

State of Play for Circular Built Environment in Asia

Countries considered:

China, India, Indonesia, Nepal and Pakistan

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The One Planet network has been formed to implement the 10-Year Framework of Programmes on Sustainable Consumption and Production (SCP), which supports the global shift to SCP and the achievement of SDG 12. The One Planet Network acts as an enabler bringing actors from all regions to pool their expertise, resources, innovation and commitment towards a shift to more sustainable modes of production and consumption. The network comprises of six programmes: Sustainable Public Procurement, Sustainable Buildings and Construction, Sustainable Tourism, Sustainable Food Systems Programme, Consumer Information for SCP, Sustainable Lifestyles and Education.

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The Sustainable Buildings and Construction Programme (SBC) aims at improving the knowledge of sustainable construction and to support and mainstream sustainable building solutions. Through the programme, all major sustainable construction activities can be brought together under the same umbrella. The work involves sharing good practices, launching implementation projects, creating cooperation networks and committing actors around the world to sustainable construction. The goal of the programme is to promote resource efficiency, mitigation and adaptation efforts, and the shift to SCP patterns in the buildings and construction sector.

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The Sustainable Buildings and Construction Programme has been preparing regional reports on the state of play for circular built environment in Africa, Asia, Europe, Gulf Cooperation Council countries, Latin America and the Caribbean, North America, and Oceania. In addition to regional outlooks, a global report has been produced to summarise and compare the state of play regarding circularity in different regions. A crucial role of the reports is not only to provide a benchmark but also recommendations on how to move forward towards a sustainable and circular built environment.

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List of acronyms

ADRA	Adventist Development and Relief Agency
ASEAN	Association of Southeast Asian Nations
BEE	Bureau of Energy Efficiency
BF	Blast Furnace
BIM	Building Information Modelling
C&D	Construction and demolition
CAGR	Compound Annual Growth Rate
CIDB	Construction Industry Development Board
DRI	Direct Reduced Iron
ECBC	Energy Conservation Building Code
FAR	Floor Aspect Ratio
FSI	Floor Space Index
GDP	Gross Domestic Product
GHG	Green House Gas
Gol	Government of India
GRIHA	Green Rating for Integrated Habitat Assessment
HR	Human Resource
IBS	Industrial building systems
IDR	Indonesian Rupiah
IMF	International Monetary Fund
INR	Indian Rupee
LFG	Landfill gas
MoEFCC	Ministry of Environment, Forest and Climate Change
MoSPI	Ministry of Statistics and Programme
MSME	Micro, small and medium enterprise
MSW	Municipal solid waste
NBC	National Building Code
NGO	Non-government organisation
NPR	Nepalese Rupee
OECD	Organisation for Economic Co-operation and Development
PKR	Pakistani Rupee
PPVC	Prefabricated Prefinished Volumetric Construction
RCC	Reinforced cement concrete
SCP	Sustainable consumption and production
SDG	Sustainable Development Goal
SME	Small and medium-sized enterprises
SWM	Solid waste management
Syngas	Synthesis gas
UN	United Nations
UNICEF	United Nations International Children's Fund
USD	United States Dollar

Executive Summary

Three words that characterise the Asian region are diversity, disparity and rapid transformation. Diversity in material resources, geo-climatic contexts and cultural traditions is reflected in its variety of very rich construction practices and traditions. Wide socio-economic disparities exist within and across countries of the region reflected in consumption levels, living standards and per capita material and carbon footprints with over 30% of the Asian population living in extremely derelict housing and infrastructure conditions. The Asian region is the fastest urbanising region in the world with associated trends of increasing material and energy intensity in building construction. The nature of urbanisation in the region focus largely on green-field growth. The building sector is also among the largest contributor of GHG emissions that result from fossil fuels used in the production, use and end of life phases of a building.

Most countries in Asia have rich deposits of minerals, including coal and iron ore that are mined for industrial applications and power production. The construction sector in the region is a significant employer; a largely informal, artisanal and unskilled construction workforce that form important stakeholders in the strategies for new economy models.

Rapid urbanisation and rising demand for new infrastructure and housing, which need materials, are placing significant strain on natural resources. Many resources such as sand, soils and aggregates are already in the critical space, competing with other economic sectors such as food production and with serious negative impacts on eco-system services. The increasing densification of cities is resulting in an increase in the volume of construction debris. Although the potential to reuse this waste in new construction exists, the quantum of material needed is much higher than what is available from the recycled debris.

Comprehensive circular models across the whole life-cycle of buildings and built environments are not evidenced in the region. However, we find that many new developments are integrating circular models in one or more parts of the building value chain; for example, in modular building designs and in the design and production of building elements. We also see emergence of new business models in the adaptive reuse of buildings. There are many examples of water and energy recycling and reuse within and across buildings at neighbourhood levels. In addition, waste streams from other sectors such as mining, power, agriculture and municipal solid wastes are also finding their way into replacing virgin materials such as pozzulanas in cements, aggregates in concretes and mortars and fillers in masonry blocks.

Countries in the region are alive to the environmental impacts of the building and construction sector and resource efficiency policies range from zero-carbon strategies in China to construction and demolition waste regulations in India. Standards for secondary material use in China and Malaysia, rating systems for incentivising resource efficiency and circularity in Japan and India are some examples. However, financial incentives, public procurement systems and regulatory measures with respect to material, water and energy circularity are not yet mandatory in the countries that were studied for this report.

Opportunities for building and construction circularity in the region exist in both green-field and brown-field urban areas. Availability of secondary materials from other sources such as industrial by-products, bio-waste and construction and demolition waste provide opportunity of substitution of critical virgin materials and building circularity through industrial symbiosis. Many countries in Asia have rich traditions of biomass use in construction, especially bamboo. Regeneration of bio-resources provides a regenerative resource that is a major area of opportunity for the region. The construction of new cities, housing and infrastructure has the potential to ensure future circularity through the use of modular assembly-based construction systems. Circular models of construction in Asia have the potential to create economic opportunities through green jobs and green entrepreneurship through reskilling the large informal construction workforce and create new business models.

1. Introduction

Objective of the report: This report provides a brief overview of the state of the built environment and construction sector in Asia in relation to the practices and potential of establishing a circular economy in the region. The overview sets out the characteristics of the sector and explores how it can be made more sustainable through circular economy approaches. The focus is on some of the fastest-developing Asian countries: India, China, Indonesia, Pakistan and Nepal. These countries have been selected to provide a representative sample of the different scales and nature of the built environment in Asia. The study analyses the current situation with regard to the built environment of Asia, identifies critical areas of improvement in relation to sustainable development and provides recommendations on how to achieve these improvements.

In order to build a broad understanding of the state of play with respect to circularity in the built environment in Asia, this report is organised as outlined below.

Section 1 explains the significance of the study in the Asian context based on the current and future impacts on the environment and the related socioeconomic impacts in this rapidly urbanising and very diverse region. It also lays out the drivers of circularity in the region.

Section 2 underlines the concept of circularity and the associated economic and environmental benefits.

Section 3 describes the state of play of circularity in the built environment in Asia. It cites practice examples from representative countries to highlight the situation in the rural, vernacular and rapidly urbanising contexts. It looks at the different stages along the value chain of the built environment and provides examples from the design, material production, construction, use, deconstruction and reuse phases of buildings. In the context of industrialising and urbanising countries in Asia, this section also describes both 'within the sector circularity', that of construction debris, and 'cross-sectoral symbiosis', connecting industrial wastes to the construction sector. This is unique to the Asian context.

Section 4 discusses various policies and strategies adopted across numerous Asian countries that are designed to address the resource efficiency, sustainable construction and production, and circular models in the construction sector.

Section 5 concludes the report by summarising the discussion in a format that enables comparison across regions.

2. Significance of this study to the Asian context

The Asian region provides a very diverse palette of population densities and growth, urbanisation, industrialisation of economies and geo-climatic conditions. On the one hand, the two most populous countries in the world, India and China, are located in this region; on the other, the region includes very sparsely populated countries such as Mongolia. The Asian region has countries that have some of the highest income brackets globally, including Japan and South Korea, as well as countries that have the lowest rates of development worldwide, such as Afghanistan, Tajikistan and Nepal (World Population Review, 2019). By and large, most Asian countries are industrialising – some rapidly, such as, India, Malaysia and Indonesia – or are already industrial, like China. However, in some Asian countries, such as Nepal and Bhutan, the primary sectors within the economy are agriculture and forestry.

The region also has the widest variety of geo-climatic zones in the world and high degrees of vulnerability to climate change impacts. While on the whole Asia is rich in natural resources, their availability and diversity vary across the region. Countries like India, Pakistan, Indonesia, Vietnam, and many in Central Asia have a variety of both mineral and biomass resources that are used in the construction sector, while the island countries such as Maldives have limitations with respect to mineral resources and Central and Middle Eastern countries face limitations in the availability of biomass. These peculiarities have over centuries shaped the form, structure and materiality of the built environment in the different sub-regions of Asia. However, globalisation and urbanisation are changing this feature of the region. Whether slow or rapid, the general trend in the region is that of shifting from rural to urban forms of settlement; and even though large parts continue to build with vernacular and traditional methods, using biomass, stone, earth and agri-residue such as straw, we see a distinct trend towards longer-life, more energy-intensive materials such as cement, steel and glass. This shift in the materiality of the built environment has implications for the durability and maintenance requirements in new constructions and for the quantity of non-renewable mineral resources required, and therefore for the strategies and solutions related to circular models that countries can adopt.

2.1 Pressures driving the need for greater material efficiency and the potential for circularity

In the Asian region, there are multiple drivers of circularity. A few are identified below that have a direct impact on the transition towards circular systems. Figures 1 and 2 show urbanisation in Asia and Pacific across subregions, 1990–2020 and regional material consumption per capita for the Asia Pacific.

Urbanisation: Rapid urbanisation has created a demand for housing and infrastructure at a huge pace and scale. For example, in India, it is estimated that 70% to 80% of the housing and infrastructure needed to meet the urbanisation demands is yet to be built, but should be completed by 2030 (McKinsey Global Institute, 2010). This has implications for the quantity of material required, and in terms of the potential GHG emissions that the manufacturing processes, construction and use of buildings will generate.

Population and demographic: With over 55% of the world's population, and with a population that is young, a median age of 32 years (Worldometer, 2020) and therefore in the working and reproductive age group, the Asian region is expected to see increased aspirational demand for housing and infrastructure.

Consumption patterns: The growing middle class across Asia alongside the fulfilment of the housing and infrastructure needs of the poor have triggered a boom in housing, such that waste management, recycling, reuse and refurbishment of buildings has become a focal point of intervention.

