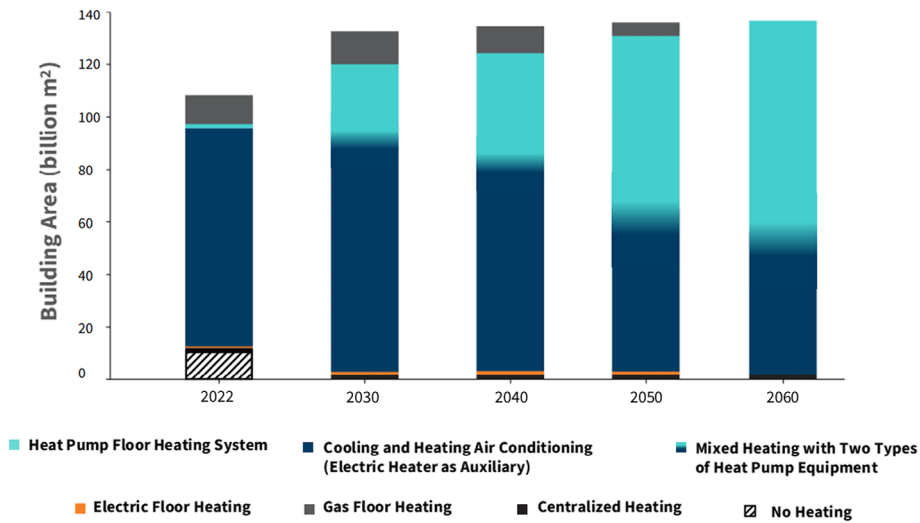
Heat pumps offer the best opportunity for decarbonizing heating in southern regions with hot summers and cold winters where district heating infrastructure is lacking due to the short winter season and intermittent heating demand. The demand for heating in these regions has increased significantly in recent years. By 2030, more than 20 million residents in the Yangtze River Delta will have new heating systems, increasing heating demand by about 40% compared with 2020. Heat pumps are ideal for deployment in these regions because they are high-efficiency, low-emissions, and cost-saving dual heating-and-cooling equipment. In the near term (before 2030), heat pumps should be used in new buildings, while in the long term, efforts should focus on low-carbon retrofits of existing buildings and the eventual phase out of gas in residential heating systems.

## Exhibit 5 Zero-carbon transition pathways for northern district heating systems and hot summer and cold winter climate zones

Zero-Carbon Transition Pathways for Centralized Heating in Northern China



Zero-Carbon Heating Pathways in Hot Summer and Cold Winter Regions (Taking the Yangtze River Delta Region as an Example)



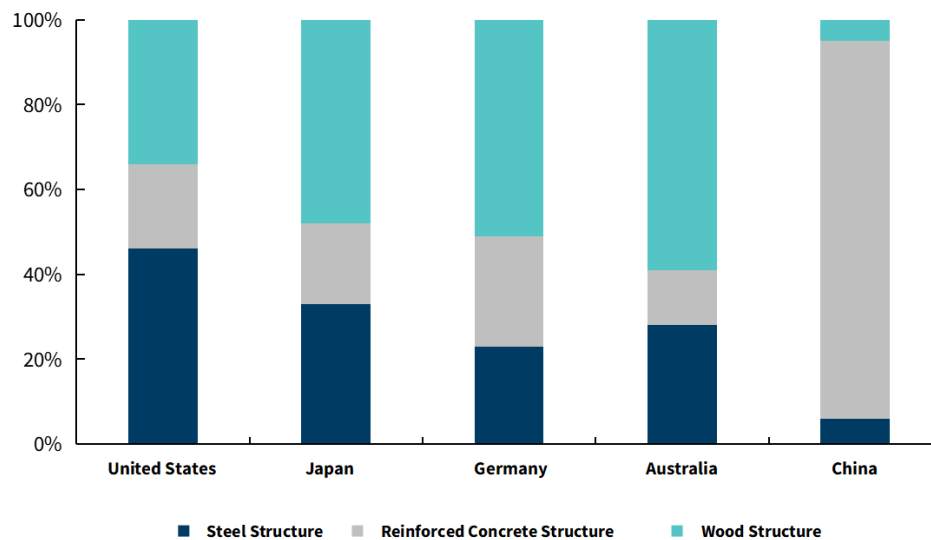
RMI Graphic. Source: RMI analysis

## Tackling Embodied Carbon: Low-Carbon Procurement and Bio-Based Materials

Embodied CO<sub>2</sub> emissions are another critical focus for decarbonizing the building sector, accounting for approximately 41% of a building's life-cycle CO<sub>2</sub> emissions. In 2022, total embodied CO<sub>2</sub> emissions in China's building sector were approximately 1.5 billion tons of CO<sub>2</sub>, accounting for 13% of the country's total. Structural materials contribute more than 60% of the embodied carbon in buildings and more than 12% of the total CO<sub>2</sub> emissions in the building sector.

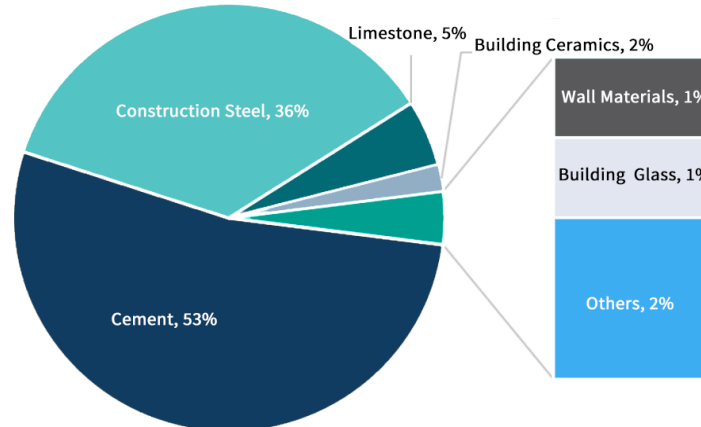
Optimizing design and structural systems is critical to reducing embodied carbon. In China, reinforced concrete structures are the most common building type, accounting for over 80% of civil buildings' structure, while wood and steel structures are less common, with steel structures accounting for only about 5% of buildings (see Exhibit 6). Among all building materials, steel and cement account for 36% and 53% of CO<sub>2</sub> emissions, respectively, making them the most significant sources of embodied carbon (see Exhibit 7).

