让我们共同打造气候中和的未来
Building a climate-neutral future together

南京大学建筑与城市规划学院
School of Architecture & Urban Planning, NJU

中华人民共和国
住房和城乡建设部

IBE环能科技

中国建筑节能协会

Schweizerische Eidgenossenschaft
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intep

skat Swiss Resource Centre and Consultancies for Development

Sino-Swiss ZEB Project - Capacity Building at Nanjing University

中瑞零碳建筑项目 – 南京大学能力建设活动

Low emissions design & lightweight construction

低碳设计与轻量化建造

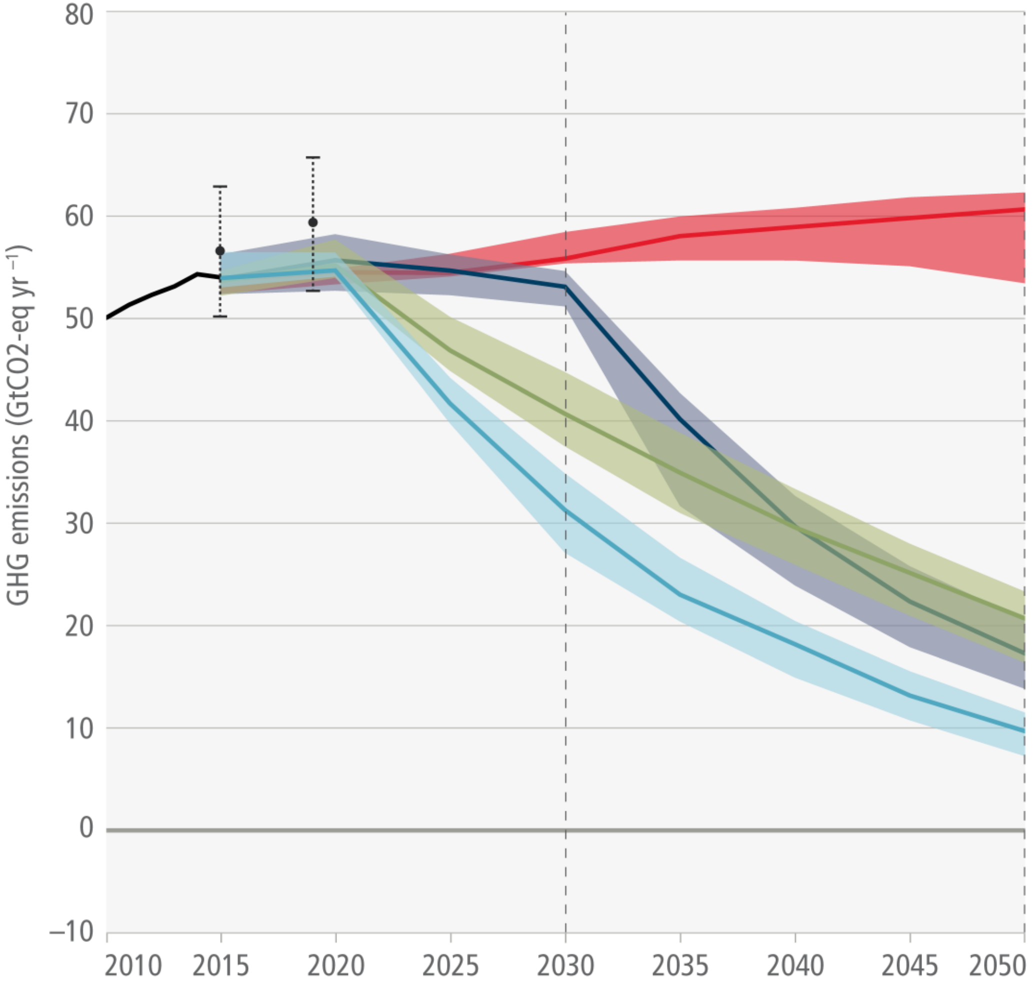
April 7th 2025，2025年4月7日

Dr André Ullal, Team Leader - Sino-Swiss ZEB Project

安德烈-乌拉尔博士，中瑞零碳建筑项目瑞方经理

Projected global CO2e emissions pathways and climate change scenarios

预计的全球二氧化碳排放路径和气候变化情景



Under current emissions scenarios, Paris Agreement targets of limiting global warming to 2˚C are unlikely to be met

根据目前的排放情况，巴黎协定将全球变暖限制在2°C以内的目标不太可能实现

Modelled pathways:

政策实施趋势 Trend from implemented policies

Limit warming to 2°C (>67%) or return warming to 1.5°C (>50%) after a high overshoot, NDCs until 2030

将升温控制在 2°C Limit warming to 2°C (>67%)

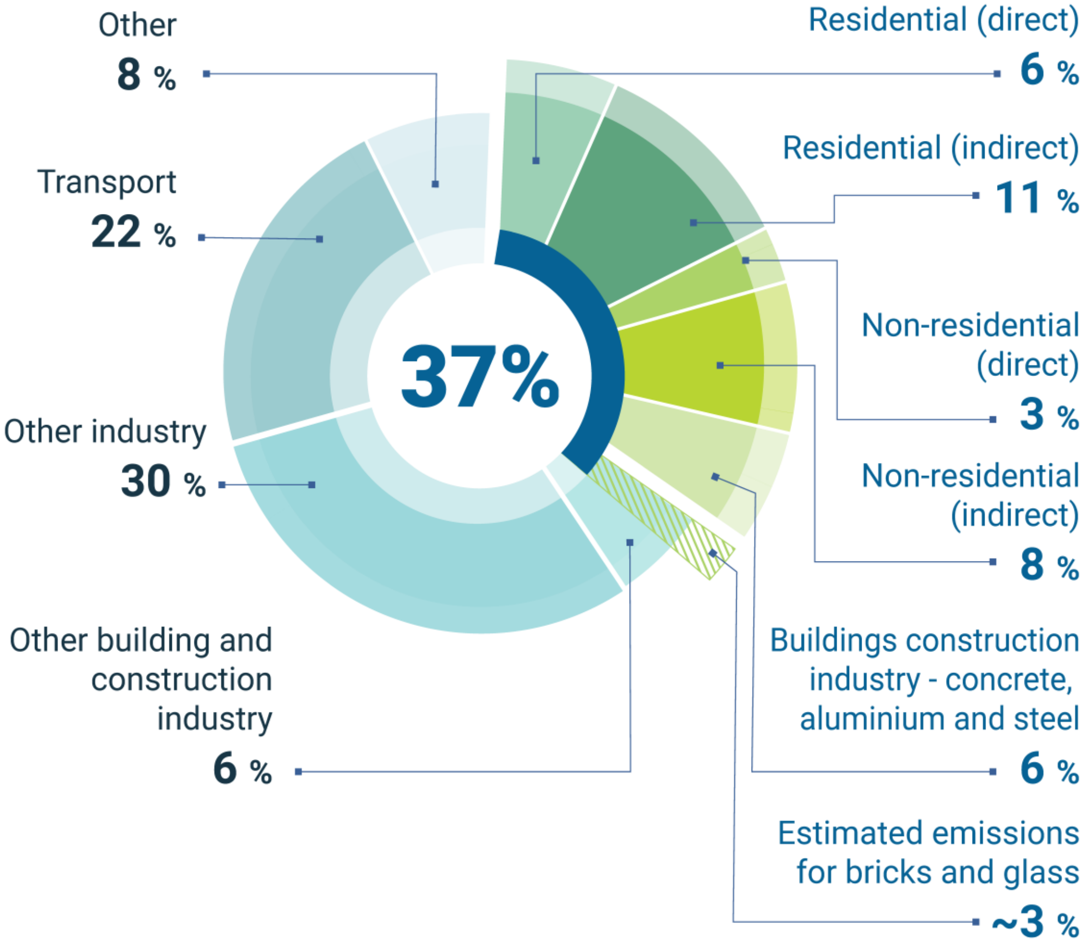
将升温控制在 1.5°C Limit warming to 1.5°C (>50%) with no or limited overshoot

Past GHG emissions and uncertainty for 2015 and 2019 (dot indicates the median)

Source: IPCC, 2022. Climate Change 2022 – Mitigation of climate change.

Sources and proportions of building-related CO2e emissions

建筑相关二氧化碳排放的来源和比例



CO_2e emissions from buildings account for around 37% of total global emissions

Includes:

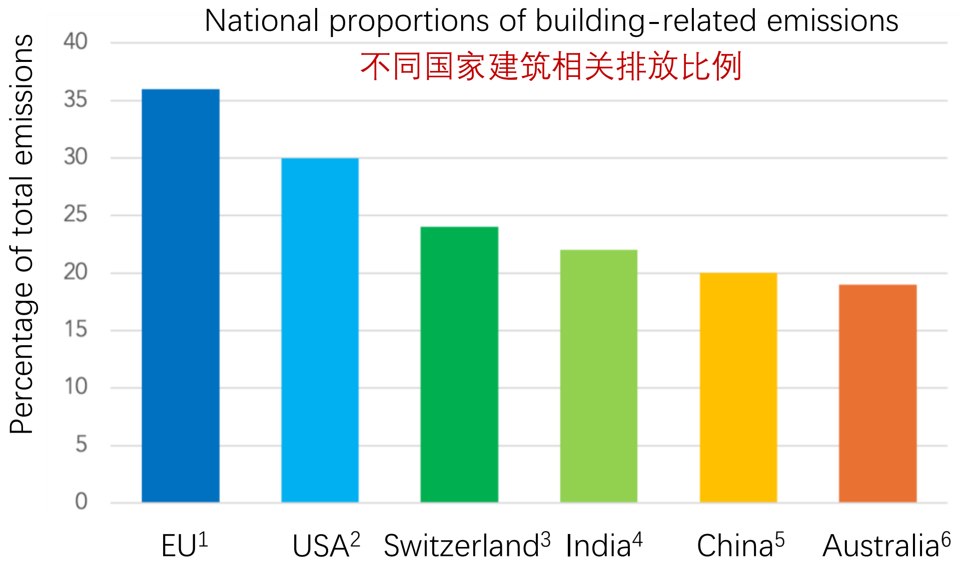
- direct emissions generated at buildings
- indirect emissions generated away from buildings – e.g., electricity production

建筑的二氧化碳排放量约占全球总排放量的 37%

包括:

- 建筑产生的直接排放
- 建筑以外产生的间接排放—例如电力生产

Source: UNEP, 2022. Global Status Report for Buildings and Construction

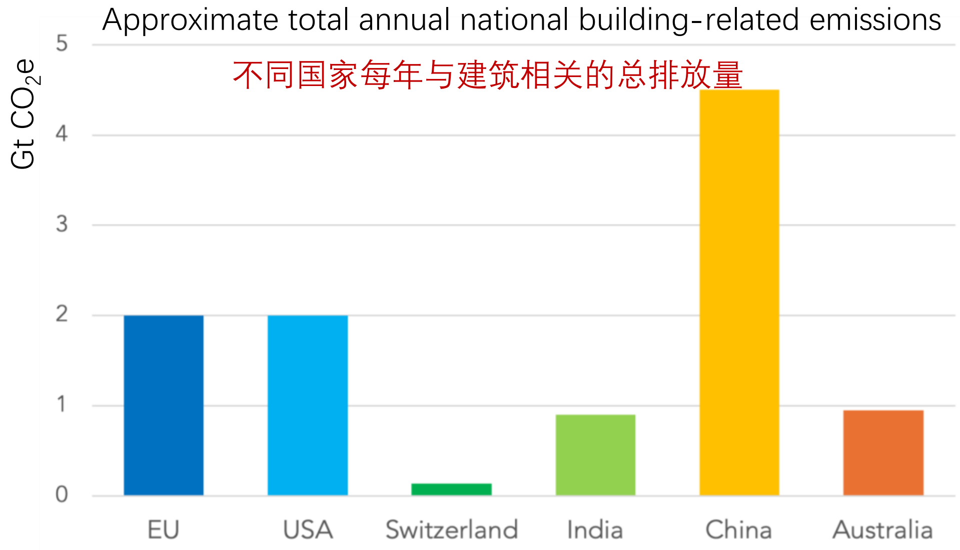


Sources: [1] European Environment Agency (EEA); [2] U.S. Environmental Protection Agency (EPA); [3] Swiss Federal Office of Energy (SFOE); [4] International Renewable Energy Agency (IRENA); [5] International Energy Agency (IEA); [6] Green Building Council of Australia

The proportion of building-related emissions varies between countries

Factors include climate, construction techniques, and modes of energy production

各国建筑相关排放的比例有所不同
影响因素包括气候、建筑技术和能源生产方式



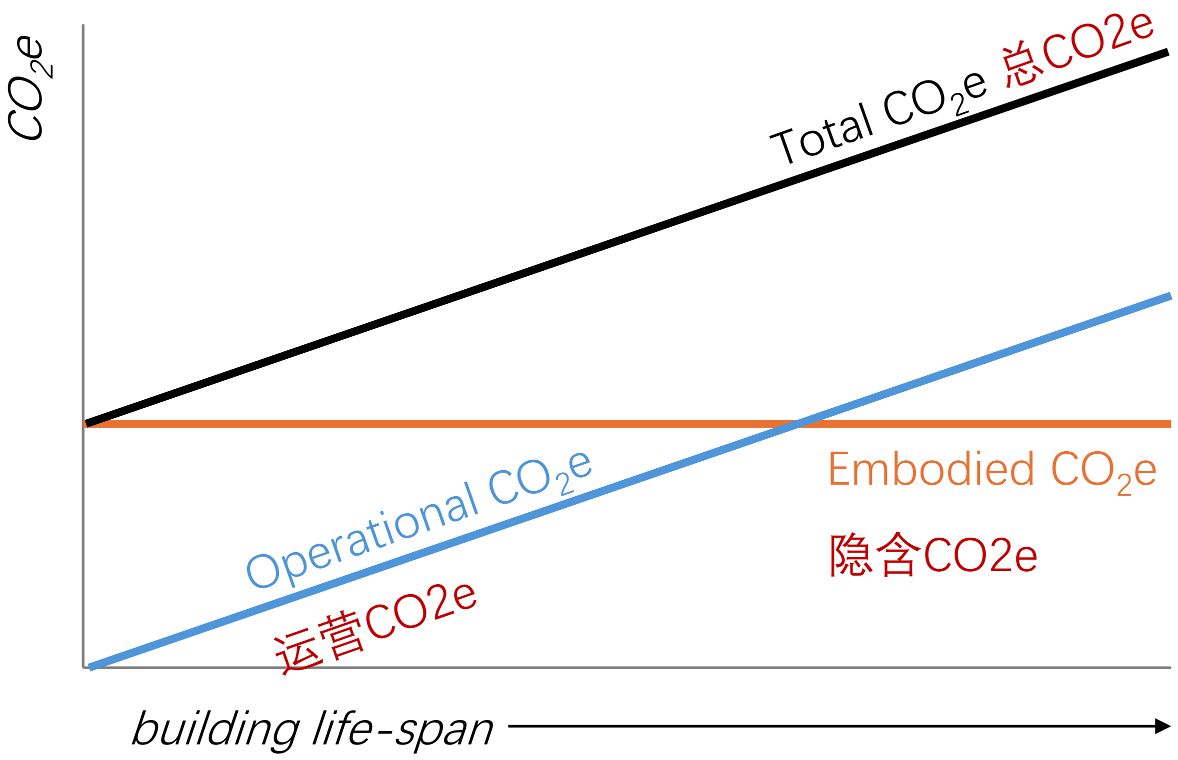
Calculations based on median values for building-related emissions as percentage of total national emissions

Total building-related emissions also vary with the amount of construction

建筑相关的总排放量也随建筑量的变化而变化

Schematic representation of operational, embodied and total CO2e emissions throughout the building life-span

整个建筑生命周期内运营、隐含和总二氧化碳排放量的示意图



Total emissions = operational + embodied emissions

总排放量 = 运营排放量 + 隐含排放量

Embodied emissions primarily relate to the building materials – which are fixed at the time of construction

建筑材料的排放量在建造时就已经确定，因此是固定的

Operational emissions relate to building use – primarily energy consumption – which increases during the building life

运营排放与建筑使用有关，主要是能源消耗，在建筑使用期内会不断增加

Embodied emissions

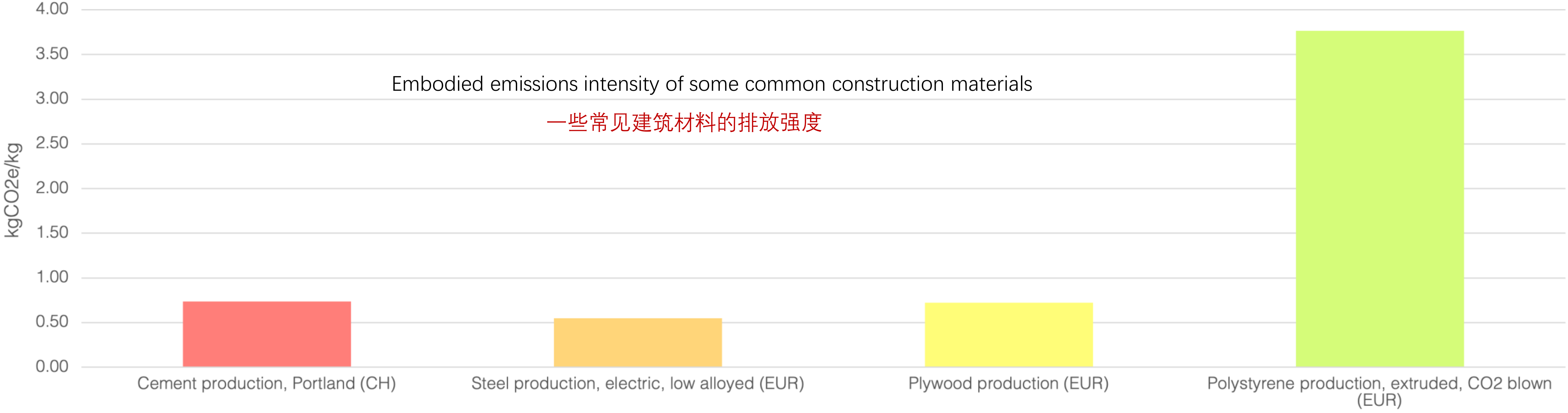
隐含排放

Embodied emissions related to the production of building materials and vary with different production processes

与建筑材料生产相关的排放量因生产工艺不同而有所差异

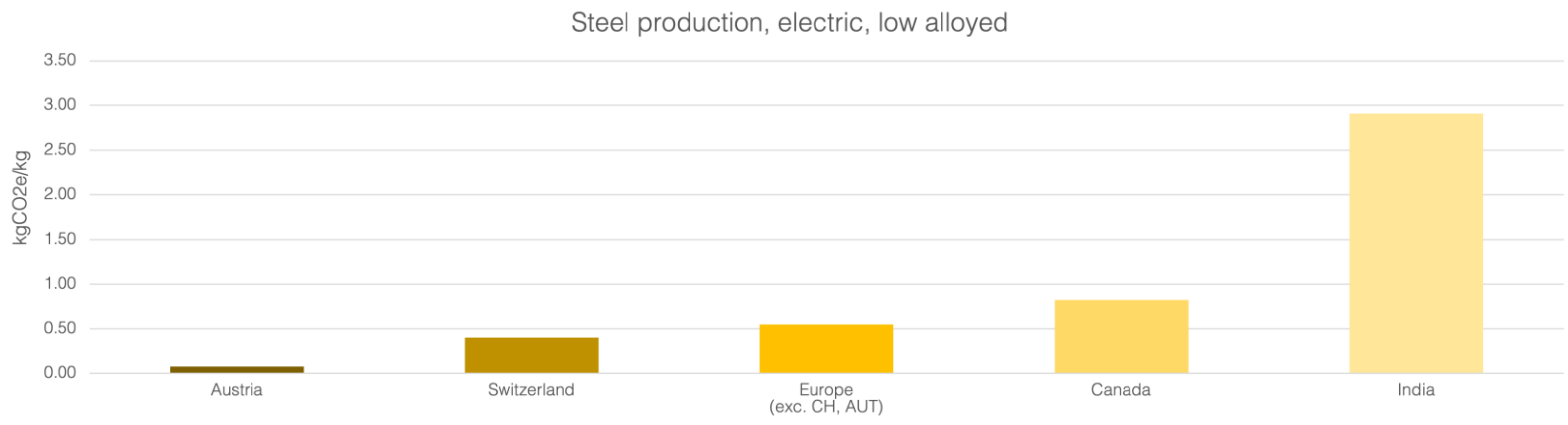
Emissions arising from transportation and installation of materials also contribute to embodied emissions, though generally these are less significant compared to materials production