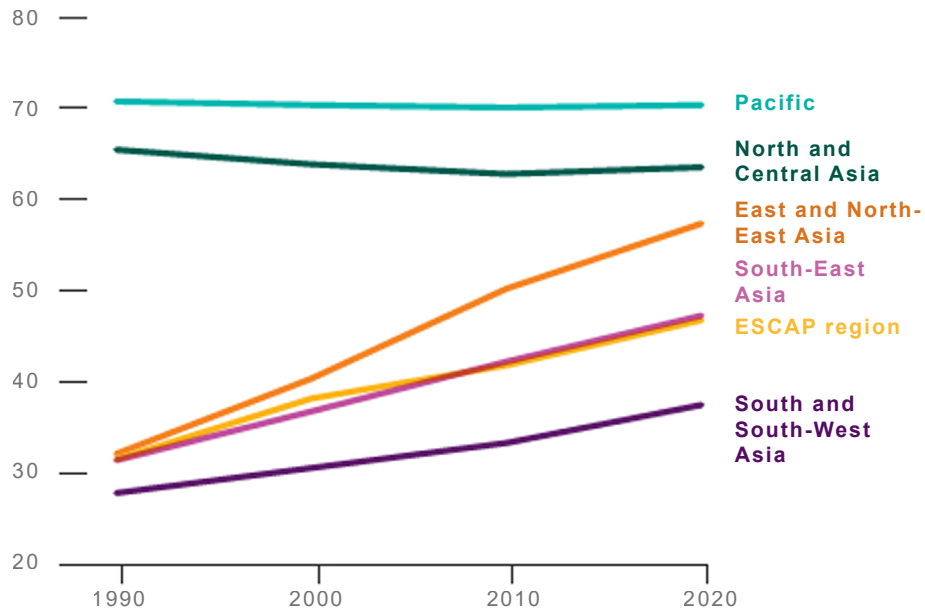


Figure 1: Urbanisation in Asia and Pacific across subregions, 1990-2020

Source: UNESCAP, 2013

Graphics modified by Ninni Westerholm

Resource criticality: As demand for land and building materials increases, pressure is also being felt in other sectors, such as food, where agricultural land and soils are being diverted for urban growth and brick-production. The concomitant rising demand for sand drawn from rivers is disturbing natural hydrological processes and ecosystems. Over-consumption and poor replacement of timber lead to deforestation and unsustainable forestry. Scarcities then cause price spikes and reduce the access of the poor to quality building materials. This in turn necessitates action around improving resource efficiency, resource substitution (industrial and biomass) and material recovery.

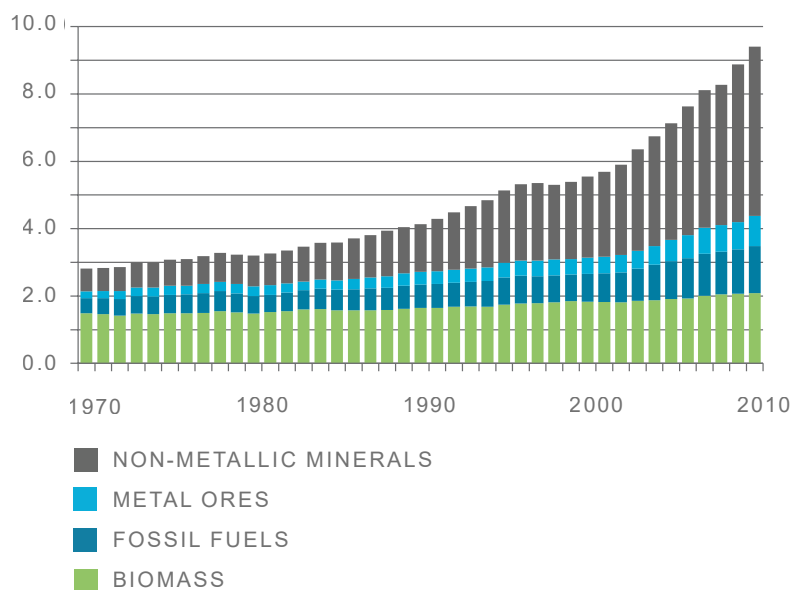


Figure 2: Regional material consumption per capita - Asia and Pacific

Source: UNEP, 2016

Graphics modified by Ninni Westerholm

Industrialisation: The shift from agriculture and forestry to manufacturing and services throughout Asia has meant that while pressure is being placed on the availability of land, there is the availability of large quantity of industrial by-products that are finding new applications in the construction sector. These industrial by-products are environmental hazards if left in the open or in landfills. However, they have use in the construction sector as substitutes for critical soils, sands and aggregates, and even as binders, so can be brought into productive use.

Environmental impact: The GHG emissions generated by the production, construction and use of materials and services necessitate action around energy efficiency and recovery. The ecological impacts of the extraction of minerals for construction require greater efficiencies in their use and reuse. As buildings reach their end of life or need to be demolished to make way for newer spaces and denser developments, construction debris becomes available that may be brought back into use – a concept that has been termed ‘urban mining’ but is now more commonly referred to as construction and demolition (C&D) waste utilisation.

Employment/entrepreneurship potential: Throughout Asia, a significant economic development requirement is the creation of jobs and income opportunities for the region’s large population of young people. Sectors that offer new and green job creating potential are desirable, such as the construction sector through the supply chains of materials manufacturing, assembly of products, repairs and refurbishment, and the delivery of infrastructure services of water and waste management. Circular models adopted in the construction sector that leverage the potential of human resources via new jobs and businesses will also contribute to much-needed local economic development. In most Asian countries, a large informal recycling economy exists and at the same time a large proportion of the workforce in the construction sector is informal (see Tables 2 and 3). New business models for the recycling, refurbishment and remanufacturing of new products provide opportunities for new skills development, bringing the informal workforce into the formal economy and with it added labour security benefits.

2.2 Population

Out of the estimated global population of 7.7 billion in 2020, the population of Asia is estimated to be 4.6 billion, over 55% of the total. With an average growth rate of 0.86%, the Asian population is expected to surge in the next few years (World Population Review, 2019). Asia has the two most populous countries in the world, China and India, with populations of 1.4 billion and 1.3 billion respectively. India, with a population growth rate of 0.99%, is expected to become the most populous country in the world, surpassing China, by 2030. Meanwhile, China is projected to see a decrease in population, with a low population growth rate of 0.39%.

Indonesia and Pakistan, each with a population of over 200 million in 2019, are the third and fourth most densely populated countries in Asia; and with a high growth rate of 1.07% and 2% respectively, the two are expected to see a rapid surge in population. The population of Nepal, which was at approximately 18 million in 1990, is likely to peak at 35.5 million by 2050 before starting a decline (World Population Review, 2019). Eastern and South-Eastern Asia with a population of 2.3 billion people and Central and Southern Asia with 2.0 billion people in 2019 were the world’s most populous regions representing 30 and 26% of the global population. The World Population Prospects Report 2019 of UNDESA, estimates that Eastern and South-Eastern Asia is projected to reach a maximum population size of 2.4 billion around 2038 and Central and Southern Asia is projected to peak some 27 years later at under 2.6 billion around 2065.

Asia also accounts for the world’s largest population in an informal settlement. Two of the five largest slums in the world – Dharavi in Mumbai, India, and Orangi Town in Karachi, Pakistan – are in Asia (Hutt, 2016). According to the World Bank (2014), the informal settlements, as a percentage of total population, comprised 25% in China, 24% in India, 22% in Indonesia, 54% in Nepal and 46% in Pakistan.

A majority of the population in Asia still does not have access to clean water and sanitation. Asia accounts for the most of the open defecation cases in the world. A large proportion of the population, estimated at 134 million in South-East Asia, does not have access to clean drinking water, with between 68% and 84% of water sources in the Asian region contaminated (UNICEF, n.d.). Rising urbanisation has led to the migration of rural workers to the cities, in turn fuelling the sprawl in informal settlements, exacerbating unhygienic water and sanitation conditions.

2.3 Rapid urbanisation and growth

Home to 55% of the global urban population, the region's urbanisation has important global implications (UNESCAP & UN-Habitat, 2015). In 2016, 48.7% of the region's 4.3 billion population lived in urban areas. Estimates indicate that within the current quarter of a century (2000–25), an addition of 1.1 billion people to Asia's urban areas is expected (UNESCAP & UN-Habitat, 2015). This rapid growth of the urban population is undoubtedly one of the key processes affecting Asian development in the 21st century. Figure 3 shows population and growth rate of selected Asian countries.

However, its dimensions, characteristics and impact vary significantly from one country to another. Millions of people in Asia continue to depend upon informal systems to gain access to housing, land, infrastructure and services. As incomes have risen, the resultant consumption and production patterns have led to a waste crisis in the region's cities. While traditional waste management practices like landfills threaten to overwhelm public resources (including land), some cities in the region are adopting waste-to-resource and waste-to-energy initiatives (UNESCAP & UN-Habitat, 2015). Even in the construction sector, late-stage solutions will no longer be viable in the future; thus, much greater commitment is needed to managing solid waste and valuing waste as a resource.

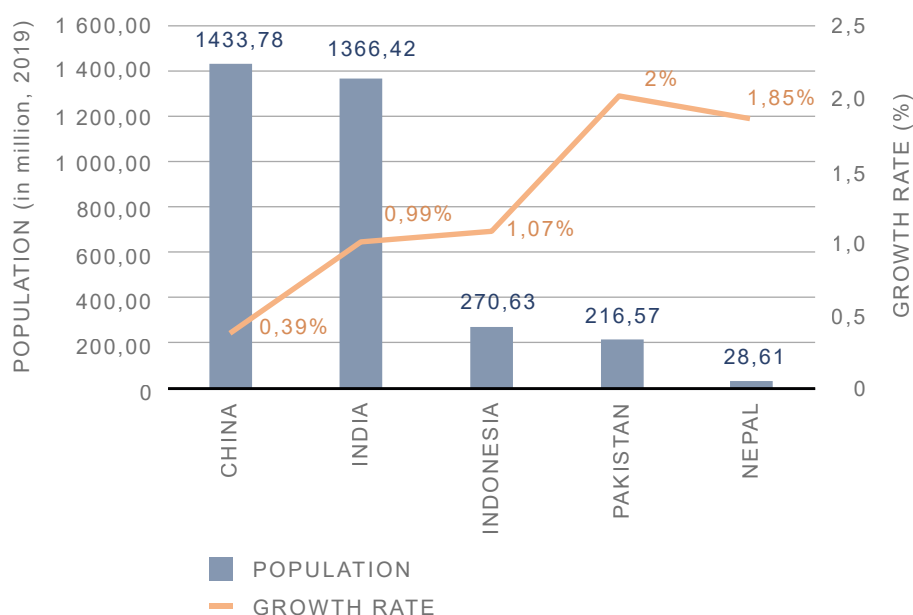


Figure 3: Population and growth rate of selected Asian countries

Source: World Population Review, 2019

Graphics: Ninni Westerholm

Asia underwent a high rate of development from 2000 to 2014. Among the five countries selected for this study, India has observed the highest built-up area change rate since 2000, at 46.6%, owing to rapid urbanisation, followed by Nepal at 40.5%, China at 39.8% and Indonesia and Pakistan, changing at a rate of 34.76% and 33.4%, respectively.