**Exhibit 6 Comparison of building structure types in China and in other countries**



RMI Graphic. Source: Data from China Building Material Federation

## Exhibit 7 CO<sub>2</sub> emissions from major building materials industries in 2020



RMI Graphic. Source: Data from China Building Materials Federation

### Challenges to Decarbonizing Embodied Carbon in Buildings

The steel and cement industries face challenges in reducing emissions due to technological maturity, cost, and lack of investment. At the same time, steel and cement remain the most important building materials. The dominance of reinforced concrete structures in China is likely to continue due to factors such as high building and population density, structural requirements, technical maturity, fire resistance, and durability requirements. This presents three challenges that need to be addressed to reduce embodied carbon in buildings: improving the durability and extending the life of existing structures, increasing investment in decarbonizing industrial sectors such as steel and cement, and promoting the use of low-carbon concrete and steel in construction.

Bio-based materials such as bamboo and wood are underdeveloped as zero-carbon building materials. Bamboo and wood offer near-zero emissions as well as faster construction times than traditional building materials. However, their strength, durability, and fire resistance still need to be improved through modern processes. There is limited awareness and acceptance of bamboo and wood structures in the construction sector, and their use is generally limited to small buildings. Issues such as the limitations of modern bamboo components in large-span, large-section buildings and concerns about their durability and fire resistance need to be addressed.

### Scaling Up Low-Carbon Materials with Public and Private Green Procurement Programs

Green public procurement and private procurement programs are important drivers to promote the use of low-carbon building materials such as low-carbon steel and concrete. In 2024, China's national government launched the third batch of pilot cities in its Green Building Material Promotion Program, covering 100 cities and 100 product categories, and it launched another national program to expand use of green building materials in rural areas. Leading construction and real estate companies are joining forces to form a green procurement alliance to support green supply chains.

However, it is important for these green procurement schemes to include emissions metrics in their definitions of “green.” It is also important to develop CO<sub>2</sub> emissions accounting rules and emissions databases to quantify low carbon in procurement practices. This area is becoming increasingly urgent as China accelerates the establishment of a product CO<sub>2</sub> emissions management system, as called for in policy from late 2023, and plans to establish accounting rules for 200 key products by 2030.

Leveraging the building industry to promote low-carbon materials can lead to huge carbon reduction potential and nurture a market for first movers of low-carbon industrial materials. RMI estimates that China’s building industry consumes approximately 350 million tons of steel and 960 million tons of cement annually. Consider low-carbon concrete: If low-carbon concrete with supplementary cementitious materials of no less than 30% were widely used in government construction projects, the carbon intensity of concrete could be reduced by 22.5%, resulting in an annual reduction of 190 million tons of CO<sub>2</sub> emissions. In addition, nationwide promotion of low-carbon concrete could potentially reduce annual CO<sub>2</sub> emissions by 590 million tons by 2035.

### **Promoting Modern Bamboo and Wood Structures to Diversify Applications**

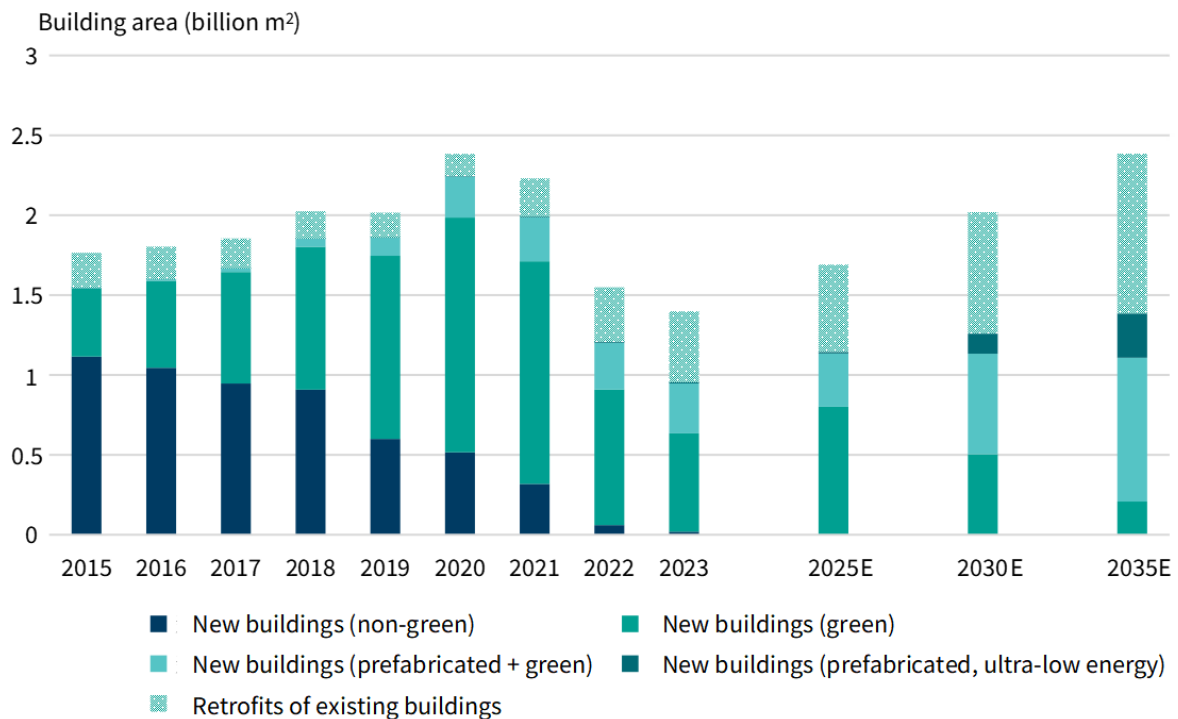
Bamboo and wood structures have significantly lower life-cycle CO<sub>2</sub> emissions and environmental impacts than steel and concrete structures. Modern wood structures can reduce material CO<sub>2</sub> emissions by 48.9% to 94.7% and life-cycle CO<sub>2</sub> emissions by 8.6% to 13.7% compared with similar structures using steel and concrete. China has published national and industry standards for engineered wood products, including glulam and cross-laminated timber components used domestically and internationally in wood structures. However, in China, most wood buildings are small tourist buildings, and the wood structure building market is less than 20 billion yuan. By contrast, the global wood structure building market reached 150 billion yuan in 2022. This is largely due to China’s underdeveloped standard systems for large-span buildings and the need for more innovations and testing to expand modern bio-based structures.