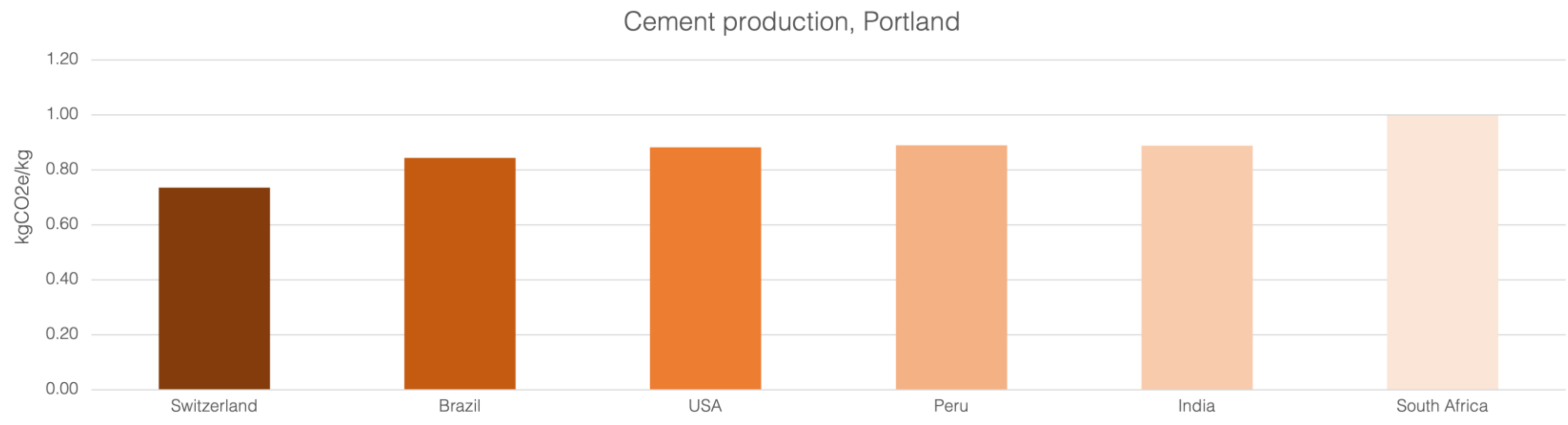
运输和材料安装产生的排放也会产生隐含排放，但通常情况下，这些排放量与材料生产相比并不显著。



Data source: EcoInvent, accessed August 2024

Embodied emissions
隐含排放





Embodied emissions depend on energy consumption during materials production

隐含排放取决于材料生产过程中的能源消耗

Thus, embodied emissions for the same material are different in different countries

因此，相同材料在不同国家的具体排放量是不同的。

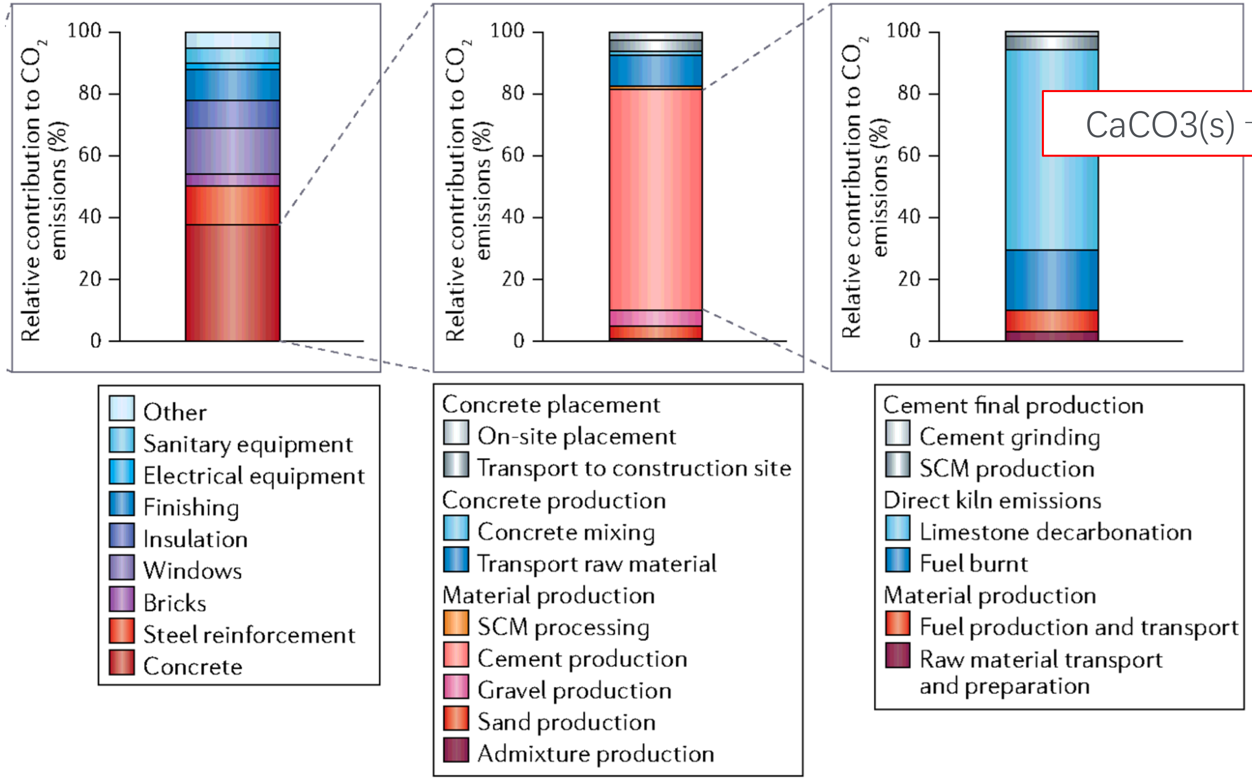
However, cement is different....

然而，水泥却不同......

Embodied emissions
隐含排放

Typical emissions from concrete in residential construction

住宅建筑中混凝土的典型排放



$CaCO3(s) \rightarrow CaO(s) + CO2(g)$

Habert, G. et al. (2020) Environmental impacts and decarbonisation strategies in the cement and concrete industries.

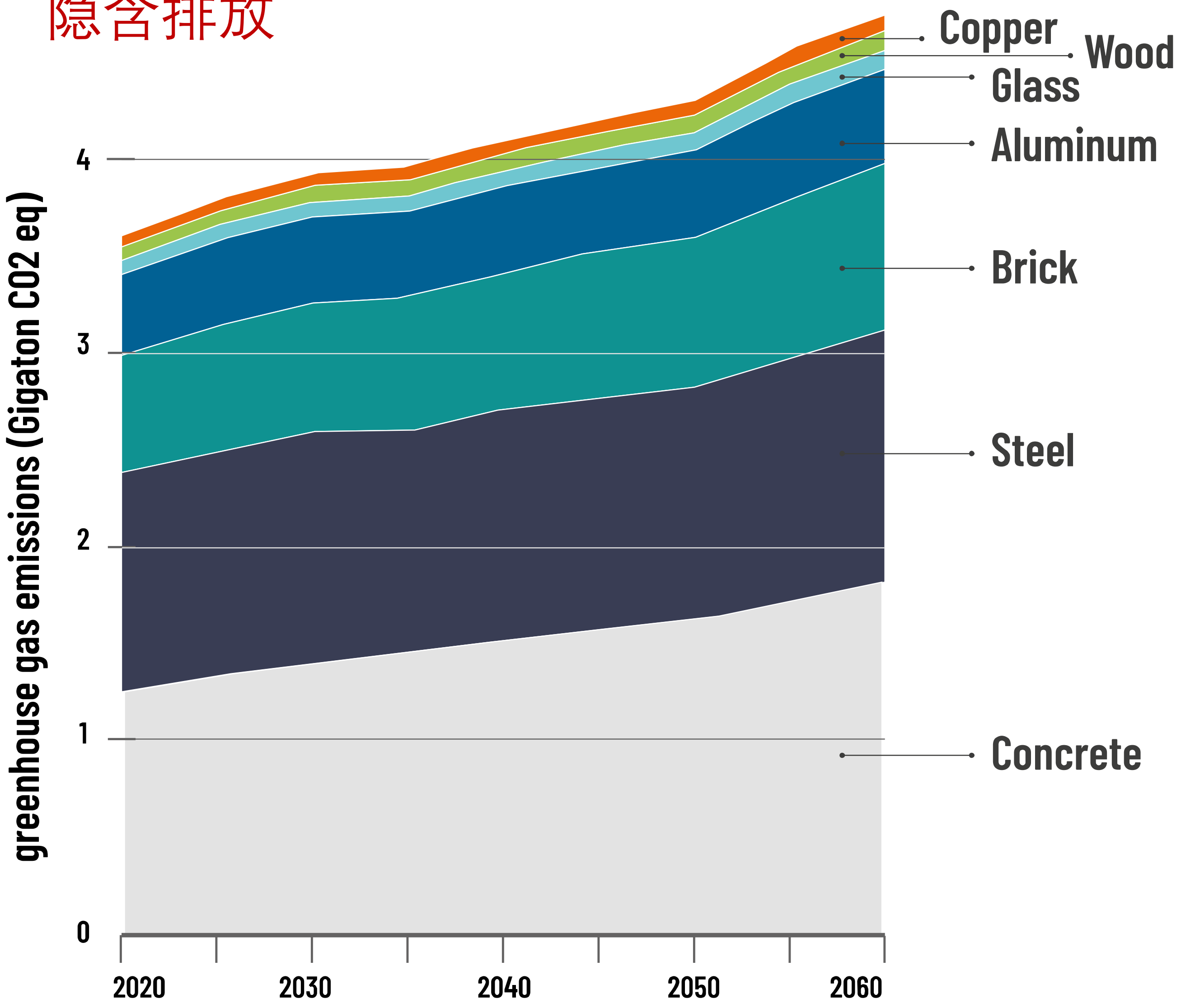
The large amount of concrete used globally makes cement production a major source of CO2e emissions

然而，全球范围内使用的大量混凝土使得水泥生产成为二氧化碳排放的主要来源。

The main source of these emissions is not from energy consumption during cement production – it is the chemical reaction of limestone decarbonation

这些排放的主要来源并非水泥生产过程中的能源消耗，而是石灰石脱碳的化学反应。

Embodied emissions
隐含排放



Use of Portland cement in concrete is the largest source of embodied building emissions

混凝土中使用波特兰水泥是全球建筑排放的最大来源

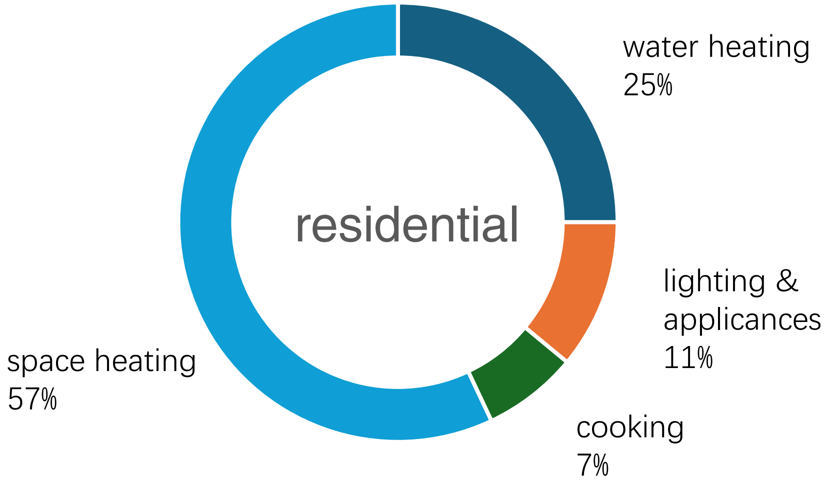
This proportion of embodied emissions from concrete is projected to increase