In terms of built-up area per capita, Indonesia recorded the highest, at 83 m² per capita, followed by China at 75 m² per capita in 2014. India, Nepal and Pakistan had a similar built-up area per capita in 2014, as shown in Figure 4 (OECD, n.d.).

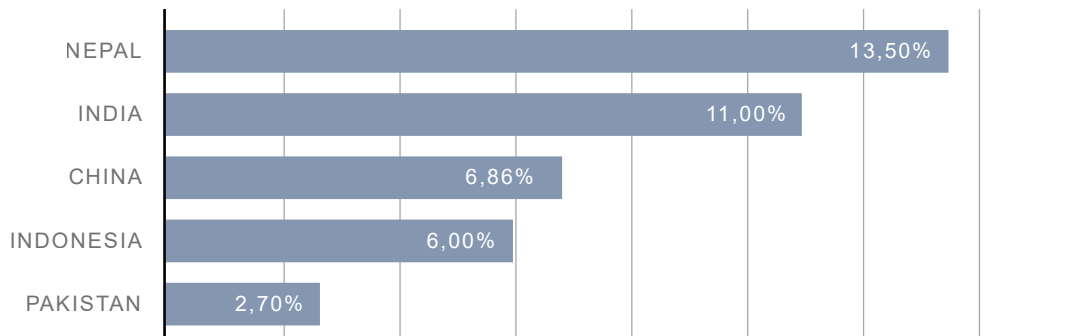


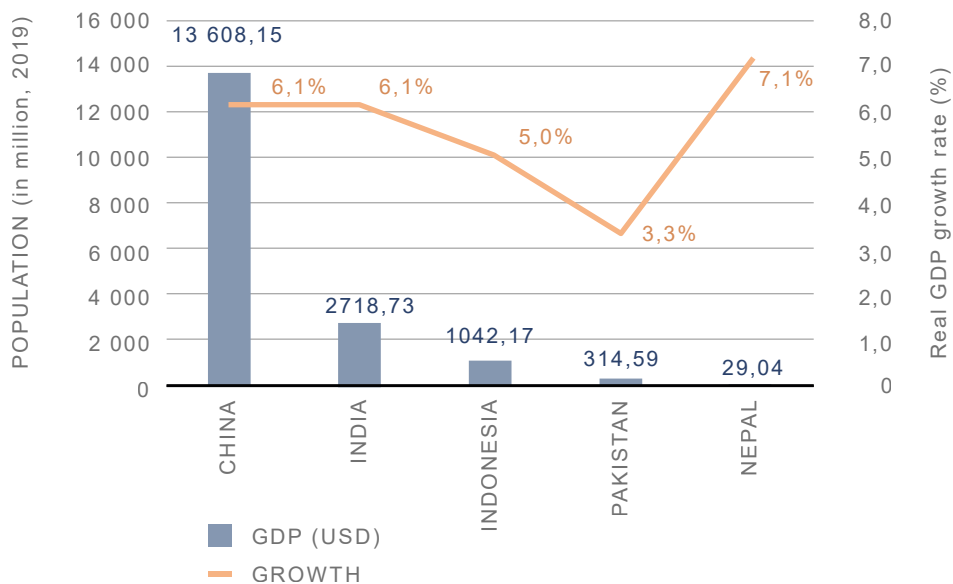
Figure 4: Construction sector contribution to national GDP in selected Asian countries

Source: OECD, n.d.
Graphics: Ninni Westerholm

2.4 Economic growth

In 2019, Asia and the Pacific recorded a gross domestic product (GDP) growth rate of 4.8%, contributing USD34.86 trillion. The International Monetary Fund (IMF) projects a GDP growth rate of 5.2% in the Asia-Pacific region in 2024, contributing USD44.17 trillion (IMF, 2019). The construction sector is one of the top performing sectors in the Asian region. Figures 5 and 6 show the relationship between growth rate and GDP and built up area change per capita in selected countries respectively.

Figure 5: GDP and growth rate of selected Asian countries



Source: IMF, 2019
Graphics: Ninni Westerholm

The contribution of the construction sector to the national economy and to the projected growth within the selected countries is summarised in Table 1.

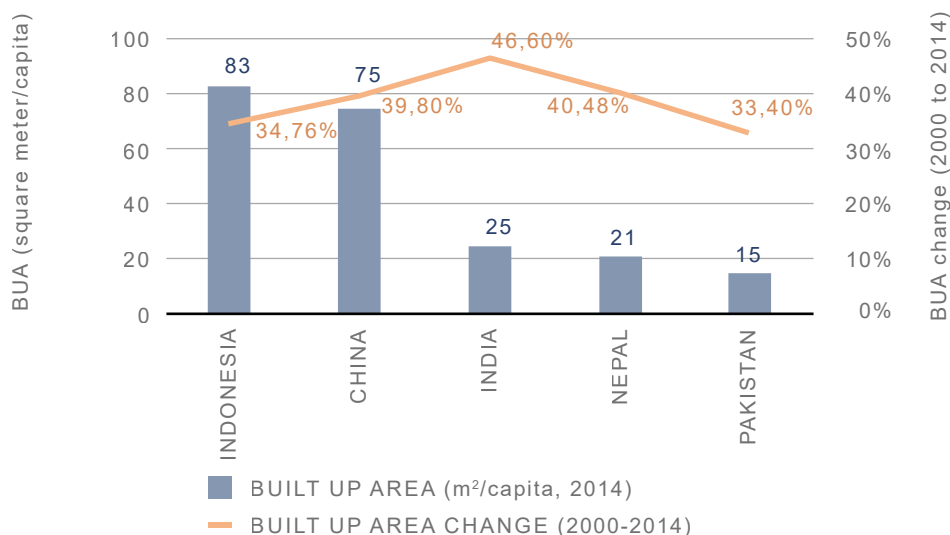


Figure 6: Built-up area change and built-up area per capita in selected Asian countries

Source: OECD, n.d.

Graphics: Ninni Westerholm

Table 1: Economic growth and potential of the construction sector

Source: Authors

Graphics: Ninni Westerholm

Countries	Construction sector's contribution to GDP	Current economic value of construction sector	Projected economic value of construction sector
China	Construction is the largest sector in China, contributing to 6.86% of the country's GDP (Zhao, 2018).	GDP from construction in China increased to USD996 billion in the fourth quarter of 2019 from USD672 billion in the third quarter of 2019 (National Bureau of Statistics of China, 2020).	The Chinese construction industry is expected to grow at a Compound Annual Growth Rate (CAGR) of 4.54%, reaching USD4.1 trillion by 2023 (at a constant 2017 US dollar exchange rate) (GlobalData, 2019).
India	The construction industry is the second-largest industry in India after agriculture. It accounted for 7.54% of India's GDP in 2018–19 (Statistics Times, 2019).	GDP from construction in India increased to USD34 billion in the fourth quarter of 2019 from USD32 billion in the third quarter of 2019 (MoSPI 2012).	The construction industry in value terms is expected to record a CAGR of 15.7% to reach USD738.5 billion by 2022 (InvestIndia, 2020).
Indonesia	The construction sector in Indonesia contributes to 6% of the country's GDP (Soemardi & Pribadi, 2018).	GDP from construction in Indonesia increased to USD19.5 billion in the fourth quarter of 2019 from USD18.6 billion in the third quarter of 2019 (Trading Economics 2020).	The construction sector in Indonesia is projected to grow at a fast pace at CAGR of 5.59% from 2020 to 2024. In May 2019, the government announced plans to invest USD412 billion in developing the country's overall infrastructure during the period 2020–24 (GlobalData, 2020).
Nepal	The industry sector in Nepal, comprising mining, manufacturing, energy production and construction, contributes to 13.5% of Nepal's GDP (CEIC 2020)	GDP from construction in Nepal increased to USD451 million in 2018 from USD414 million in 2017 (CEIC 2020).	Nepal's construction industry is expected to experience an average growth rate of 10-11% from 2016 to 2029 (Nepal Build Con, 2019).
Pakistan	Pakistan's construction sector contributes to 2.7% of the country's GDP (Tribune, 2017).	GDP from construction in Pakistan increased to USD2.133 billion in 2018 from USD1.994 billion in 2017 (State Bank of Pakistan, n.d.).	The China-Pakistan Economic Corridor will drive Pakistan's construction industry growth, with real annual growth at 8.9% from 2019 to 2024 (FitchSolutions, 2019). According to Trading Economics (2020b), GDP from construction in Pakistan is expected to reach USD2.186 billion by the end of 2020.

2.5 Environmental impact of the built environment

The construction industry is the largest contributor to global GHG emissions. Together, building and construction are responsible for 39% of all carbon emissions in the world (UNEP & IEA, 2017), with operational emissions (from energy used to heat, cool and light buildings) accounting for 28% of total global energy-related emissions. It is the second-largest emission-intensive sector, after industry. With increasing access to energy in emerging economies, the residential sector consumes the highest amount of energy. The role of the built environment in energy related emissions are shown in Figures 7 and 8.