In the future, bamboo and wood structures are expected to become more popular in new rural houses, cultural and tourism buildings, commercial complexes, and high-end residences. The construction of facilities in the five major national parks is expected to create significant opportunities for wood structures, with an estimated new construction floor area of about 4 million m<sup>2</sup>. Approximately 760,000 villages and 5 million rural homes are built or rebuilt each year in China. RMI estimates that if 10% of the new rural houses built each year were modern wood structures, it would create a market of about 150 billion yuan for wood building material. In addition, using wood structures for these houses could reduce embodied carbon by approximately 18.24 tons per house, potentially avoiding 4.56 million tons of CO<sub>2</sub> emissions annually across the country.

## Driving a New Growth Model: Technology Integration and Business Model Innovation

Over the next decade, China's building industry will be driven by both new green buildings and low-carbon retrofits of existing buildings as part of its carbon neutrality goals. RMI estimates that new construction will grow at a rate of 3% per year, reaching approximately 1.38 billion m<sup>2</sup> by 2035. All new buildings will meet 100% green building standards, 85% of which will be prefabricated buildings and 20% of which are expected to be ultra-low-energy buildings. Existing buildings, especially those built before 2015, will require energy-saving and low-carbon renovations, estimated at 1 billion m<sup>2</sup> per year by 2035. Overall, the total floor area of new and renovated buildings in China will reach nearly 2.4 billion m<sup>2</sup> annually by 2035, with the share of existing building renovations increasing to 42%, highlighting the growing importance of retrofitting in the building sector (see Exhibit 8).