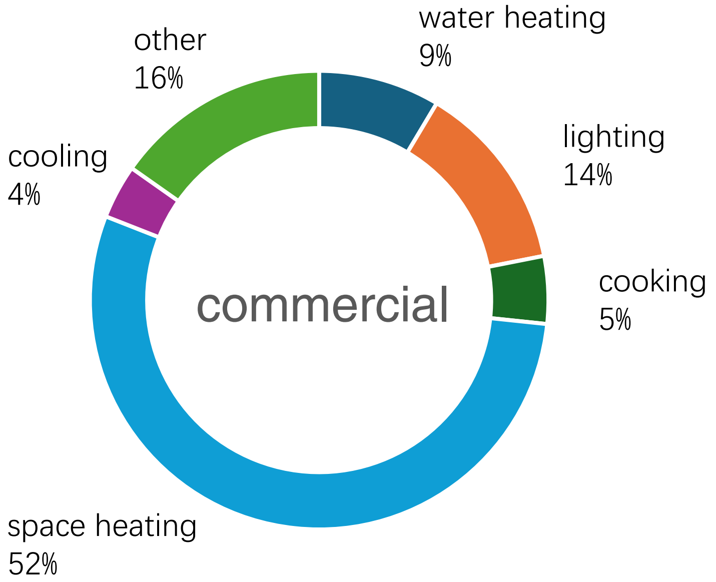
预计混凝土的这种具体排放比例将增加

Projected greenhouse gas emissions from building materials in a business-as-usual scenario to 2060
UNEP, 2023. Building Materials and the Future – Constructing a new future, p.10

Global building energy use by function

按功能划分的全球建筑能耗





Operational emissions
运营排放

Operational emissions relate to building use, which varies with climate, building type, and building energy efficiency

运营排放与建筑使用有关，而建筑使用又因气候、建筑类型和建筑能效而异

Generally, heating is the main function of building energy use

一般来说，供暖是建筑能耗的主要部分

New regulations and technologies have reduced building energy consumption significantly in many countries

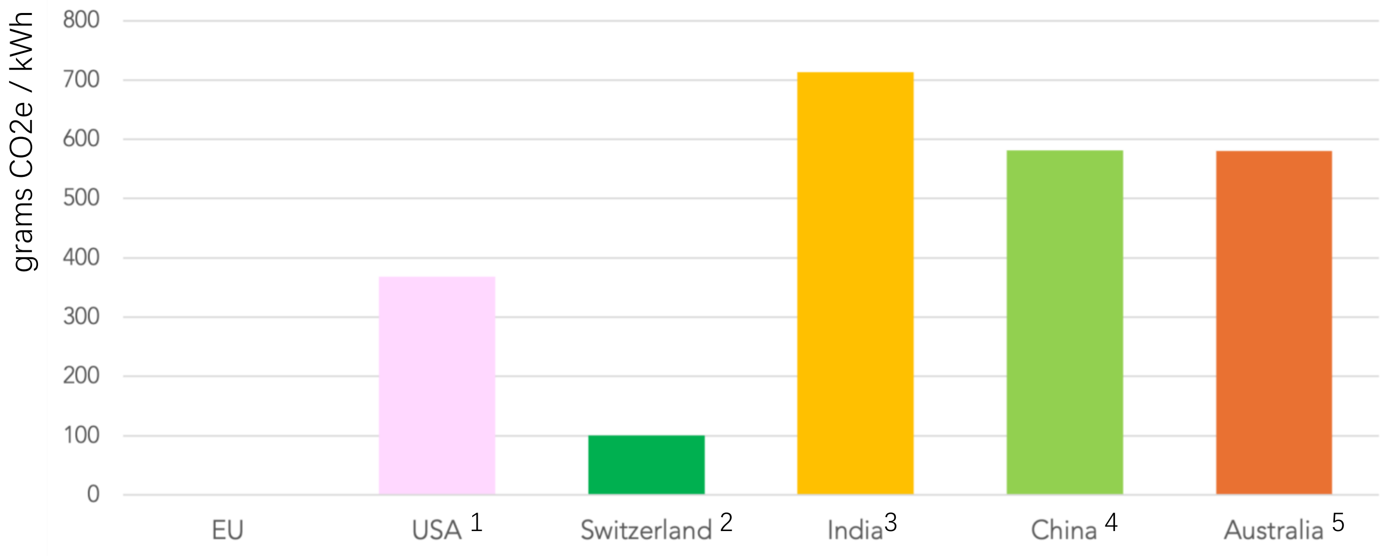
在许多国家，新法规和新技术大大降低了建筑能耗

Source: UNEP, 2021. Status of the World's Buildings Report

Operational emissions
运营排放

Approximate CO2e emissions intensity of national electricity grids

各国电网的二氧化碳排放强度



Sources:

[1] https://chalg.quarto.pub/carbon-intensity-of-electricity-consumption/

[2] https://en.wikipedia.org/wiki/Energy_in_Switzerland

[3] https://en.wikipedia.org/wiki/Electricity_sector_in_India

[4] https://ember-energy.org/latest-insights/global-electricity-review-2023

[5] https://cer.gov.au/markets/reports-and-data/quarterly-carbon-market-reports/quarterly-carbon-market-report-december-quarter-2023/emissions-reduction

The amount of CO2e emissions arising from energy use depends upon the emissions intensity of electricity production

能源使用产生的二氧化碳当量排放量取决于电力生产的排放强度

Emissions intensity is higher in countries that rely on coal-fired power plants

在那些依赖燃煤发电厂的国家，排放强度更高

Transitions away from fossil-based power production will reduce energy-related emissions

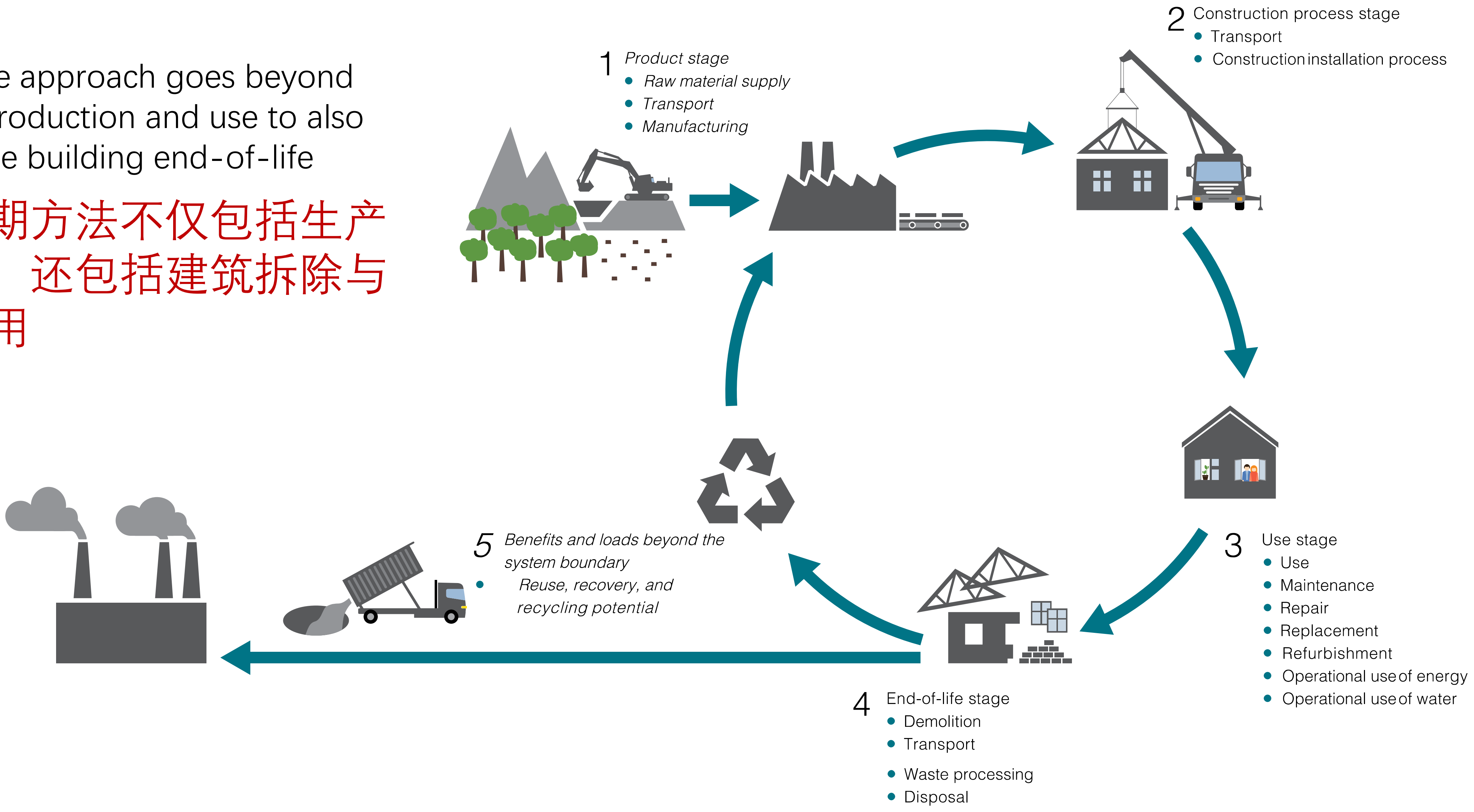
从化石能源发电转向其他能源将减少与能源相关的排放

Life-cycle approach

生命周期方法

A life-cycle approach goes beyond building production and use to also address the building end-of-life

生命周期方法不仅包括生产和使用，还包括建筑拆除与回收再用



End-of-life
结束建筑寿命

End-of-life for building materials can include disposal, recycling, or reuse

建筑材料的生命周期结束处理包括处置、回收或再利用。

Recycling involves downgrading building components into basic materials – e.g., through crushing or melting