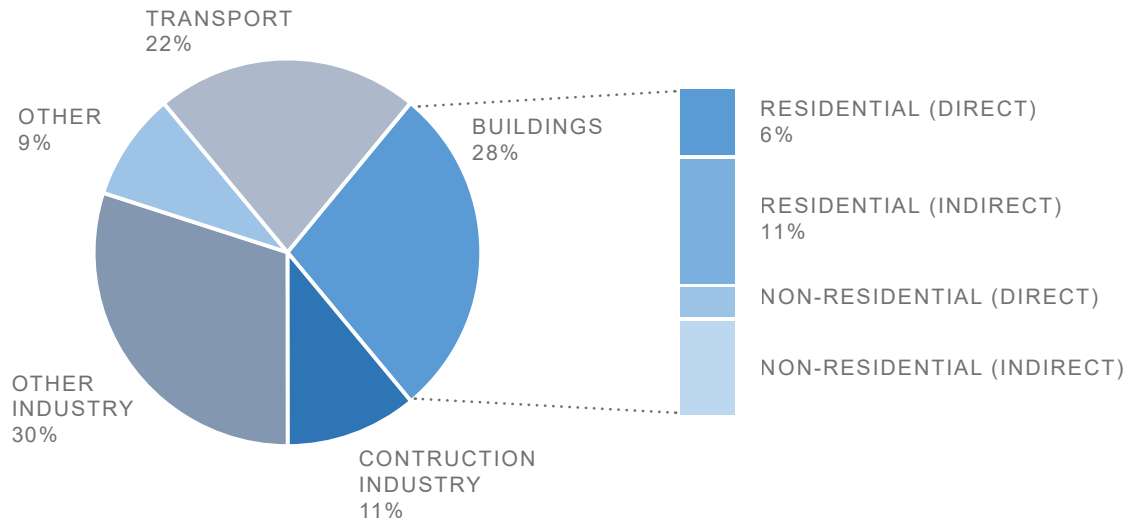


Figure 7: Global energy-related CO₂ emissions by sector, 2015

Source: UNEP & IEA, 2017
Graphics: Ninni Westerholm

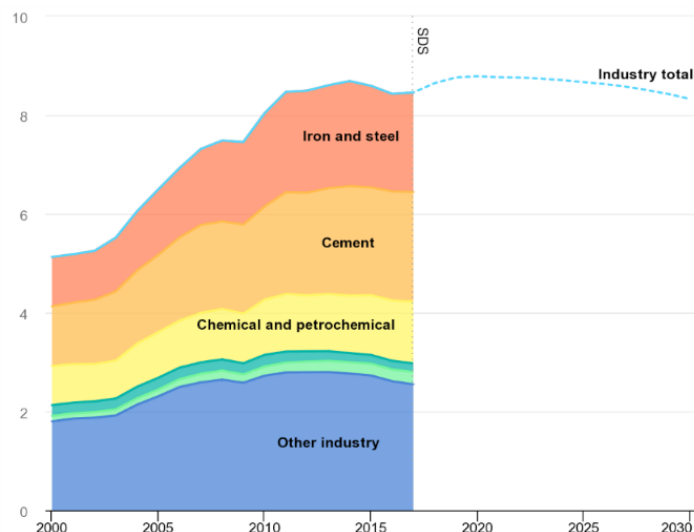


Figure 8: Industry direct CO₂ emissions in the sustainable development scenario, 2000-2030

Source: IEA, 2019

In 2017, the total industrial GHG emissions amounted to 8.5 Gt, a 0.3% rise on the previous year. Of this amount, the cement industry contributed the most, amounting to 26% (2.6 Gt) of the total industry emissions, followed by the iron and steel industry, at 24% (2.04 Gt). Energy-efficient technology and resource-efficient materials can be used to support sustainable manufacturing in these two emission-intensive manufacturing industries (IEA, 2019).

In the complete lifecycle of the building and construction sector, the proportion of energy usage and its corresponding emissions are the largest during the building use phase, followed by the indirect energy emissions from the material manufacture and production sector. Increasing built up area is the main driver behind energy consumption and carbon emissions, and is expected to grow globally, in particular, as a result of projected growth in the built-up areas of developing countries.

2.5.1 Carbon emissions in Asia

Asia is the largest CO₂ emitter in the world, contributing to 53% of total global emissions in 2017, amounting to an order of 19 billion tonnes CO₂ (Our World In Data, 2019). China, India and Japan, are among the top five emitting countries in the world. Asia's total CO₂ emissions are projected to grow further, particularly as a result of urbanisation and development in China. See Figure 9.

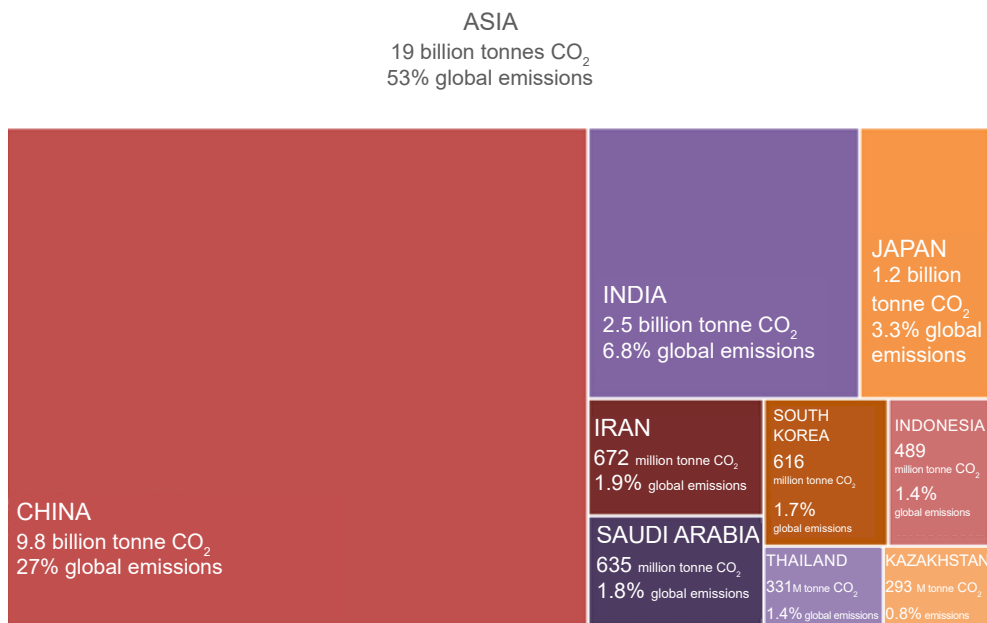


Figure 9: Global CO₂ emissions in 2017

Adapted from: Our World in Data, 2019
Graphics modified by Ninni Westerholm.

2.5.2 Material consumption patterns in Asia

In 2013, according to the UNEP (2013), the Asia-Pacific region surpassed the rest of the world in becoming the highest material consumer, at a rate three times that of the rest of the world, and is expected to continue growing in future years. From 1970 to 2005, consumption of construction minerals increased by 13.4 times, metal ores and industrial minerals by 8.6 times, fossil fuels by 5.4 times and biomass by 2.7 times. In 2008, among all the Asian countries, China and India accounted for the majority of consumption by 2008, with China accounting for over 60% of total regional domestic material consumption and India contributing over 14%. Figure 10 shows the domestic material consumption of the ten highest consumers of materials in the Asia-Pacific region, 1970-2005.

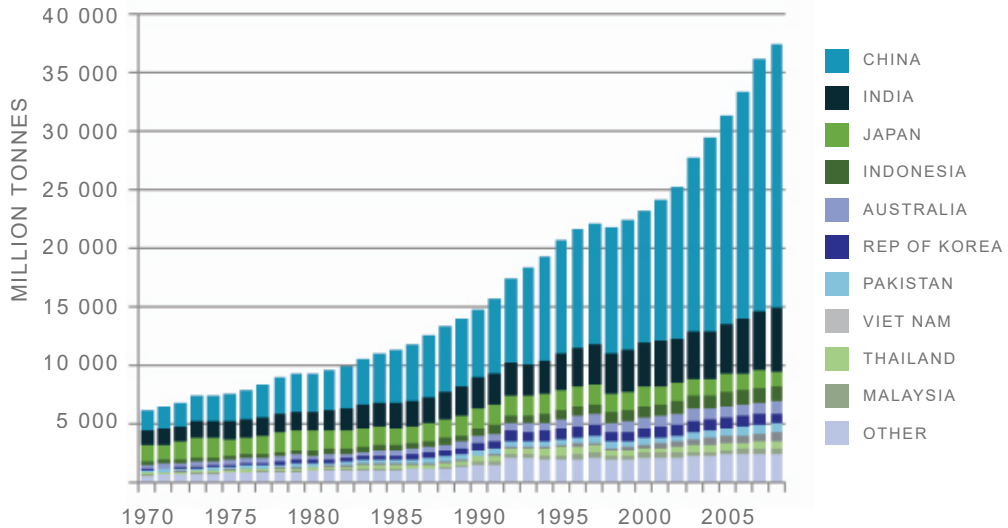


Figure 10: Domestic material consumption of the 10 highest consumers of materials in the Asia-Pacific region, 1970-2005

Source: UNEP, 2013
Graphics modified by Ninni Westerholm.

Consumption of the major categories of materials – metal ores/industrial materials, fossil fuels, construction materials and biomass – rose considerably across the Asia-Pacific region from 1970 to 2008. See Figure 11. Construction material consumption observed a rapid growth in this period, driven by the growth of the built-up environment, primarily in China and India.

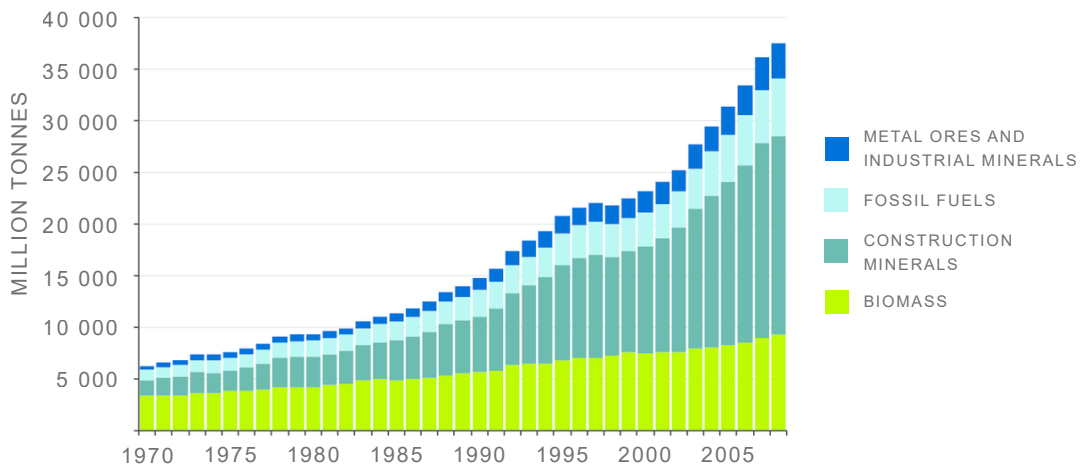


Figure 11: Domestic material consumption in the Asia-Pacific region by major category of materials, 1970-2008

Source: UNEP, 2013
Graphics modified by Ninni Westerholm.

2.6 Social impact and potential of the construction sector

The construction sector in Asia is one of the top employers of workers in the region. Increased investments in large infrastructure projects, like China’s ambitious Belt and Road Initiative, population growth and government spending will further drive growth in the construction sector in Asia in the coming years. Hence, employment in this sector is also slated to rise, creating

millions of jobs over the next five years. The Asian construction industry is labour-intensive, highly informal and decentralised, employing unskilled rural workers who are not protected by labour laws and are often subjected to exploitation. There is thus an urgent need to formalise the construction sector, and to protect the labour interests and skills of workers. The state of labour market in the selected Asian countries are summarised in Table 2 below.