**Exhibit 8 Building floor areas under construction per year, new buildings and retrofits, 2015–35**

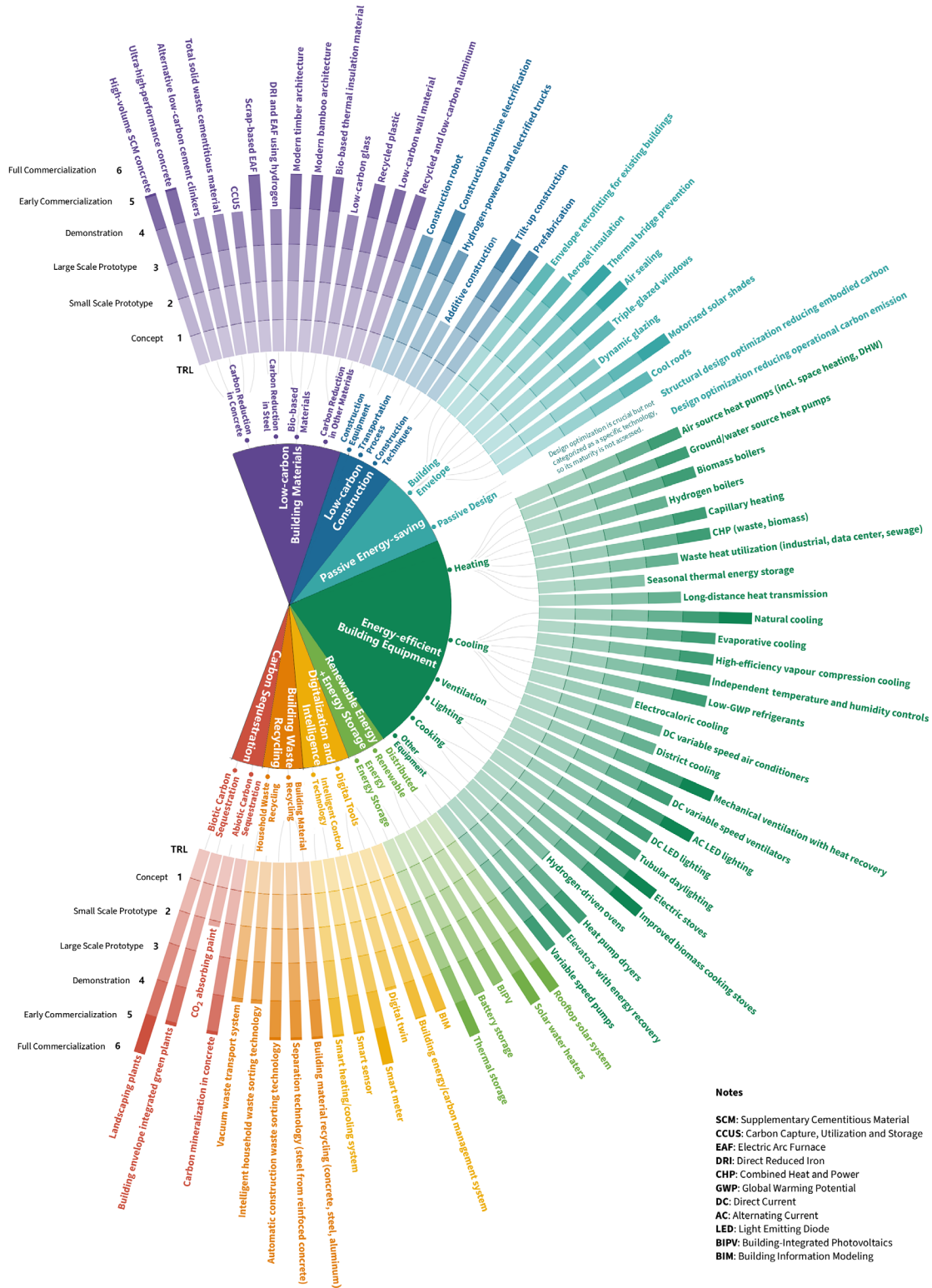


RMI Graphic. Source: RMI analysis

## Scaling and Integrating Decarbonization Technologies Becomes a New Growth Driver

Decarbonizing the building sector requires the widespread use of low-carbon technologies and products. RMI has identified eight key technology categories to decarbonize the entire building sector: building materials, construction, passive energy-saving, equipment energy-saving, renewable and energy storage, digitization, recycling, and carbon sequestration. RMI analysis shows that within these eight categories, the 76 most representative building technologies have an average technology readiness level (TRL) of 4.8

# Exhibit 9 Maturity analysis of carbon reduction technologies in the building sector in China

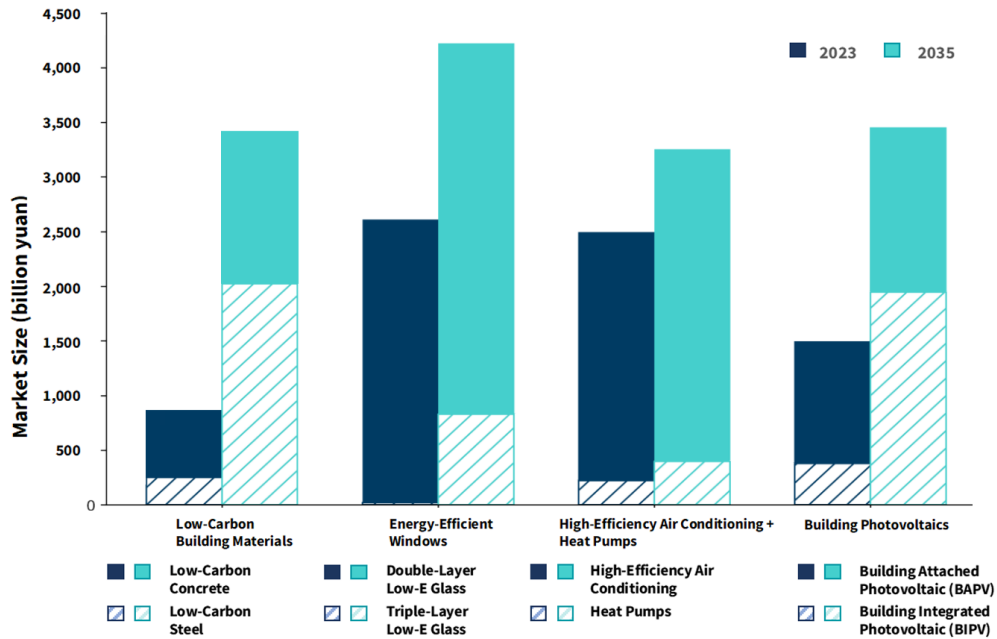


Note: The technology readiness levels (TRLs) are simplified based on the IEA's classification for clean energy technology maturity, divided into six levels: (1) concept, (2) small scale prototype, (3) large scale prototype, (4) demonstration, (5) early commercialization, and (6) full commercialization.

RMI Graphic. Source: RMI analysis

out of 6 (see Exhibit 9). More than half of these technologies are already in commercial use, and over 90% have reached the early commercialization level or higher. Therefore, the strategy for decarbonization technology deployment in the building sector should focus both on scaling up technologies at commercial scale and on integrating technologies as a system, which will require both market power and public support.