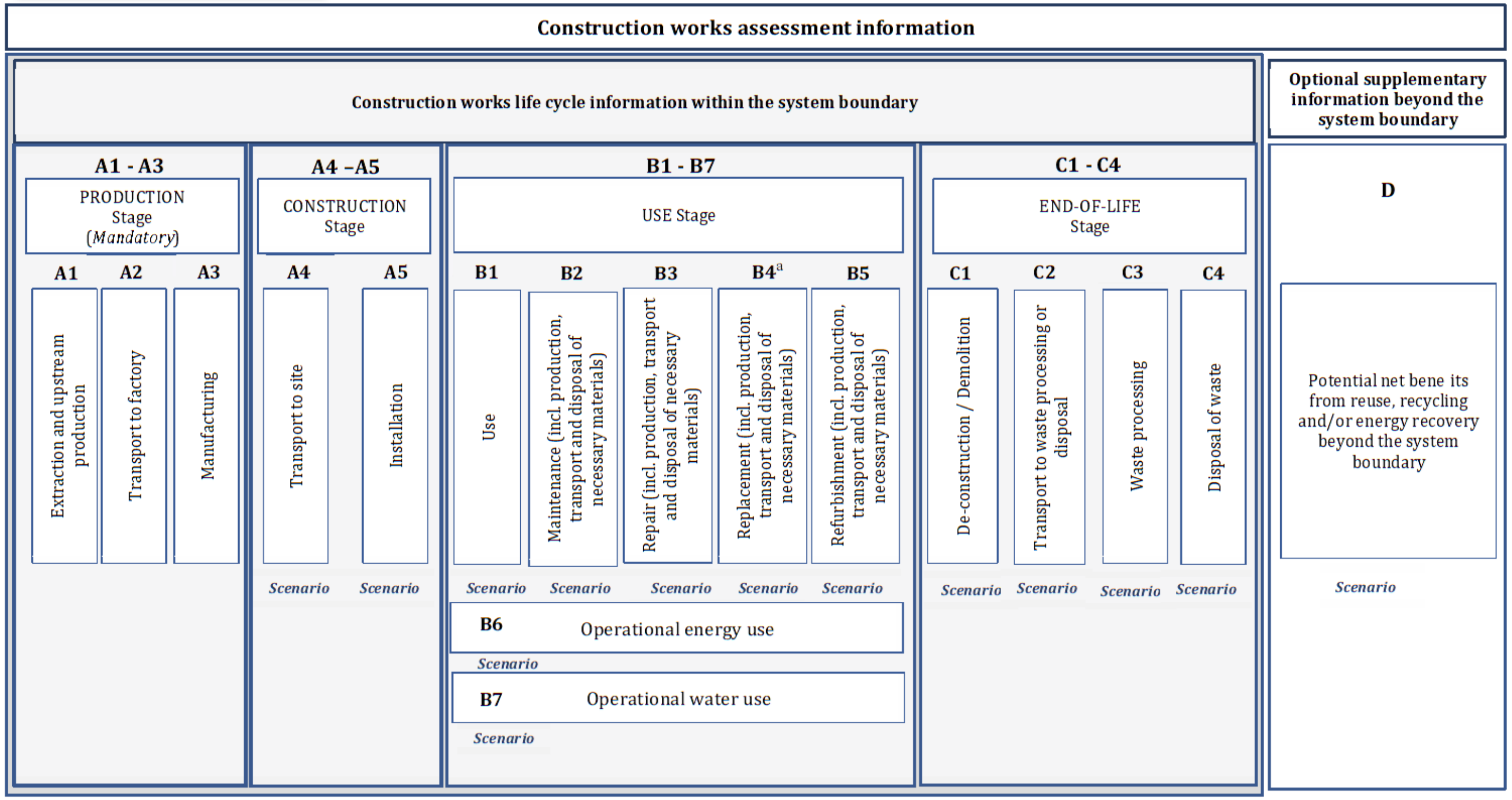
回收利用是指将建筑构件降级为基本材料，例如通过粉碎或熔化 。

Reuse involves maintaining the form and value of building components

再利用是指保持建筑构件的形式和价值

Life-cycle approach
生命周期方法

ISO-21930 Building LCA Framework
ISO-21930 建立生命周期评估框架



ISO 21930, 2017. Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services

Life-Cycle Assessment (LCA) is a framework for assessing emissions across the entire building life-cycle, including:

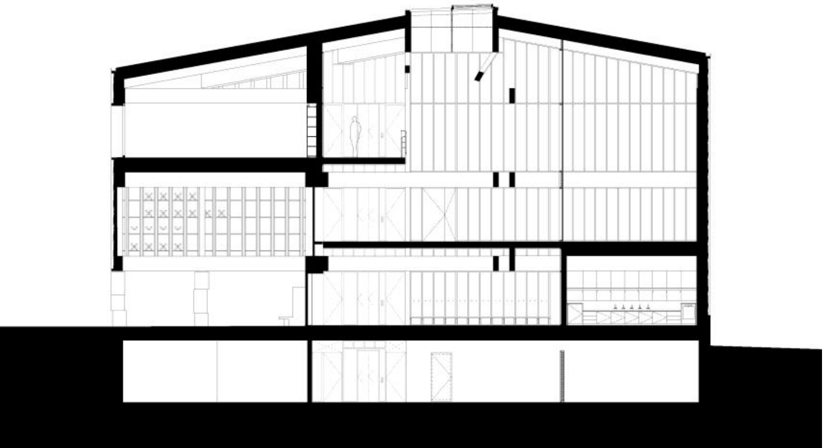
- materials production
- building construction
- building use
- building end-of-life