Table 2: Labour type in the construction sector of selected Asian countries

Source: Authors
Graphics: Ninni Westerholm

Countries	Employment	Type of labour
China	<p>Chinese construction enterprises employ 45.37 million workers, accounting for 5.7% of the country's employed population (Zhao, 2018).</p> <p>The construction industry, driven by large infrastructure projects, will see rapid expansion and is expected to create millions of jobs in the coming years.</p>	<p>The Chinese construction industry is still a traditional industry, characterised by low efficiency, high pollution, large capital requirements and an amorphous structure, hindering its development (Zeng, 2011). As a labour-intensive industry, with low requirements in terms of workers' skills and education levels, and flexible employment, the construction industry has become the main industry that employs rural migrant workers (Zhao, 2018). Migrant workers are usually subjected to relatively low wages, long and irregular working hours and a very intense pace of work. The daily wage of a construction worker is around USD23.3 (165 yuan, based on the exchange rate at the time of writing of 1USD = 7.08 yuan) (Statista, 2020). The vast majority of them do not receive written labour 'contracts' and often only have verbal agreements with labour subcontractors. Moreover, the construction sector is traditionally dominated by men, with 88% male employees and 12% female employees (Bohong, Li, & Yang, 2015).</p>
India	<p>The Indian construction industry employs 35 million people and its market size is estimated to be valued at USD126 billion.</p> <p>The construction and real estate sectors in India are expected to create over 15 million jobs in the next five years, with an estimation of over 67 million people working in the construction and real estate sectors by 2022 (NITI Aayog, 2019).</p>	<p>The labour employed in the construction sector in India is primarily informal and most of its workforce consists of migrant rural workers. India's construction sector is labour-intensive and traditional, not requiring skilled workers. The informality of the sector is discussed in section 1.7. One-third of the workers in the construction sector are women, working mostly as helpers or unskilled workers. There remains a wage disparity between male and female workers: women are paid USD1.09 per day compared to the daily wage of USD1.36 of men (Devi & Kiran, 2013).</p>
Indonesia	<p>The construction sector in Indonesia employed 7.21 million people or 6.10% of total employment in February 2014, representing the strongest performance of the sector in over a decade.</p>	<p>Most Indonesian construction labourers are unskilled, not possessing a specific job skill. Meanwhile, Indonesian labourers who are skilled have special skills in carpentry (25%), bricklaying (20%), plumbing (14%) and painting (5%). For construction work, a standard of technical skills has been established, known as the National Work Competence Standard of Indonesia (SKKNI) (Adi, 2017). The daily wage of construction labourers in Indonesia is USD0.19(1USD = 15717 IDR) (CEIC, Labor wage by occupation, 2019). The construction sector is dominated by men.</p>

Nepal	Nepal's construction industry has the second-largest labour force in the country, next to agriculture. It is estimated that this sector is creating employment opportunities to about 1 million people. According to World Bank data, 13.5% of the labour force was employed in this industry, and is expected to grow in future years.	In Nepal, the recruitment of labourers in the formal sector through intermediaries (labour contracting), called <i>naikea</i> , is an established practice in the construction sector. Labour outsourcing is responsible for most of the labour in the construction industry. Unskilled labourers recruited by <i>naikeas</i> receive on-the-job skills training (Wells, 2006). Informal labour in the construction sector in Nepal is prevalent. Women's participation is primarily observed in unskilled labour, where they earn a daily wage of between USD0.65 and USD0.91; while men in unskilled labour earn between USD0.85 and USD1.07 (1USD = 123.05 NPR) (International Labour Organization [ILO], 2005).
Pakistan	Construction is one of the most labour-intensive industries in Pakistan – its contribution to the labour force in monetary terms (7.3%) is more than double its contribution to GDP (2.7%) (SBP, 2020). Within the construction industry, housing is deemed to be more labour-intensive, especially in urban areas. Thus, a projected boost in the housing industry will go a long way in generating urban employment.	Pakistan's construction industry, in spite of its sizable share in GDP and its fairly large contribution towards employment generation, remains neglected, especially in relation to skills development among its workers. Most of the construction enterprises in Pakistan remain distanced from modern HR practice and therefore do not consider investment in the development of their human resources (Riaz, Din, & Aftab, 2015). Women's share of the labour force is 21.2% compared to 78.8% for men. However, female participation in the construction sector has increased over the years. Most of these female workers are unskilled, working as helpers, movers, labourers and carriers. However, women in the construction sector earn a daily wage almost equal to that of their male counterparts (ILO, 2011). The daily wage of unskilled labour in 2017 was noted to be around USD0.012 (1USD = 167 PKR) (CEIC, 2018).

2.7 Informal economy

A recent ILO report shows that 1.3 billion people work informally in the Asia-Pacific, comprising 65% of the world's informally employed. Most of them lack social protection, rights at work and decent working conditions. Informal employment represents the highest share in the industrial sector (68.8%) in the Asia-Pacific region (ILO 2020). The construction sector requires legal procedures such as tenders from the government, legal contracts and monitoring, but at the same time employs labour on a completely casual basis. Therefore, while the sector is formal it perpetuates informality.

China's experience in the expansion of the informal economy is unique. It has established a highly centralised economy. Those who have been laid off from public enterprises and large numbers of internal migrant workers have been absorbed by small production units and service industries in the private sector. The informal economy has thus become the source of alternative employment and income opportunities for many workers who have lost jobs in the transition, yet, is rife with lack of skills and low productivity. Most informal workers are vulnerable, as their labour rights are easily infringed (Zhao, 2018). Women's share in informal sector employment in China is on the rise; a survey revealed that 42.39% of women were engaged in informal employment in 2015 (Bohong, Li & Yang, 2015).

India's construction sector has boomed, especially in the big cities such as Delhi, Mumbai, Chennai and Bangalore. The workers employed on a casual basis are seldom registered with the Labour Commission and therefore do not have any legal entitlements. Out of all workers in the non-agriculture informal sector, 76% in rural areas and 72% in urban areas belong to

construction, manufacturing, and wholesale and retail trade. These are sectors where majority of workers are in informal employment (MoSPI, 2012). See Table 3.

Table 3: Proportion of informal sector workers by sector activity in India

Source: MoSPI, 2012
Graphics: Ninni Westerholm

INDUSTRY ACTIVITY	RURAL	URBAN
Manufacturing	86%	78%
Construction	64%	72%
Wholesale or retail trade etc.	91%	92%
Transport, storage and communication	82%	68%

According to the World Bank, in 2007 almost 61% of the labour force belonged to the informal sector in Indonesia. Yet, more recently, there has been considerable progress towards formalisation of the economy. In February 2014, in Indonesia 46.4% of those employed were working in the formal economy, while 53.6% were working in informal employment. The pattern of economic growth since 2010, alongside gains in labour productivity, regulatory reform and social security expansion, is likely to have played an important role in the shift towards formal employment in Indonesia (ILO, 2014). In Nepal, more than 70% of the workforce is in the informal sector. Moreover, the country's informal economy is rapidly expanding (ILO, n.d.). In Pakistan, the bulk of the female labour force is employed in the informal economy and is not covered by legal protection or labour welfare institutional mechanisms. In the urban informal sector of Pakistan, 67.5% of women work as home-based or casual workers on low wages, or as domestic workers with extremely low remuneration (ILO, 2011).

Overall, the Asian construction sector employs a massive workforce of informal and unskilled workers. There is a need to drive the adoption of circular business models within the informal sector, to support formalisation and better livelihoods of the workforce. Large-scale capacity building across the workforce in all sectors, in accordance with the shift to circular business models, including awareness-raising campaigns targeting stakeholders at all levels, is required, complemented by an emphasis on sustainable design and technology adoption in the construction industry.

2.8 Sustainable Development Goals (SDGs): Asia and the building and construction sector

The UNESCAP (2019) Baseline report estimates that the Asia-Pacific region will miss all the 2030 SDG targets considering the current pace of progress. Moreover, in view of the prolonged lockdown in various countries of the Asian-region due to the COVID-19 pandemic in 2020, with a registered slowdown of the economy, achieving the SDG targets will take more time than anticipated by many monitoring bodies. With the growing informal sector in most Asian countries, the region has seen negative trends in terms of Goal 6 (clean water and sanitation), Goal 8 (decent work and economic growth) and Goal 12 (responsible consumption and production). Among all the goals, SDG 12 (responsible consumption and production) has seen the greatest decline. The construction and housing sector in Asia significantly impacts many of the SDGs, so it is important to track the interrelationships between these impacts and goals, as shown in Table 4 below, especially in the context of understanding resource efficiency and circularity in the sector.

Table 4: Significance of construction sector in Asia in relation to SDG goals

Source: Authors

Graphics: Ninni Westerholm

Goals	Impacts (direct/indirect)	Significance in the Asian context
1. No poverty	Poverty reduces access to housing and infrastructure	As Asia is home to the world's largest poor population, improved access to shelter and quality housing is a critical need across the region. This will mean the creation of housing and infrastructure of a more permanent nature and at a rapid pace. This requires shifts in construction technology and materials.
3. Good health and wellbeing	Quality shelter and safe human settlements contribute to better health, wellbeing and productivity.	
6. Clean water and sanitation	Safe and resilient shelter and human settlements are required to ensure clean water and sanitation.	Harvesting rainwater and recycling wastewater for productive use will be necessary to satisfy the demands of the growing populations of cities, necessitating water system circularity at the building and settlement levels in the design of new buildings and townships and the retrofit of older constructions.
8. Decent work and economic growth	The construction sector is one of the most significant job creating sectors and promotes GDP growth.	Most Asian countries are young, with a median age of 32 years (Worldometer, 2020) and there is a need for jobs and decent work opportunities. Skills, jobs and entrepreneurship, especially in 'green construction systems', can promote low-carbon and resource-efficient construction.
9. Industry, innovation and infrastructure	The building and construction industry is important in terms of economic development and potential as well as environmental and social impacts. Therefore, innovation in the construction industry affects all three pillars of sustainability.	The construction sector in Asia is responding to high demand and market potential in a resource - and climate-constrained context. This drives research and innovation in design, construction systems, business models and policies to promote resource efficiencies and circular models in technology and business systems. Industrial development in Asia also provides an opportunity for cross-sectoral synergies or industrial symbiosis strategies.
11. Sustainable cities and communities	The nature of buildings and the construction sector impact the sustainability of cities and human settlements. The materiality, technology and sustainability of buildings are in turn impacted by city planning, land use and decisions regarding settlement density.	Rapidly urbanising Asia has both greenfield (new cities) and brownfield (densification and expansion of existing cities) situation. Newer settlements that integrate circular models in the design of buildings and communities will need to ensure savings in materials and energy, both at construction and at the end of life of buildings. Brownfield situations will need to integrate strategies of recycling and reusing construction debris and waste.
12. Responsible consumption and production	The building and construction sector is the largest consumer of mineral resources and energy, and has a huge water footprint. At the same time, users or consumers of buildings are driven by needs and aspirations that drive the nature and quantum of market demand.	Enabling sustainable consumption and production (SCP) strategies in the construction sector will bring savings in materials, energy providing climate change mitigation benefits and reduced ecological impacts. It will also reduce the demand for materials that are needed in other key sectors such as agriculture (critical for the Asian region). SCP in the building and construction sector is the most significant connecting goal between the social and economic development goals (1–11) and the environment management goals (6, 7, 13–15).