### Exhibit 10 Projected market growth of four key low-carbon technologies, 2023–35



RMI Graphic. Source: RMI analysis

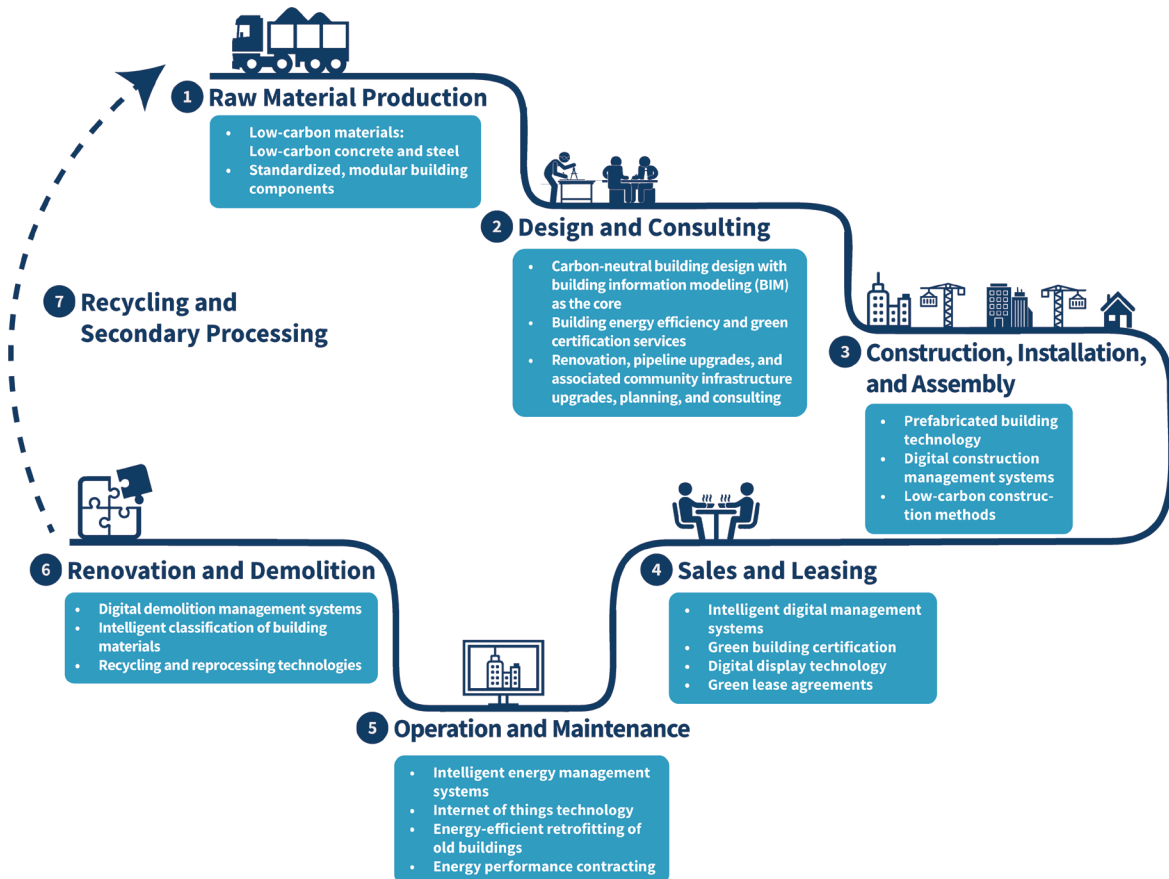
RMI also analyzed the market potential for four key technologies: low-carbon building materials, energy-efficient windows, high-efficiency air conditioners and heat pumps, and building photovoltaics (see Exhibit 10). The main opportunities for scaling up low-carbon steel and concrete remain in certification and market schemes, such as large green procurement programs. The market for high-efficiency air conditioners and heat pumps will be mainly driven by the trade-in policy that replaces old equipment with new, more efficient equipment, as explicitly mentioned in the 2024 National Measures to Promote Large-Scale Equipment Replacement and Trade-in of Consumer Goods, as well as the increasing demand for residential heating in southern China. Building photovoltaic technologies will be driven mainly by progress in nationwide photovoltaic policies and continued cost reductions in building photovoltaic production.

### Business Model and Institutional Innovation: Value Chain Integration, Smart Management, Standardization, and Beyond

The development of new business models and institutional mechanisms is critical for the large-scale deployment of low-carbon products and technologies. Value chain integration, smart management, and standardization across industries are key trends that are powerful enablers for reducing emissions across the entire building industry value chain. Value chain integration involves connecting supply chain players for consistent action and implementing life-cycle design and management approaches. Smart management, enhanced by digitalization and artificial intelligence, will support optimal and real-time energy management and improve process efficiency. Building standardization is the provision of modular components to improve construction efficiency and reduce waste, as well as product, design, and rating

system standardization. In the context of carbon neutrality, new business models for the building sector will require the synergistic action of various actors along the value chain, including building material manufacturers, designers, construction companies, developers, operation and maintenance service providers, retrofitters, and building waste recyclers (see Exhibit 11).

## Exhibit 11 Stakeholder actions in the building industry value chain



RMI Graphic

At the same time, innovative market mechanisms can effectively mobilize corporate actions by leveraging capital and investment. China is gradually exploring the opening up of the carbon trading market in the building industry, internalizing the cost of CO<sub>2</sub> emissions by trading CO<sub>2</sub> emissions rights, and providing incentives for construction enterprises to accelerate emissions reduction. Innovative green financing systems, such as green credit, green bonds, green funds, green insurance, and a combination of these tools, can support the development of star-rated green buildings, assembly buildings, near-zero-energy buildings, energy efficiency of existing buildings, and green renovation projects.