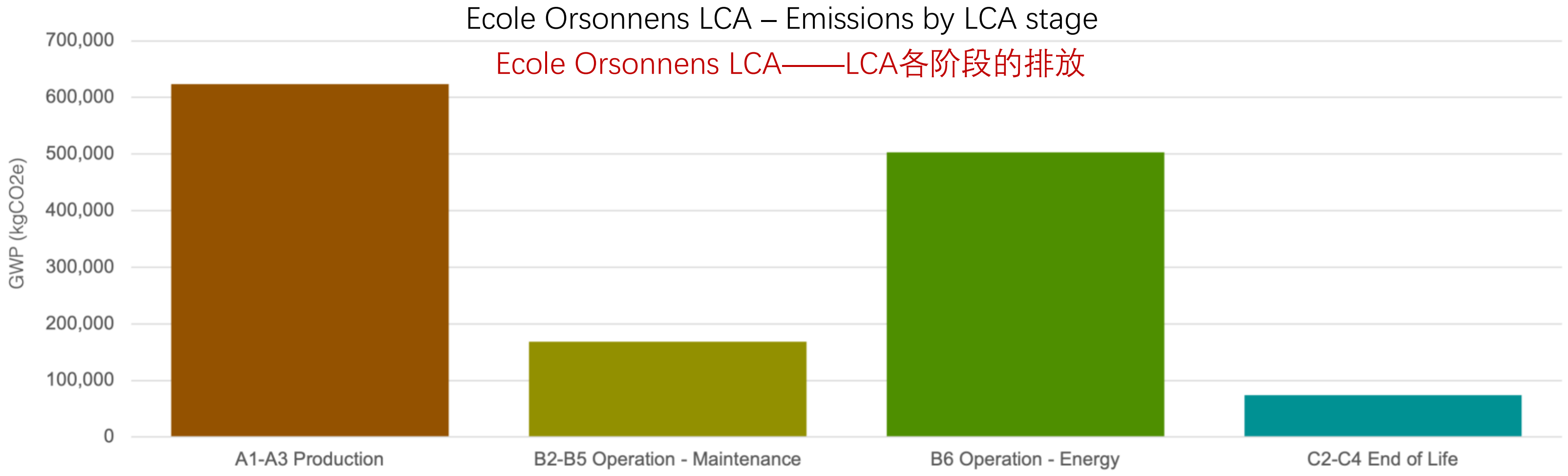
生命周期评估（LCA）是一个评估整个建筑生命周期排放的框架，包括：

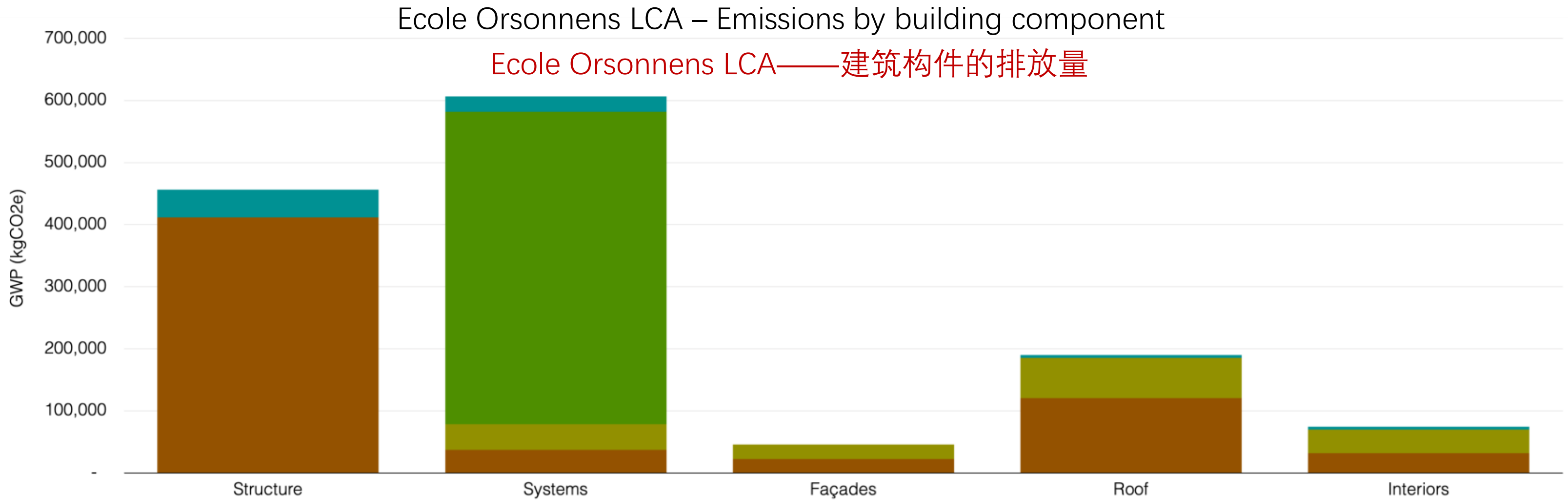
- 材料生产
- 建筑施工
- 建筑使用
- 建筑报废

ISO-21930 provides a consistent framework for calculating life-cycle emissions

ISO-21930为计算生命周期排放提供了一个统一的框架



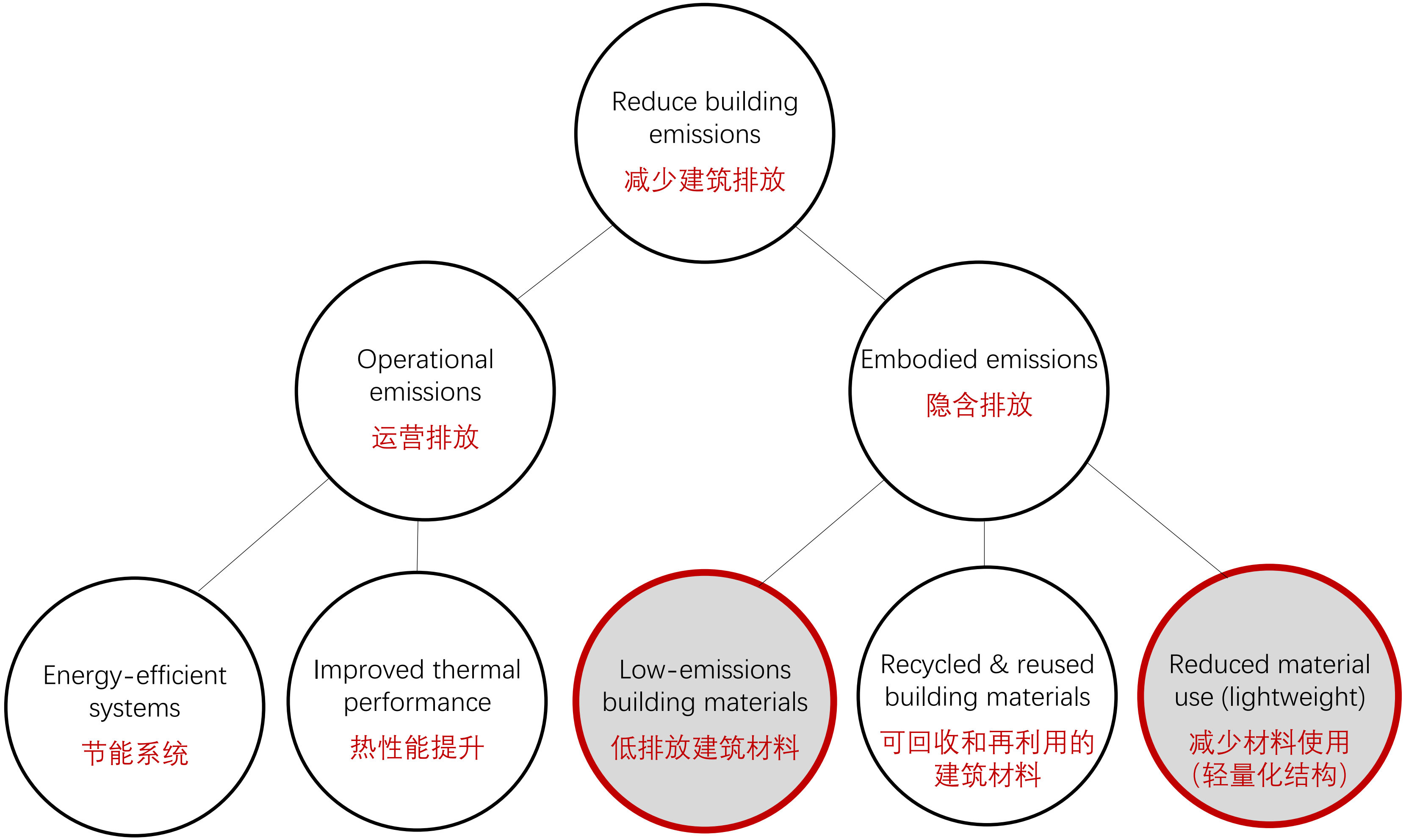




Each building is different. However, generally, building structure contributes most embodied emissions

每栋建筑都有所不同。但一般来说，建筑结构是造成建筑隐含排放的主要原因。

CO2e emissions reduction strategies
二氧化碳减排战略



Project site at the Old Floating Bridge Area of Shuidong Town, Ganzhou

Low-emissions building materials
低排放建筑材料

The pyramid organises materials with regard to embodied emissions

金字塔根据具体排放情况对材料进行分类。

Generally, bio-based materials are at the bottom, while metals and polymers are higher

一般来说，生物基材料位于底部，而金属和聚合物位于顶部

10kgCO2e/kg

1kgCO2e/kg

0kgCO2e/kg

https://www.materialepyramiden.dk/#

Low-emissions building materials
低排放建筑材料

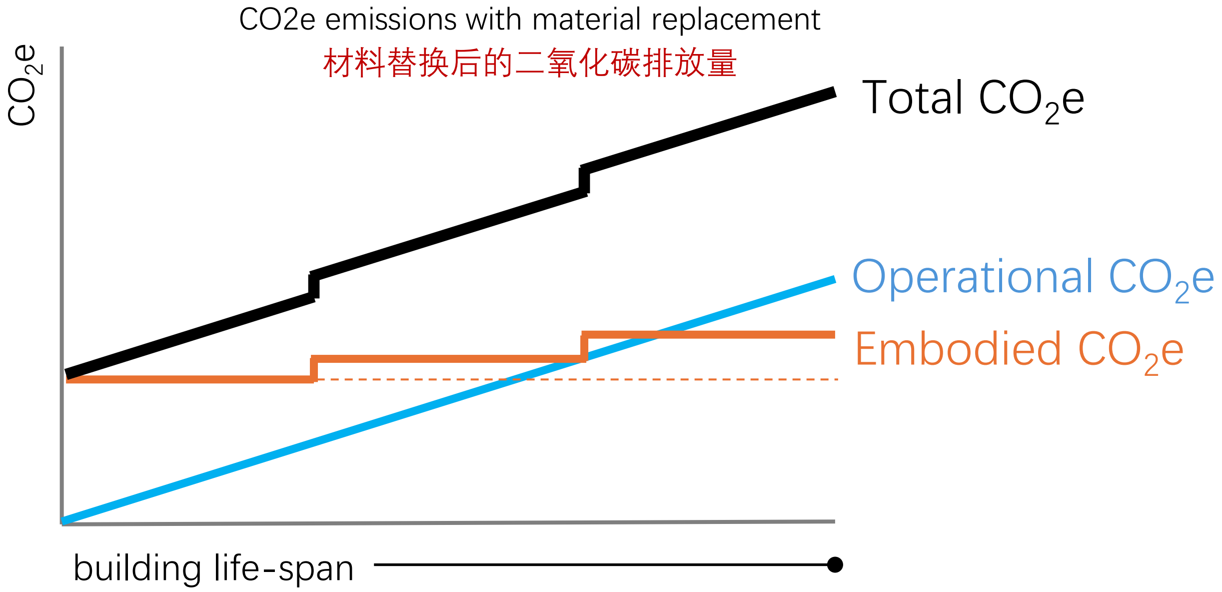
Beyond emissions intensity, actual embodied emissions depend upon material performance and the amount (mass) of material required

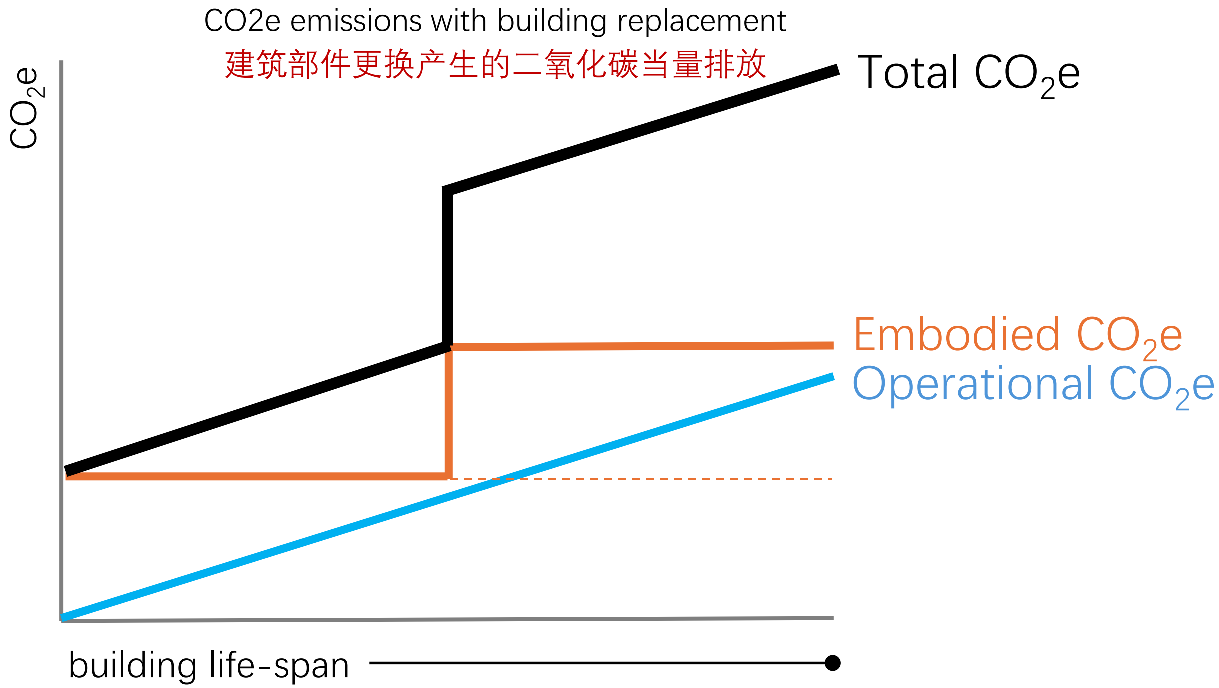
除了排放强度，实际排放量还取决于材料性能和所需材料数量（质量）。

Structural column 1,000kN strength, 4m length

	Granite (reinforced) 150x150	Limestone (reinforced) 200x200	Glulam timber 340x340	Reinforced concrete 200x200	Steel SHS 140x140	Steel UB 240
Embodied emissions ($kgCO_2e$)	42	52	76	150	239	272

Calculations using ICE 2.0





Low-emissions building materials

低排放建筑材料

Beyond emissions intensity, actual embodied emissions depend upon material durability

除了排放强度，实际排放量还取决于材料的耐用性。

Maintenance and replacement of materials increases life-cycle emissions

维护和更换材料会增加生命周期排放量

Replacement of buildings increases life-cycle emissions

建筑部件的更换会增加生命周期内的排放量

Increasing the life-span of buildings and building components reduces life-cycle emissions