13. Climate action	The building and construction sector is the second-largest emitter of GHGs. Material extraction for building impacts landuse and natural eco-systems impact adaptive capacities of natural systems and of society.	Asia is the biggest contributor to global CO ₂ emissions, accounting for almost 53% (Our World In Data, 2019). Additionally, rapid urbanisation and the explosion of the middleclass are pointing to increased per-capita emissions. The Asian region also has high vulnerability to natural disasters and climate change impacts. This requires the building and construction sector to reduce GHG emissions across its value chain and to respond to shifts in temperature and precipitation in design, material use and construction systems in order to adapt to the changes.
14. Life below water	The extraction of sands from river systems for construction impacts the marine life in rivers.	Asian rivers are the life blood of the agriculture and energy sectors in Asia. Materials that can substitute river sand and/or construction systems that do not require river sand are needed in all Asian countries.
15. Life on land	Land use shifts from forest to mining to mineral extraction and from agriculture to urban development impact land, forests and biodiversity.	The Asian construction sector, especially in rural areas, depends significantly on biomass and forest resources, even though this trend is reducing. Timber, bamboo and agri-produce provide zero waste to landfill models of construction. However, the increased use of land-based resources will require resource regeneration strategies. At the same time, the growth in the number and scale of human settlements and the need for greater land use efficiency must be addressed in the context of a rapidly urbanising Asia.
17. Partnerships for the goals	The construction sector does not work in isolation. By nature, it brings in a varied range of stakeholders that create, manage and operate the built environment.	The construction sector throughout most of Asia has a high degree of informality across its value chain connected to a well-established formal market response system. All countries have well-developed institutional frameworks with standards and regulations that govern and guide the sector. The Asian construction materials sector is also connected with international trade flows. Domestic, inter-regional and international public-private partnerships can provide knowledge sharing, technology transfer and learning.

3. Circularity in the construction sector

A circular economy approach calls for ‘**closing the loop**’ in production and consumption cycles and is based on the following three key principles (Ellen MacArthur Foundation, 2017):

1. Design out waste and pollution
2. Keep products and materials in use
3. Regenerate natural systems.

Circular economy thinking necessitates that the production and consumption systems be seen **systemically** beyond the waste minimisation and recycle and reuse approaches. **Closing the loop** essentially means zero waste in both production and consumption processes; it means maintaining the highest value of resources within a production system for the maximum time,

requiring durability and increasing the lifespan of products; and it means the return of resources into the eco-system after use in essentially the same state as they were drawn out – thus using regenerative methods. Three shifts in our ways of production and consumption are therefore called for:

- Design re-think or **eco-design**
- Process re-think or **eco-production**
- Use re-think or **eco-consumption**

‘The concept of circular economy is about decoupling growth from resource consumption and maximizing the positive environmental, economic and social effects’ (World Economic Forum, 2014). The Green Growth Knowledge Platform has called it ‘more with less for more’. Circular economy thinking is thus a trans-economy systems thinking approach that addresses production and consumption processes across different sectors and explores the possibility of creating synergies and value from the by-products of all processes. In addition, it provides new economic opportunities for local wealth and prosperity, a necessary outcome for the achievement of the SDGs. The key operational elements emerging from these principles are as follows:

- Products and production systems are designed such that they generate no waste. By-products from one process in the production cycle become inputs for another in the same or a different sector.
- Products are designed for extended life, reuse and repair, thus ensuring that the value of resources in the consumption cycle is retained for as long as possible.
- Products that cannot be reused any more for a different application are refurbished and preferably upcycled so as to retain or enhance the resource value in the system while maintaining the CO₂ footprint of the new product or service.
- Consumer behaviours change from consumption to use, such that ownership gives way to sharing, renting and leasing, thus expanding product use, and services are the new products.
- End of life and next life conception is a key criterion in the design of products and production processes. All products have to be either biodegradable or durable so that everything can be either reused or put back into nature. Disposable products are replaced by biodegradable resources, while extended life and reuse, repair, retrofit or recycle methods are applied to durables. Complex objects are designed to be dismantled so that they can be sorted into either the ‘to be composted at the end of life’ or ‘to be recycled as a next life’ category once they are no longer in use (The Earthbound Report, 2014).

4. State of circularity in the construction sector in Asia

The Asian region encompasses huge diversity in terms of material resources, geo-climatic conditions and the cultural traditions that have influenced its building practices. Although the region is rapidly urbanising, over 50% of its population still lives in rural areas (Worldometer, 2020) and many of these rural areas still employ vernacular construction practices dependent on low processed earth, stone and biomass resources. Some of these vernacular ways of building are providing inspiration and a basis for the new circular models in construction and it is therefore important to understand the inherent and embedded aspects of circularity in the vernacular traditions in the region.

The construction technologies, material use and practices are transforming quite rapidly in the urban areas. However, as different aspects of the construction practice are managed and

controlled by different stakeholders, the changes are not seen uniformly across the value chain of construction in rural and urban areas. Consequently, we do not see a holistic ‘circular building approach across the life cycle’ in either urban or rural areas. However, we do find examples of the core principles of circularity (as discussed in the previous section) in different phases of the building lifecycle, including: (1) **design** – of the building as well as of the building products; (2) **manufacturing** – both of the products and the construction of buildings; (3) **building use** – use of the buildings and of the built environment more broadly; and finally (4) **post life** – reuse as well as recycling of materials and building elements, that is, reuse of deconstruction and construction debris. The sample buildings presented in this chapter are by no means comprehensive, but they do give us an idea of how the core principles of circularity are being applied in building and construction. For example, these applications include: (a) **designing out wastes** from the production and construction processes by using modular assembly-based products and modular designing; (b) **keeping resources in use through durable design**, adaptive reuse of buildings, reuse of building elements, recycling of construction debris at the end of building life, recycling water and energy or using secondary materials from other industrial processes; and (c) **contributing to the regeneration of natural systems** by opting for recyclable and biodegradable products such as bamboo, timbers and earth in different phases of the building lifecycle.

4.1 The vernacular view of circularity

Vernacular traditions in Asia reflect the core principles of harmony with nature and in material use. Civic architecture in rural areas has been based on the use of available natural resources, mainly low processed lime, stone and earth, and biomass. With perishable materials being returned to the earth, only community buildings such as temples were expected to last for a long time, while common people’s homes would be renewed often (Ranjith, 2018). Based on local material availability, the building elements of vernacular homes are more or less standardised and modular. Therefore, windows, lintels, beams and roofing units are sized so that they can be reused in new buildings.

In most Asian countries, 50–70% of the total population still lives in rural areas. And even though there are shifts in the materiality of construction in these regions, there remains a huge dependence on biomass – timbers, bamboos and other grasses – for structural support, wall panels, roof under-structure and thatching. The Asian region accounts for 65% of the total bamboo production in the world. And within the region, China, India, Indonesia, the Philippines, Vietnam and Myanmar use the largest share of bamboo, with Sri Lanka, Nepal and Bangladesh following close behind (Lobovikov et al., 2007). Bamboo is used widely in the rural buildings in these countries, for all parts of the building. Indeed, in India, a special bamboo mission was established and the Prime Minister’s rural housing programme supported the documentation and standardisation of design of rural home options using engineered and treated bamboo products. A growing industry of ‘Bamboo Wood’, which consists of bamboo slivers in resin shaped as timber sections, used for supporting beams, door frames and furniture and floor boards, is growing in both China and India (DA & CANSA, n.d.).

4.1.1 Examples of vernacular and indigenous construction

4.1.1.1 Use of rammed earth

Rammed earth is an ancient construction technique based on compacting loose soil inside a formwork in successive layers to make a homogeneous wall. The technique has been developed independently in different regions of the world, with variations according to a number of factors, such as the availability of materials and the capacity of the workforce (Schneider et al., 2019). Rammed earth has been applied as a vernacular practice in Asian countries including Bhutan, China, India and Nepal, and provides many advantages in terms of sustainability compared to

other traditional and modern construction methods (Jaquin, 2011). The soil for the construction can be sourced onsite, at zero or almost zero cost, providing a solution for housing in remote areas and avoiding the consumption of energy in transportation. Besides, rammed earth structures are durable and do not require any painting or wall treatment, ensuring easy, low-cost maintenance.

An example of rammed earth usage is a typical Bhutanese house, wherein a three-storey rammed earth structure with space for livestock on the ground floor, a grain store on the middle floor and living quarters on the top floor are constructed. Another storage space for drying meat and vegetables is normally kept between the top floor and the roof (Natural Homes Bhutan, 2020).

4.1.1.2 Tribal architecture

Sherdukpen houses in Arunachal Pradesh, India: Sherdukpen houses are usually rectangular, built on three levels with a ridged-roof, and often with a Tibetan Buddhist prayer flagpole on top. Floors are made of wood. Walls are made of stone from the ground up to half a metre above the floor of the living room and then wood above that, with bamboo matting walls on the second floor. The roof is covered with wooden shingles and stone weights, although recently layers of bamboo matting or metal have been used (Kolkman & Blackburn, 2014). Bamboo in these regions is locally available and reusable.

Batak architecture, Indonesia: The Batak are one of the many ancient populations of Indonesia. They live in the volcanic regions of northern Sumatra. The traditional house of the Batak Toba community (See Figure 12), 'rumahadat', is essentially a rectangular infrastructure composed of impressively large wooden pillars resting on flat stones that protect the residents from humidity. At the front of the house are two rows of pillars that support the entrance. The pillars are connected to each other by inset planks that not only help to stabilise, but also to form a more closed structure in which to keep livestock (Ownvilla, 2018). Stone and wood, which are the primary construction materials of the Batak houses, can be reused for future constructions.



Figure 12: Batak house

Source: Encyclopaedia Britannica, 2019

4.2 Biomass-based construction in Asia: bamboo, timbers and agri-residue

The Asian region has the world's largest bamboo reserves, mainly found in India, China, Indonesia, Myanmar, the Philippines and Vietnam. Figures 13 and 14 show the contribution of bamboo by continent and countries in the Asian region, respectively. Table 5 the extent of bamboo forest area as reported by previous inventories.

