Supplemental Information

Current status: consumption of building materials and CO_2 impact

Currently, the embodied CO_2 emissions of buildings contribute to 11% of total worldwide CO_2 emissions and will account for about half of the total carbon footprint of new construction between now and 2050.[1] Reducing embodied emissions is critical – not only for industrialized nations but also for other urbanizing countries – to achieve the Paris Agreement goals of limiting the global average temperature increase to 2 °C and pursuing efforts to limit it to under 1.5 °C.

China is the world's largest construction market, emitting about a quarter of the global building embodied CO_2 emissions.[2] The production of building materials was responsible for more than 80% of the embodied emissions in China's buildings sector, contributing to 17% of China's total CO_2 emissions and emitting 1,400 million tonnes (Mt) of CO_2.

In 2015, the buildings sector consumed about 148 Mt of steel and 574 Mt of cement, accounting for about 18% and 24% of China's total steel and cement production consumed in buildings construction, respectively (Figure S). In addition, about 4 Mt of aluminum and 16 Mt of flat glass were also used in China's buildings sector, representing 14% and 40% of China's aluminum and flat glass production. It should be noted that in this analysis the buildings sector. The scope of this analysis does not include city infrastructure (e.g., roads and pavements), industrial warehouses and facilities, ports, or other types of construction. Considering the obvious difference in material intensity unit area and share of building structure, referring to the existing studies[3-5], we divided all building into three categories: urban residential, rural residential, and public and commercial buildings. Urban residential and rural residential buildings are used to conduct residential energy-using activities. public and commercial building buildings are used to conduct activities related to trade, finance, real estate, public administration, health, food and lodging, education, and other commercial services.

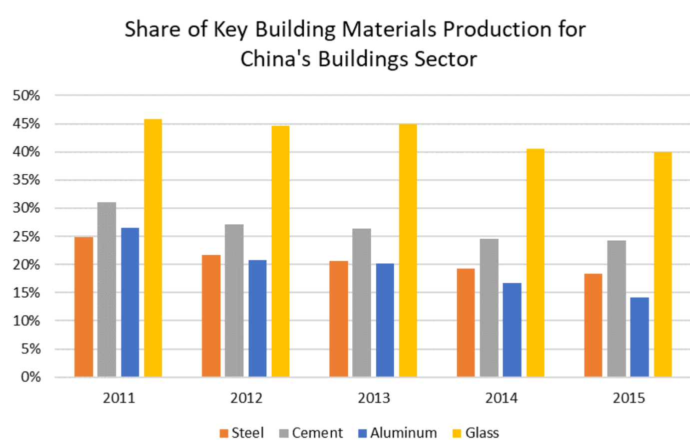

Figure S1. Share of key building materials production for China's buildings sector, Figure S1 related to the Material production data in STAR Methods.
Source: this analysis.

Note: national materials production data are from the National Bureau of Statistics (NBS) of China ; building materials demand (steel, cement, aluminum, and glass) is estimated based on a building stock turnover model. The buildings sector's material demand does not include products used within the buildings after the buildings are constructed.

Current status: building archetypes in China

China's buildings sector has multiple types of building archetypes, including concrete & brick structures, wooden structures, steel-based, and concrete & steel-based archetypes. However, compared to other industrialized countries such as the United States, Japan, Germany, and Australia, China's building sector is unique as it is dominated by concrete& steel structures, accounting for about 80% of all building structures (

Figure S). Wood and steel-based structures only represent less than 10%. In addition, buildings that are built with a combination of concrete and brick, brick and wood still exist in China, even if their quantities are few. This is quite different from other countries, where wood and steel structures are the main building structure types. This also indicates that China's buildings sector relies more significantly on energy and carbon-intensive materials (e.g., cement and steel), and potentially has a higher embodied carbon impact.

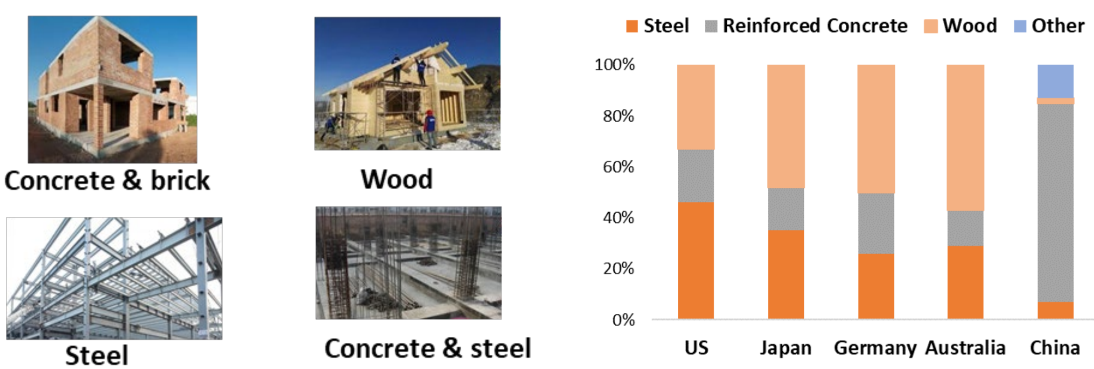

Figure S2. Typical types of building archetypes (left) and percentages of material contribution in the buildings sector by country (right), related to the building archetypes data in STAR Methods.