延长建筑和建筑构件的使用寿命，减少生命周期内的排放

Low-emissions materials
低排放材料

Technologies for timber structural systems have advanced rapidly

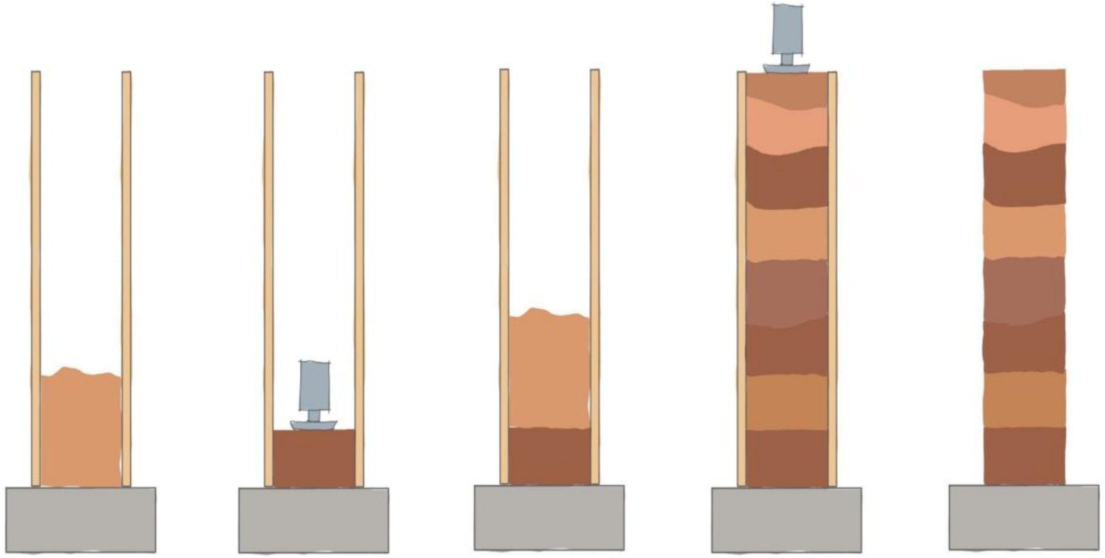
木结构体系技术发展迅速

Timber production (growth) sequesters (traps) CO_2, which is released upon disposal of the timber

木材生产（生长）吸收（捕获）二氧化碳，而木材处理时又会释放二氧化碳

Fire safety and sustainable supply chains are significant impediments to expanded use of timber in high-density settings

消防安全和可持续供应链是木材在高密度环境中广泛使用的重大障碍



Low-emissions materials

低排放材料

Rammed earth and other earthen construction techniques are traditional in many places

夯土和其他土制建筑技术在许多地方都是传统建筑技术

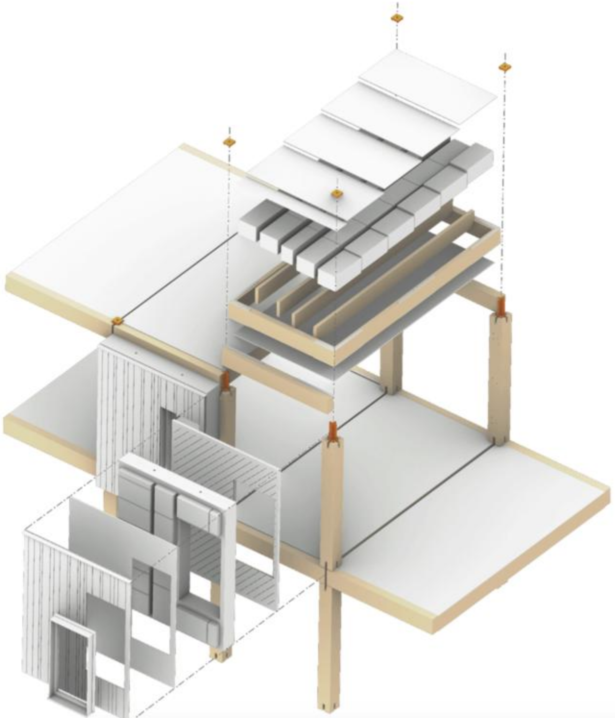
Structural properties limit use in large scale applications and high-density settings

结构特性限制了其在大型建筑和高密度环境中的使用

Addition of cement stabilisers undermines emissions reduction impacts

添加水泥稳定剂会削弱减排效果

Morocco Pavilion Exp 2020 Dubai
Oualalou+Choi Architects



Low-emissions materials
低排放材料

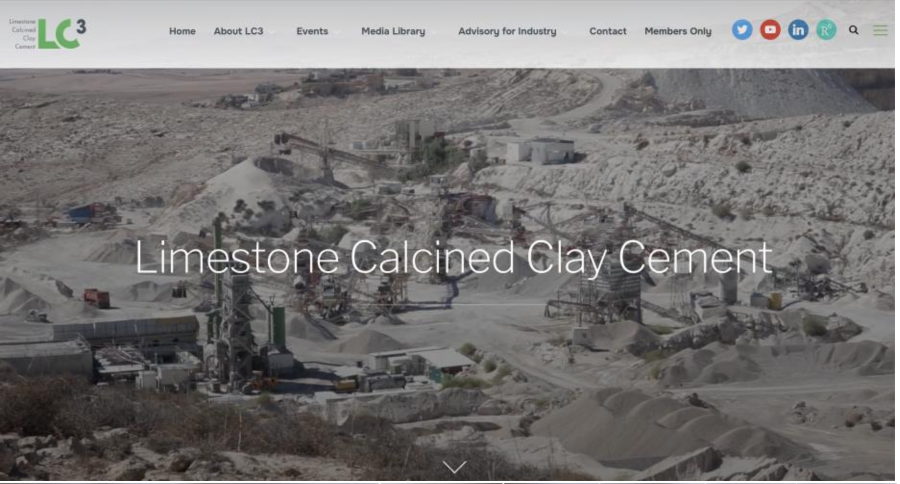
Straw-bale construction combining envelope and insulation

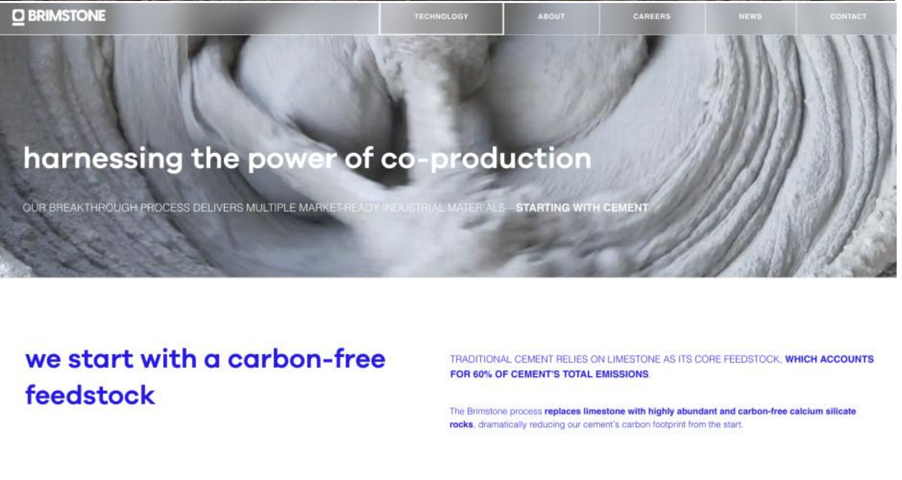
稻草结构结合围护结构和保温材料

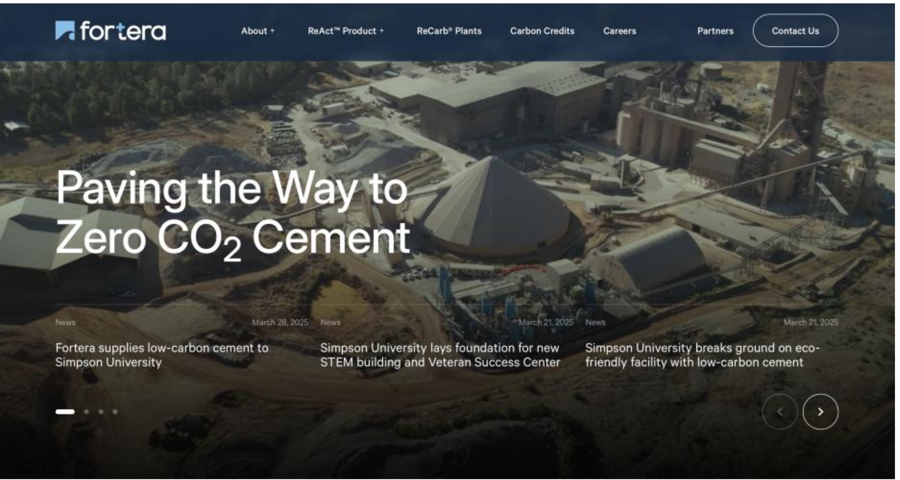
Application is urban settings is limited by fire safety standards and by the volume/dimensions of straw-bale systems

城市环境中的应用受到消防安全标准和草砖系统的体积/尺寸的限制

Vivihouse modular system for straw-bale construction
https://www.vivihouse.cc/de/







Low-emissions materials

低排放材料

Research and investment in low-carbon concrete solutions, e.g.:
对低碳混凝土解决方案的研究和投资，例如：

- LC3: https://lc3.ch
- Sublime systems: https://sublime-systems.com
- Fortera: https://forteraglobal.com
- Brimstone: https://www.brimstone.com

LC3 substitutes limestone with calcined clay in clinker production, potentially reducing CO2e emissions of cement by 30%

LC3在熟料生产中用煅烧粘土代替石灰石，有望将水泥的二氧化碳排放量减少30%

Existing cement and concrete supply chains involve very large investments at global and local levels. These investments entail resistance to new cement technologies

现有的水泥和混凝土供应链涉及全球和地方层面的巨额投资。这些投资对新的水泥技术持抵制态度

Low-emissions materials

低排放材料

Insulation is an important factor in improving energy performance of existing and new buildings