This material has been traditionally used in almost all parts of building – as under-structure for roofs, roofing tiles and structural framing, wall panels, floors, and door frames and door panels. There are three kinds of bamboo housing: the traditional houses that use whole bamboo culms as the primary building material, and bamboo mesh panels plastered with clay; an upgraded type in which bamboo panels are plastered with cement and lime and panels are standard and modular sizes; and modern prefabricated engineered bamboo buildings made from laminated boards, veneers and panels. Along with rural and vernacular applications, the use of bamboo treatments and re-engineering that produce longer-lasting building products for modern applications is now growing across Asia. Resin-bonded bamboo wood, bamboo panels made from woven bamboo mats and bamboo particle boards are now being produced by both small-scale entrepreneurs and large factories. China started producing bamboo panels as early as the 19th century. Presently, more than 20 different types of bamboo panels are manufactured in Asia, and bamboo wood and bamboo floor boards are particularly popular. In 2004, China was producing over 17.5 million square metres of bamboo floor boards annually, supplying to markets across Asia and Europe. Now this technology is available in India and Indonesia also (Lobovikov et al., 2007).

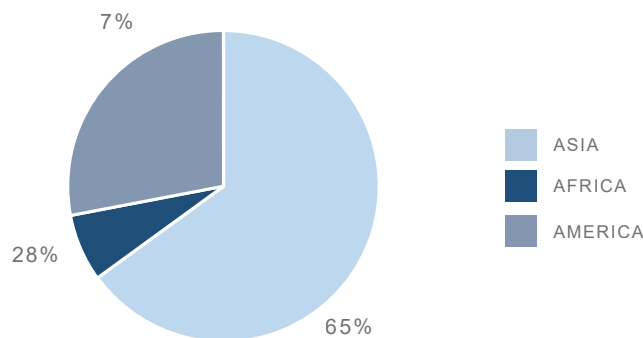


Figure 13: Contribution of bamboo by continent

Source: Lobovikov et al., 2007
Graphics: Ninni Westerholm

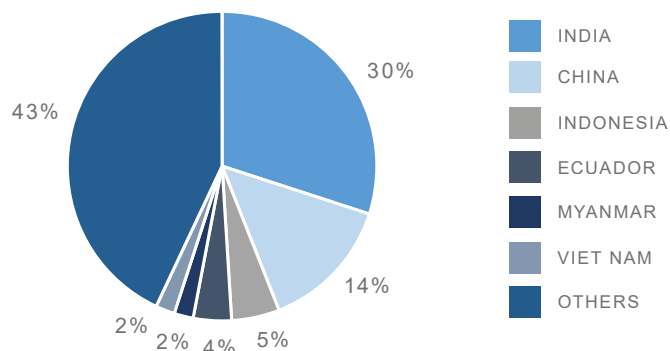


Figure 14: Countries with largest bamboo resources

Source: Lobovikov et al., 2007
Graphics: Ninni Westerholm

Table 5: Extent of bamboo forest area as reported by previous inventories (1000 ha)

Source: Lobovikov et al., 2007

Graphics: Ninni Westerholm

Country	FRA 1980	FRA 1985	Kigomo 1988	FRA 2000
Bangladesh			213	23
Cambodia	380	380		34
China			3 300	4 211
India	1 440	1 420	9 570	
Japan			125	
Lao People's Democratic Republic	600	600		1 532
Malaysia			20	
Myanmar	632	617		3 251
Nepal	1	1		
Philippines			8	
Republic of Korea				8
Thailand	900	865	1 020	261
Viet Nam	1 200	1 200	1 300	813

4.3 Construction and structural application

Traditionally bamboo culms were used as primary building materials for constructing houses or a bamboo frame was plastered with cement or clay, but building practices are now shifting towards the construction of prefabricated bamboo houses with the help of bamboo-based panels, veneers and laminated boards. Figure 15 shows some examples. The technology that has evolved can be used for the construction of low-cost (single-storey) houses, for a cost ranging from approximately USD45 to USD75 (1USD = 73 INR) per square meter, depending on the design of the house and the nature of the interior finish. Research and technology development has resulted in improving the technology and techniques used to produce bamboo that is suitable for construction. There has been improvement in bamboo preservation and protection technology as well as in jointing techniques so that the use of bamboo can be proliferated as construction material. These technologies are helping to increase the durability of bamboo as a construction material (DA & CANSA, n.d.).

Agri-residues also offer huge potential as a construction material in the Asian region (Bentsen, Felby & Thorsen, 2014). The use of a variety of grasses and rice stalks in thatching is an established rural practice. Agri-residues have been compressed and bonded to produce wall panels and boards. Engineered straw-bale construction is a recent innovation of which some examples are seen in China.

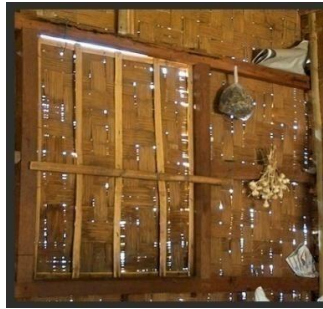
Traditional Bamboo Roof



Modern Bamboo Roof



Traditional Bamboo Window



Modern Bamboo Window



Traditional Wall



Modern Bamboo Wall



Figure 15: Transformation of traditional bamboo construction to modern construction techniques

Source: DA & CANSA, n.d.

4.3.1 The first International Bamboo Architecture Biennale, China

The first International Bamboo Architecture Biennale was held in Baoxi, Longquan, China, on 28 September 2016, which showcased the work of 11 architects who used bamboo as the primary building material to construct structures in the rural space (CDC, 2018). See Figures 16 and 17.



Figure 16: Left: Contemporary Celadon Ceramic Museum; Right: Welcome Center

Source: CDC (2018)



Figure 17: Eco-energy efficient experimental house.

Source: CDC (2018)

4.3.2 Indian Plywood Industries Research and Training Institutes (IPIRTI)

IPIRTI is an autonomous body under the Indian Government's Ministry of Environment, Forest and Climate Change (MoEFCC). It is an innovative organisation dedicated to developing new environmentally friendly technologies for the wood-based industries. One of IPIRTI's areas of applied research is developing technologies for manufacturing wood alternatives from natural/renewable fibers. It has also come up with new and innovative bamboo-based products such as bamboo mat corrugated roofing sheets, bamboo mat board and bamboo mat veneer composites. IPIRTI has been involved in the construction of affordable housing and earthquake-resistant housing systems using bamboo and its composites (DA & CANSA, n.d.). Figure 18 is a demonstration house constructed using wood alternatives by IPIRTI.



Figure 18: Demonstration House

Source: IPIRTI Bangalore, 2001

4.3.3 Straw bale as a construction material: Heilongjiang, China

In June 2000, the Province of Heilongjiang in north-east China joined with the international non-government organisation (NGO) Adventist Development and Relief Agency (ADRA) in a project with an objective to promote energy-efficient housing in the local rural communities of the region. (China Daily 2005, Schneider et al., 2019). As the region is one of China's grain production bases, especially of wheat, for this initiative ADRA elected to employ straw bales as the insulation material used in the construction of houses. In comparison to conventional construction with bricks and rocks, straw bale housing is a more efficient insulator, thereby reducing fuel consumption in the house (IGES, 2010). The material also improves housing resistance to earthquakes, given its enhanced elasticity compared to traditional building materials, and allows for constructions with much lower costs (IGES, 2010). As of 2009, more than 600 buildings had been built within the project, which, in 2005, won the United Nations World Habitat Award. One of the key achievements of the project was the cooperation with local communities and local government to empower and build capacity, involving them in the housing design, material acquisition and village education (World Habitat, 2017).

4.3.4 Timber construction in Malaysia

Indigenous construction in Malaysia has often made use of timber as a material due to its local abundance. In recent times, Malaysia's National Green Technology Policy established standards for construction under the Timber Certification Scheme enacted by the Malaysian Timber Certification Council which is responsible for the overall development of the timber industry in the country. In Malaysia, timber is mainly used for non-structural elements such as formworks, panelling and partitions (MTCC, 2020).

4.3.5 Forest Research Institute of Malaysia, Selangor

The use of three-dimensional structural systems in building construction is derived from progress made in jointing techniques. With a three-dimensional structure, loads are spread in all directions and forces are balanced out. As a result, less material with less weight is required for a three-dimensional structural system. The development of this structural system can be seen at the Forest Research Institute of Malaysia where, in 1989, an experimental shed for a motorbike parking space was built using a timber space frame. Space frame structures provide a more economical solution where reused off-cut timber is used to construct roof members. This form of construction represents another feasible alternative for long-span structures that illustrates versatility, strength and potential for industrialised prefabrication (Wong, 1995).

Engineered wood products like glue-laminated posts and beams and cross-laminated timber panels are being experimented with in the architectural design space. In 2011, the Malaysian Timber Industry Board built Galeri Gulam in Johor Bharu, the first completed building in the country that uses glulam beams for its main structure (Shari, 2019).

4.4 Circular principles in building product and space design

Modularity as the core principle of design of both space and building elements lends itself very well to circularity – it involves assembly, disassembly and reuse after the useful life of the building is over.

At one end is building element modularity promoted through industrial building systems (IBS) or prefabricated building elements assembled onsite (such as assembly-based interlocking blocks for masonry, or Hydraform), standard lintel and opening elements, stone slabs for roofs, steel frame under-structure, precast concrete elements for roofs and panels for walls such as brick panels, RCC planks and joists, and ferro-cement panels. These systems, although not always properly used, are seen in a number of Asian countries including Malaysia, India and Nepal. They were first promoted with the aim of reducing waste during the construction process and enhancing quality and resource efficiency. They are mainly used in integrated structures where core elements are prefabricated and assembled and the roof slabs, stairways and service cores are cast onsite (Schneider et al., 2019). At the other end is complete unit modularisation, as we see in the case of the Clement Canopy in Singapore, discussed below. Disassembly of both individual building elements as well as complete unit design would be a basic requirement for future circularity at the end of a building's life.

Modularity in space design, such that the building may be repurposed to increase its useful life, is used for the purpose of heritage conservation in Asia. There are many examples of repurposing or adaptive reuse of old buildings such as the conversion of industrial sheds and factories into offices or exhibition spaces. The most popular examples are seen in the hospitality sector where heritage buildings and historic housing developments are converted into shopping spaces, heritage hotels and museums. This has the advantage of maintaining the character of a city and retaining cultural continuity while saving on materials and costs. Examples can be found in Singapore (Development Asia, 2017; Urban Hub, 2018), China (JLL, 2018; M Moser Associates, 2019), India (Thakkar, 2018), Thailand and Malaysia (ASEAN

Tourism, 2015). However, these are mainly niche architectural and urban regeneration projects, and there are no such examples in mass housing. This is primarily because it is more financially viable for developers to pull down old structures and rebuild afresh when undertaking the higher-density construction required for housing developments. This process does generate some construction debris that can be reused, but the reuse of whole buildings in this context is not preferred.