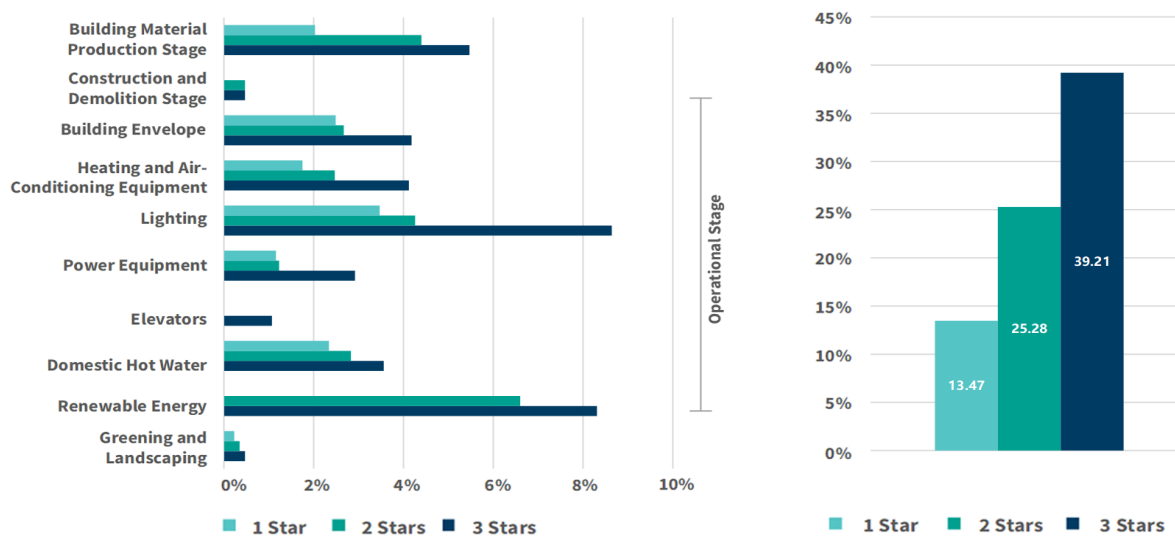
## Improving Equity and Inclusiveness: Carbon Neutrality for Vulnerable Groups

Carbon neutrality in the building sector cannot be achieved without addressing issues of equity and inclusion in policies, services, and resource allocation to ensure that everyone, especially vulnerable groups, has equal access to clean energy, low-carbon technologies, and improved quality of life. Although over 90% of new buildings in China are required to meet green standards, existing buildings often fall far short of current energy efficiency requirements. Low-carbon technologies are scarce in older residential communities and in rural housing due to outdated building standards and inadequate financing. Affordable housing, old neighborhoods, and rural housing are key battlegrounds in the transition to carbon neutrality. RMI estimates that these three types of housing in China cover nearly 35 billion m<sup>2</sup> of floor space, representing 56.5% of the country's total floor area, and that promoting low-carbon building technologies for them could benefit approximately 850 million residents.

### Leveraging Affordable Housing for Low-Carbon Technology Adoption

Following policy calls to stabilize the housing market and promote housing equity, the development of affordable housing will continue to be a top priority in China. China already has the most extensive affordable housing system in the world: Since 2008, a total of 80 million affordable housing units have been built nationwide, helping more than 200 million people improve their housing conditions. Policy already requires new affordable housing to meet green building standards. However, the use of deep decarbonization technologies, such as those used in ultra-low-energy buildings and modular construction, is still limited due to cost concerns. Integrating these technologies into affordable housing nationwide will accelerate the adoption of low-carbon technologies, leading to significant reductions in CO<sub>2</sub> emissions and improvements in quality of life (see Exhibit 12). RMI estimates that the introduction of prefabricated construction and the development of ultra-low-energy buildings for 20% of affordable housing projects, along with appropriate government investment and a requirement to achieve two-star green building certification, could lead to a 40% to 50% reduction in CO<sub>2</sub> emissions from affordable housing projects, benefit 13 million people, and create a market worth around 1.8 trillion yuan.

## Exhibit 12 CO<sub>2</sub> emissions abatement potential of green star-rated residential buildings by stages (left), and CO<sub>2</sub> abatement potential of green star-rated residential buildings (right)



RMI Graphic. Source: China Academy of Building Research, *Research on carbon emission of green building based on life cycle theory*

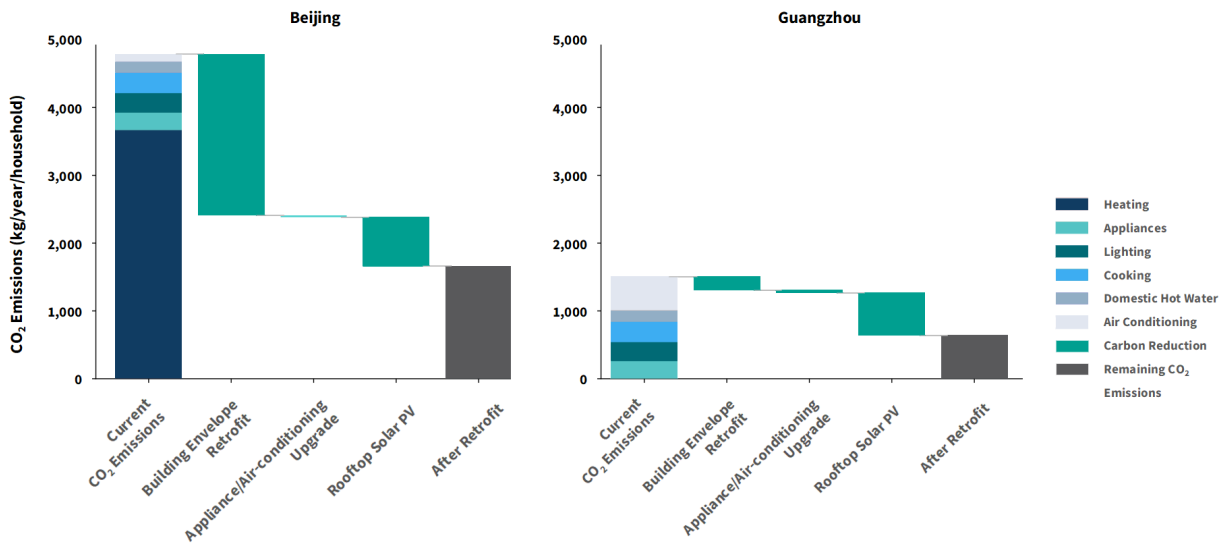
## Promoting Low-Carbon Retrofits of Old Residential Neighborhoods

China has an increasingly large existing building stock in old residential neighborhoods, another area needing low-carbon buildings. China has nearly 160,000 old neighborhoods in cities built before 2000, with more than 42 million households and a floor area of about 4 billion m<sup>2</sup>. The old neighborhoods generally have poor energy efficiency performance, especially poor thermal insulation, which results in significant heat loss. There are basically no energy-saving measures for old residential buildings built before 1990, and those built before 2000 are mostly unable to meet 50% of the current energy-saving standard, with energy intensity in old buildings being two to four times that of a new residential building.