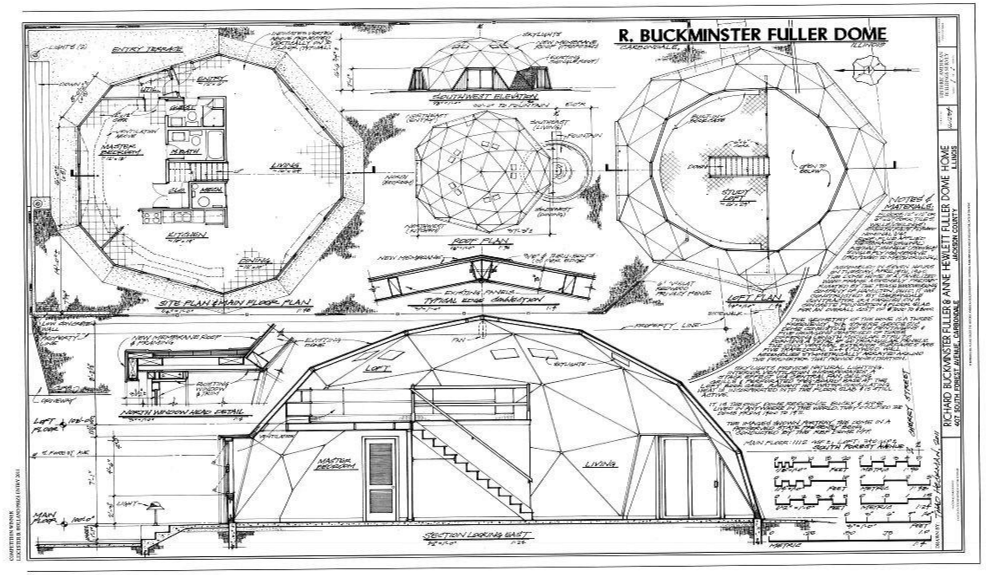
保温是提高现有建筑和新建筑能源性能的重要因素

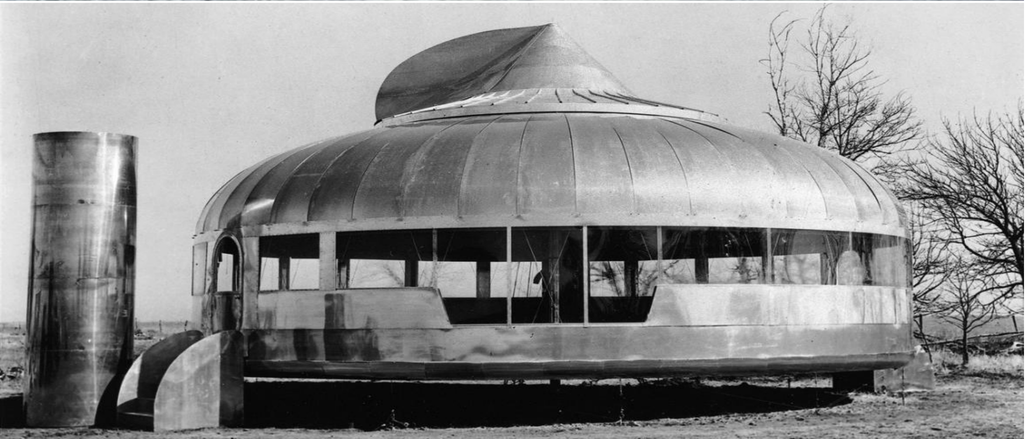
Polymer insulation materials such as XPS and EPS are emissions intensive

聚苯乙烯泡沫塑料（XPS）和发泡聚苯乙烯（EPS）等高分子绝缘材料是排放密集型材料

Bio-based alternatives differ in performance and dimensional (thickness) requirements

生物基替代品在性能和尺寸（厚度）要求方面有所不同





Lightweight architecture

轻量化架构

Buckminster Fuller pioneered lightweight architecture in the US in the 1940s and 1950s

巴克敏斯特·富勒（Buckminster Fuller）在20世纪40年代和50年代开创了美国轻质建筑的先河

Geodesic dome and experimental Dymaxion House designs emphasized spatial and material efficiency and the potential of industrialized building production

测地线穹顶和实验性Dymaxion House设计强调空间和材料效率以及工业化建筑生产的潜力

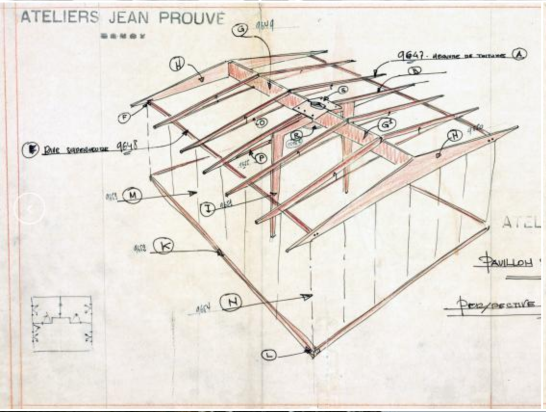
Top: Geodesic dome house patent application drawings
Middle: Geodesic dome house prototype
Bottom: Dymaxion House prototype
Source: Buckminster Fuller Institute <https://www.bfi.org>

Lightweight architecture

轻量化架构

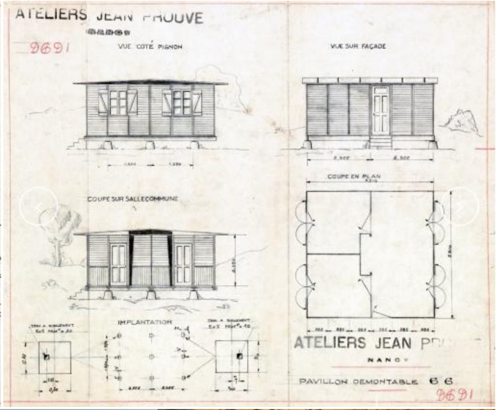
Jean Provéʼs demountable house design responded to urgent need for housing in Europe following WW2

让·普罗维尔的可拆卸房屋设计满足了二战后欧洲对住房的迫切需求



The design emphasises both material efficiency and labour efficiency

设计强调材料效率和劳动效率。



Industrial prefabricated components are integrated with local building materials

工业预制构件与当地建筑材料相结合

The design considers simplified assembly and disassembly requirements in response to shortages of skilled labour

设计考虑了简化装配和拆卸的要求，以应对熟练劳动力短缺的问题

Lightweight architecture

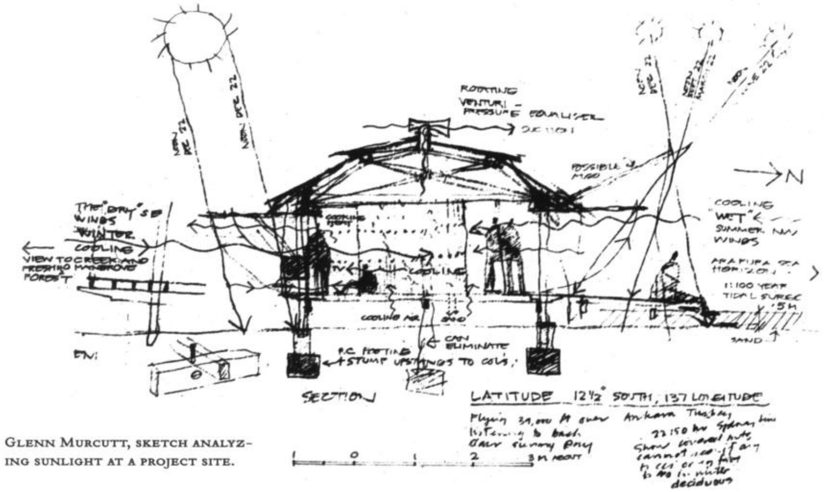
轻量化架构

Glenn Murcutt’s housing designs for outback Australia emphasize material efficiency and climatic responsiveness

格伦·马库特（Glenn Murcutt）为澳大利亚内陆地区设计的住宅强调材料利用率和气候适应性

Remote location of the Malika Alderton House and the precise character of Murcutt’s architectural detailing promote off-site prefabrication

Malika Alderton House地处偏远，而Murcutt的建筑细节又非常独特，因此促进了异地预制



GLENN MURCUTT, SKETCH ANALYZING SUNLIGHT AT A PROJECT SITE.

Lightweight architecture

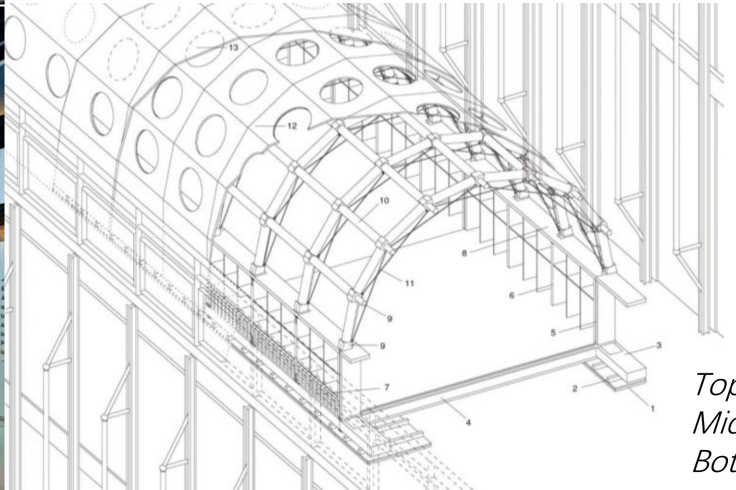
轻量化架构

Shigeru Ban’s paper log houses are an architectural response to humanitarian shelter

坂茂的纸制圆木屋是对人道主义庇护所的建筑回应

Different versions of paper log houses are notable for specific responses to different building requirements such as structure, lighting, and insulation

不同版本的纸木屋因对结构、采光和隔热等不同建筑要求做出特定响应而引人注目。



Top: Paper log houses, Kobe, 1995
Middle: Paper log house, Noto, 2023
Bottom: Temporary studio, Pompidou Centre, Paris

Lightweight architecture

轻量化架构

Humanitarian shelter for people affected by natural disasters and conflicts requires lightweight architectural solutions

为受自然灾害和冲突影响的人们提供人道主义庇护所需要轻量级的建筑解决方案

Material efficiency and cost efficiency are critical factors for temporary humanitarian shelter

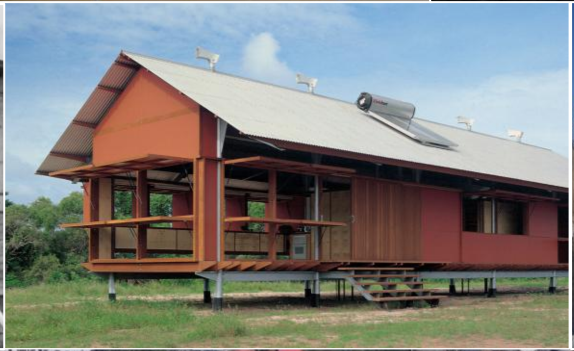
材料效率和成本效率是临时人道主义庇护所的关键因素

Top: UNHCR tents, Dadaab, Somalia
Middle: Cortex shelter, Cutwork architects
Bottom: Refugee Housing Unit, Better Shelter








Project site at the Old Floating Bridge Area of Shuidong Town, Ganzhou

让我们共同打造气候中和的未来
Building a climate-neutral future together

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School of Architecture & Urban Planning, NJU

中华人民共和国
住房和城乡建设部

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THANK YOU!

提问环节

YOUR QUESTIONS?


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