Source: this analysis.
Note: "Other" include building structures developed using concrete and brick, brick and wood.

Policy support

Strong policy support is critical for China to achieve carbon neutrality in building materials and construction. In Table S1, we outlined a number of policy strategies, policy areas, as well as specific policy levers that can be implemented by to promote low-carbon building materials and material efficiency practices.

We also identified a list of enabling institutions, ranging from central government agencies, influential think tanks, research institutes, industry associations to key stakeholders in the buildings and constructions sectors, such as designers, architects, engineers, and contractors that will play important roles in implementing these policy measures.

In addition, recognizing the largest mitigation potential is from material efficiency strategies, we recommend adopting policy measures to support them immediately, along with near-term support on fuel switching and energy efficiency. Innovative policy support on research, development and deployment (RD&D) related to hydrogen and CCUS development and infrastructure planning is also essential, and need to be carried out in order to achieve deep mitigation in building materials sector.

Table S1. Policy Strategies, areas, and levers to support green building materials in China

Policy Strategies	Policy Areas	Timeframe	Policy Levers	Enabling Institutions
Deploy commercialized material efficiency strategies	Prefabrication, light-weight materials, alternative materials	Near-Term (Before 2030)	▪Codes for promoting use of low-carbon materials in buildings ▪Codes for promoting use of material efficiency construction practices ▪Standards on low-carbon materials ▪Labeling and certification of low-carbon products ▪Government-level and corporate-level green procurement programs ▪Carbon pricing ▪Develop professional workforce on low-carbon materials	**Develop standards on low-carbon materials** ▪China National Institute of Standardization ▪China Building Materials Academy ▪China Cement Association ▪China Iron and Steel Association **Develop software tools** to support designers, architects, and contractors to benchmark and choose low-carbon materials ▪Research institutes, think tanks, universities, NGOs ▪Industry associations and companies
	High-quality production, extending building lifetime	Near-Term (Before 2030)		
	Improve design and construction of buildings (e.g., green design)	Near-Term (Before 2030)		
Improve circular economy systems	Encourage component reuse	Near-Term (Before 2030)	▪Incentives on component reuse and recycle	

	Increase scrap collection and recycling	Near-Term (Before 2030)	▪Standards on low-carbon materials ▪Government-level and corporate-level green procurement programs	**Develop labeling and certification for low-carbon materials** ▪Ministry of Industry and Information Technology ▪Ministry of Housing and Urban-Rural Development ▪China Academy of Building Research ▪Industry associations and companies
Accelerate the transition away from coal and promote alternative sources	Reduce coal use, increase electrification, increase the use of renewable energy	Near-Term (Before 2030)	▪Stringent standards on cement energy and carbon intensity ▪Incentives on using wastes (e.g., Municipal Solid Wastes) ▪Incentives on using renewables (e.g., differential pricing) ▪Investment in RD&D on green H_2 and renewable heat ▪Develop pilots and demonstration projects ▪Carbon pricing	**Develop/revise building codes to encourage use of low-carbon materials** ▪Ministry of Housing and Urban-Rural Development ▪China Academy of Building Research
	Encourage alternative fuels, such as Municipal Solid Wastes	Near-Term (Before 2030)		
	Invest in RD&D, testing, piloting, and scaling-up of green hydrogen (H_2) and renewable heat	Mid-Long Term (After 2030)		
Strengthen energy efficiency and improve capacity on carbon management	Deploy commercialized energy efficiency technologies in cross-cutting systems (pumps, fans, motors, process heating systems, boilers, heat exchangers, steam systems, etc.)	Near-Term (Before 2030)	▪Energy efficiency benchmarking ▪Energy assessments ▪Green financing ▪Energy management system implementation ▪Promoting digitalization ▪Promoting low-carbon technologies ▪Develop professional workforce on energy efficiency and carbon management	**Develop incentive policies and programs to promote the use of low-carbon materials** ▪Government procurement agencies ▪Ministry of Finance ▪Local governments
	Establish energy management systems and digital platforms	Near-Term (Before 2030)		
	Improve capacity building on carbon inventory, carbon	Near-Term (Before 2030)		

	tracking, and carbon management		
Research and development on carbon capture, utilization, and storage	Life-cycle and resource assessment of carbon removal	Mid-Long Term (After 2030)	▪Investment in RD&D on carbon removal technologies and practices
	Financing mechanisms of carbon removal technologies and practices	Mid-Long Term (After 2030)	▪Develop financing mechanisms for carbon removal technologies ▪Standards and policy framework on carbon monitoring and reporting
	Carbon storage (regional storage potential, storage integrity, and monitoring)	Mid-Long Term (After 2030)	▪Infrastructure planning for H_2 production, transportation, and carbon transport and storage

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