It is therefore essential to develop tailored low-carbon retrofit strategies for old neighborhoods across the country, taking advantage of local climate characteristics, local resources, and new technologies. In cities in northern China, low-carbon retrofit opportunities include improving building envelopes, deploying rooftop solar photovoltaics (PV), and transitioning to zero-carbon urban heating systems. RMI estimates that envelope improvements in Beijing can reduce CO<sub>2</sub> emissions by 50% and increase indoor temperatures by 2°C to 3°C. In addition, installing PV systems on 40% of the rooftop of a six-story building can power the whole building.

In cities in southern China, old residential communities can be retrofitted with rooftop solar panels and energy-efficient appliances. RMI analysis shows that upgrading building envelopes and air-conditioning systems in Guangzhou can directly reduce CO<sub>2</sub> emissions from cooling, and if 40% of a building's roof area is used for PV installation, the electricity generated can meet 80% of the building's total electricity demand (see Exhibit 13).

## Exhibit 13 Low-carbon retrofit potential for old residential buildings in Beijing and Guangzhou



Note: The analysis assumes carbon reduction strategies and effects for a typical six-story slab-type residential building constructed in the 1980s in Beijing and Guangzhou.

RMI Graphic. Source: RMI analysis

## Transforming Rural Housing into Net-Zero Homes across Their Life Cycle

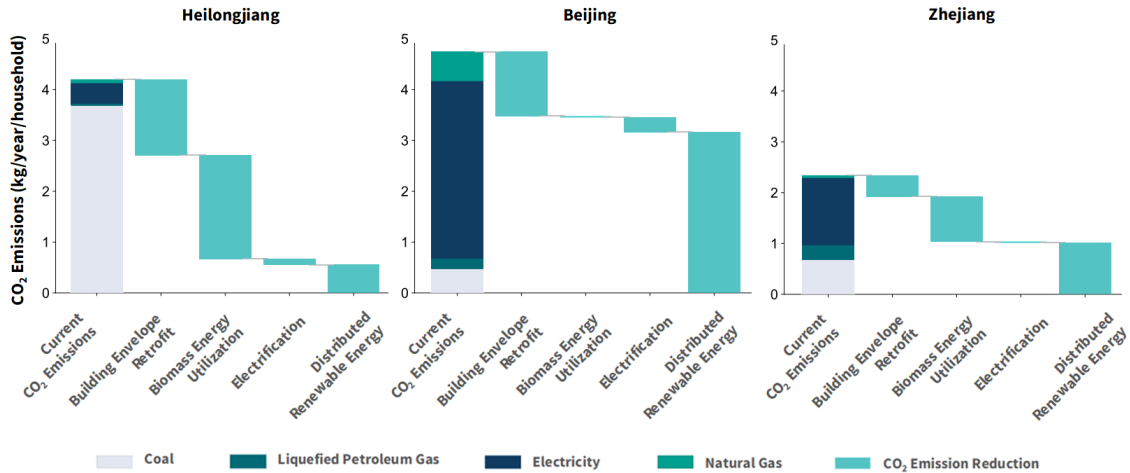
Rural housing in China has a floor area of about 25.9 billion m<sup>2</sup>, which accounts for 42.5% of the country's total housing floor area and involves nearly 500 million people. CO<sub>2</sub> emissions from rural housing account for about 20% of the total emissions from the building sector. After more than four decades of development, rural per capita housing space grew from 8.1 m<sup>2</sup> in 1978 to 45.8 m<sup>2</sup> in 2018. Thanks to progress in the electrification of rural housing, electricity accounted for 42% of rural housing energy consumption in 2022. However, fossil fuel energy such as coal and natural gas still accounts for 37.6% of the energy mix, leading to high CO<sub>2</sub> emissions. Lack of construction supervision and non-compliance with building codes, relatively poor building envelopes, and underdeveloped renewable energy potential significantly increase the indirect CO<sub>2</sub> emissions from rural housing.

Rural buildings in China offer great potential for demonstrating life-cycle net-zero homes because of their relatively low building density and the potential for renewable energy use and new construction. China's rural areas have a rooftop solar generation capacity of 2.9 trillion kilowatt hours (kWh) per year, far more than their electricity demand of 350 billion kWh per year. They also have abundant biomass resources from agricultural residues to meet heating and cooking demand.

Decarbonization opportunities for rural housing include building envelope retrofits, biomass use, distributed renewable energy, and electrification. In northern rural areas, the focus is on decarbonizing heating, with biomass and electrification being the most prominent opportunities. In southern rural areas, where energy use is primarily driven by cooling and cooking, distributed renewable energy and biomass are the main decarbonization opportunities (see Exhibit 14). There will also be significant demand for new construction and renovation in rural areas. This presents a critical opportunity to promote low-carbon

building materials and construction methods, such as prefabricated rural houses, modern bamboo and wood structures, and low-carbon cement and concrete.

### Exhibit 14 Decarbonization measures and abatement potential for rural houses in different regions of China



Note: This model uses the average household energy consumption and CO<sub>2</sub> emissions of rural residences in the target province as the baseline for determining decarbonization pathways for rural housing.

RMI Graphic. Source: RMI analysis

# From Peaking to Net Zero: Near-Term Actions to Speed up the Transition

## 1. Actions to accelerate decarbonization of building operations

- **Develop and promote smart technologies to improve energy flexibility:** Scale up smart control and Internet of Things technologies to integrate equipment through energy-carbon management platforms. Develop response strategies such as load shifting and load shedding based on big data and artificial intelligence to improve the accuracy of energy and carbon management. Accelerate the development of core technologies for the interaction of the grid, buildings, and electric vehicles.
- **Innovate business models and incentives to unite homeowners in demand response:** Explore business models and incentive mechanisms that bring together scattered building loads to participate in demand response, such as energy performance contracting. Investigate bidirectional charging and discharging applications that efficiently integrate electric vehicles with buildings.
- **Strengthen R&D in long-distance heat transmission and seasonal thermal storage:** Accelerate the research, development, and application of long-distance heat transfer and seasonal thermal storage technologies to address the mismatch of waste heat availability in time and space, thereby improving the flexibility and stability of waste heat utilization. Conduct pilot projects in northern cities to test the practicality and economic feasibility.
- **Establish an interdepartmental mechanism for waste heat utilization:** Form a coordinating group to manage waste heat recovery, set clear goals, and define roles and responsibilities. Conduct comprehensive surveys and assessments to identify available waste heat resources in urban areas. Publish benchmark prices for waste heat resources and facilitate connections between CHP plants and waste heat resource owners to establish a comprehensive waste heat utilization process.

## 2. Actions to control embodied emissions in buildings

- **Establish a carbon footprint management and indicator system for building materials:** Develop carbon accounting and labeling systems for building materials. Develop Product Category Rules and standardize Environmental Product Declaration certification for major building materials. Incorporate low-carbon indicators into the green building material evaluation system and integrate CO<sub>2</sub> emissions metrics into the green building evaluation system.
- **Promote low-carbon building materials through existing support programs:** Increase the use of low-carbon building materials in government-funded buildings and infrastructure projects by incorporating emissions requirements into government procurement policies. Use successful green public procurement projects to establish the credibility and market acceptance of low-carbon materials, and then promote their wider use in private projects.
- **Improve standardization for advanced bamboo and wood structures:** Develop design, construction, and certification standards for large-span, high-density bio-based building

structures with tested solutions for durability and fire resistance. Establish a quality certification system for bamboo and wood structures to ensure reliability.

- **Implement incentive policies to promote the development of bamboo and wood structures:** Refine land use, taxation, and fire safety policies to support the commercialization and market development of bamboo and wood structures, and introduce financial incentives, tax credits, and supporting policies. Improve the overarching strategy for promoting bamboo and wood construction in the country, and prioritize demonstration projects in new rural houses, cultural and tourism buildings, commercial complexes, and high-end residential areas.

### 3. Actions to mobilize market and technology development

- **Support demonstration of key carbon-neutral technologies of lower maturity:** Increase R&D investment in emerging technologies such as low-carbon building materials production and carbon sequestration. Provide financial support and tax incentives to encourage the development of innovative technologies. Early technologies with significant carbon reduction potential could be demonstrated in publicly funded projects such as public buildings.
- **Strengthen market mechanisms to accelerate full market adoption of commercially available technologies:** Explore market-based mechanisms to accelerate the adoption of technologies that are in the early stages of commercialization, such as heat pumps and BIPV. Develop green finance tools and publish investment guides to support low-carbon building projects and low-carbon retrofits of existing buildings.
- **Promote integration of building technologies through value chain integration, smart management, and standardization:** Strengthen collaboration among material suppliers, construction companies, and subcontractors with business models such as the engineering, procurement and construction model to manage CO<sub>2</sub> emissions throughout the project life cycle. Encourage the adoption of building information modeling, smart energy management systems, and virtual power plants in the building sector.

### 4. Actions to improve social equity in building decarbonization

- **Integrate higher levels of deep decarbonization technologies into green building standards for new affordable housing projects:** Scale up green building technologies in affordable housing by increasing the share of two-star green affordable housing and setting quantitative targets for prefabricated housing and ultra-low-energy buildings in affordable housing policies and standards.
- **Address access to renewable energy and efficiency in retrofitting older neighborhoods:** Develop building energy efficiency retrofit standards and codes applicable to different climate zones and demonstrate low-carbon retrofits in key cities and regions. Establish a long-term monitoring mechanism to continuously optimize retrofit programs. Compile the experience of retrofit projects to create an inventory of low-carbon retrofit programs and develop guidelines for deep retrofits using a combination of building envelope retrofits, rooftop solar PV, decarbonization of district heating systems, energy-efficient appliance upgrades, and efficient air conditioning.

- **Create the first zero-carbon rural home projects by tapping into renewables, electrification, efficiency, and materials:** Develop strategies and first demonstrations of zero-carbon rural houses in China. The priority in northern rural China should be upgrading the performance of the envelope insulation of rural housing together with clean heating programs. The priority in southern rural China should be modern bamboo and wood structures, modular construction, and green building materials.

Wei Li, Meng Wang, and Guangxu Wang, *Unlocking New Opportunities for Carbon Neutrality in China's Building Sector*, RMI, 2024, <https://rmi.org/insight/unlocking-new-opportunities-for-carbon-neutrality-in-chinas-building-sector/>.

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