4.4.1 Examples of circularity in building product and design

4.4.1.1 Lego-style prefab construction: The Clement Canopy, Singapore

Standing at 140 metres tall, the 40-storey residential twin towers of the Clement Canopy private condominium at Clementi Avenue 1 in Singapore are considered the world's tallest concrete modular towers, built using the prefabricated prefinished volumetric construction (PPVC) method. In modular construction, the carcass of the building and the modules are completed in an offsite factory before they are transported to the site and assembled. With the PPVC method, construction time is 24 to 30 months, a 20–30% reduction on the time required for business-as-usual construction. Lifting operations to hoist the modules into place are also less noisy and dusty than traditional construction methods. Another benefit of modular construction as seen in the Clement Canopy is the consistent high quality, as up to 85% of the interior finishing is pre-done before assembly. The fittings in each module are completed in a controlled environment at an offsite production facility. This includes plumbing, tiling and waterproofing works, wall finishes and painting, installation of electrical outlets, and the installation of air-conditioning units, as well as doors and window frames. The Cement Canopy under construction is seen in Other finishing work completed offsite includes the installation of wooden flooring, kitchen cabinets and bathroom units (Shari 2019).

4.4.1.2 Space reuse: Stone Art Gallery, Guangzhou, China

The Stone Art Gallery (See Figure 19) is an architectural experiment involving an industrial site that has been transformed into a postmodern relic, located in the highly urbanised Pearl River Delta Area in Guangdong Province, China (DIVISARE, 2017). This renovation project was aimed at establishing a new art gallery to showcase stone art and culture, within the 1960s building. In order to preserve the historic memory of the era of centralised state-based economic planning, the building and site context of the YJQ building was fully respected and maintained in the design scheme. A cross-shaped public area is the backbone linking the interior and outdoor spaces. It works as the T-stage of the gallery and allows for various forms of exhibit and activity, including art performance or forums. The remaining interior space is designed to house specific showcases, and a cafeteria and sitting area. Again, a cross-shaped office deck has been implanted into the prefab concrete structural framework and hung above the public space, highlighting its core area. The bottom of the new steel-structure deck is furnished with translucent polycarbonate panels, and includes an LED lighting installation. This implanted lighting vessel floats in the air of the historic brutal prefab concrete structure. The architectural dialogue has been created between the new and the old, between the weight and the weightless, between the past and the future, all together form the performing background of the stone art, the art that represents a billion years of geological memory.



Figure 19: Stone Art Gallery, Guangzhou

Source DIVISARE, 2017

4.4.1.3 Adaptive reuse of Kolkata Town Hall, India

The British-built Kolkata Town Hall in 1813 in Kolkata, India, is located in a central business district. The town hall was designed on the Palladian-Doric Roman style, reflecting the physicality and functionality of the city at that time. The process of restoration included repair work of different building elements such as roofs, floors and doors. The building currently comprises the first high-tech storytelling museum Kolkata Panorama, a public gathering space, an administrative area, an academic seminar area and a sociocultural event area. Figure 20 shows the Kolkata Town Hall before and after restoration (Wikimedia Commons, n.d.).



Figure 20: Kolkata Town Hall, before and after restoration

Source: Wikimedia Commons, n.d.

4.4.1.4 Industrialised building systems: Malaysia

IBS are construction methods characterised by the mass production of structural components in a factory or at site. The use of IBS in construction allows for a higher-quality control of the structural components, less labour onsite, reduced construction time and cost savings. Additionally, IBS represents a more sustainable construction method compared to conventional systems, generating less waste due to the controlled production and enabling faster and less energy and water consuming construction works.

Since the early 1960s, the Malaysian Government has undertaken efforts to establish and successfully implement this practice throughout the country. Jalan Pekelling Flat in Figure 21 is the first IBS undertaking initiated by the Government at Jalan Pekeliling, Kuala Lumpur. In the 1990s, IBS became more popular with the construction of many infrastructure and mega projects, such as the Kuala Lumpur Convention Centre and the Kuala Lumpur International Airport. In 1999, the Construction Industry Development Board (CIDB) formed the IBS Steering Committee to promote a greater use of IBS in the Malaysian construction industry, leading to the development of different strategic plans and roadmaps for IBS in the country. However, many efforts did not result in significant progress. Therefore, Malaysia's Construction Industry Transformation Programme 2016–2020 emphasises the importance of accelerating the adoption of IBS in the country's construction industry.



Figure 21: Jalan Pekeliling Flat, Kuala Lumpur

Source: Othuman Mydin et al., 2014

4.5 Materials and building elements: extraction, manufacturing and construction

Many Asian countries are blessed with large mineral deposits and natural ores that are extracted for use in the building and other industries such as automobile and white goods manufacture. Industrial efficiencies that reduce material wastage and use the by-products of mining and material production are becoming increasingly prevalent in the Asian region. For example, China and India boast one of the most efficient industry standards as far as production of steel and cement is concerned. Extraction and manufacturing processes produce many by-products that are increasingly being seen as secondary resources that can substitute primary resources in the building industry. The case study of fly-ash from the power sector being utilised as a limestone replacement in cements and a soil replacement in bricks is now an established practice, accompanied by industry standards and regulatory guidelines that govern the quality of the products being manufactured from these secondary materials. Similarly, slag from iron and steel and red mud waste from aluminium production have been used to replace aggregates and soils in concrete and bricks. The most recent breakthrough in mining waste

utilisation comes from the use of china clay mine over-draft as a substitute for virgin limestone in cement production, resulting in reduced requirement of raw material and emissions. This industrial symbiosis is not unique to the Asian region, but has tremendous potential in Asia, especially in the new industrialising countries in South and South-East Asia and in China. It provides a source of materials that was hitherto ignored or considered to be a waste or an environmental hazard. This enables savings in virgin materials, partially decoupling resource use and environmental impact from development. Table 6 provides some examples of industrial symbiosis.

Table 6: Potential industrial symbiosis applications and analysis studies

Source: Neves et al., 2019
 Graphics: Ninni Westerholm

Country	Location	Sector	Waste/Secondary materials
China	Handan	Agriculture, manufacturing and energy	Ash, water and wastewater, plastics and rubber, waste heat and steam, metallic and others
	Shanghai City and Jiangsu Province	Manufacturing and urban areas	Plastics and rubber, organic and others
	Jinqiao	Manufacturing, energy and water and waste	Sludge and waste oil
	Yunfu	Manufacturing and energy	Chemicals and waste heat and steam
	Guiyang	Manufacturing, energy, and commercial and residential construction sectors	Metallic, plastics and rubber, ash, waste heat and steam, and others
	Liuzhou	Manufacturing, energy and construction	Chemicals, waste heat and steam plastics and rubber, and ash
	Wuhan	Agriculture, manufacturing, and water and waste	Water and wastewater, sludge, and paper
South Korea	Ulsan	Manufacturing and urban area	Wood, plastics and rubber, waste heat and steam
Japan	Shinchi Town	Manufacturing and energy	Waste heat and steam
	Tanegashima	Agriculture, manufacturing and energy	Waste heat and steam, organic and wood
Malaysia	Kedah	Manufacturing, energy, and water and waste	Chemicals, plastics and rubber, organic waste, water and wastewater, and sludge
Turkey	Gaziantep	Manufacturing, energy, water and wastes	Organic, plastics and rubber, sludge, chemicals, non-metallic, waste heat and steam, and others
	Ankara	Manufacturing	Waste heat and steam
India	Bihar, Odisha	Manufacturing	Fly-ash, slag, red mud, China clay mine wastes

4.5.1 Examples of circularity in material manufacturing

4.5.1.1 Metal product supply chain in South Asia's building sector

Small and medium-sized enterprises (SMEs) make a significant contribution to the environmental and resource friendliness of production processes in Asia. Against this background, a team of local and international project partners has begun advising 400 enterprises from the metalworking and building sectors in Bangladesh, Nepal and Sri Lanka through the METABUILD project (2016–20) on the adoption of sustainable production processes in the metal products supply chain for the building and construction sector (Balakrishnan et al., 2016). The project's target industries cover steel rerolling mills, ferrous and non-ferrous foundries, and blacksmith and light engineering products that are linked to the construction sector, such as bathroom fittings, electrical cables, roofing materials, gates, doors, grills and frames. The project is funded by the EU SWITCH-Asia Programme.

4.5.1.2 Coal gasification plant and the use of by-products: Angul, India

Jindal Steel and Power Ltd's Angul site has adopted the use of coal for steel making. The lack of natural gas at the Angul site was overcome by an innovation: a coal to gas plant was set up at Angul. It uses high ash coal that is available in the vicinity of the site and converts it into synthetic gas, or syngas. It is the first plant of its kind in India and the second in the world. At Angul the syngas contains methane, carbon monoxide, carbon dioxide, hydrogen and water vapour from coal, water and air produced by the gasification process. This process has a lesser impact on the environment compared to the coal combustion process – the CO₂ emitted in the process is entirely absorbed back into the process and all of the hydrogen sulphide emitted is converted into sulphur production. The setting up of the syngas plant required a very large initial investment and had a long gestation period of three years. But it will improve energy efficiency and reduce the environmental impact in the long term. In addition, all the seven by-products of the Syngas plant are being recycled through internal use or by sale to external parties. This also protects the health and safety of employees and local communities, and supports environmental protection (Jindal Steel Power, 2020).

4.5.1.3 Fly-ash brick industry in India

The Indian brick industry is dominated by resource depleting and highly polluting technologies. In Bihar in East India, the production of fired clay bricks consumes around 4.8 million tonnes of coal per year, emitting 16 million tonnes of CO₂ (Schneider, et al., 2019). About 6000 acres of land are destroyed every year in the city due to red brick kilns, compromising the agricultural land in the region and depleting groundwater sources. In response to the issue, the Bihar State Pollution Control has mandated the adoption of fly-ash brick by all traditional brick kilns. In many markets, fly-ash can be a cost-effective substitute for Portland cement with the advantage of being more environmentally friendly, given that it is a by-product and has low embodied energy. Moreover, the production of fly-ash requires less water than the production of Portland cement and includes other benefits such as better resistance to cold weather, greater workability, reduction of cracking, permeability problems, and CO₂ emission reduction. In addition, the technology does not consume any top soil in the brick production process and presents an opportunity for Bihar to shift to a technology that promotes circularity through the employment of by-products in production and thereby reduces the use of natural resources.

In order to promote the utilisation of fly-ash, the Ministry of Environment, Forest and Climate Change (MoEFCC) of the Government of India has issued a notification under the Environment (Protection) Act 1986, dated 14 September 1999, stating that the manufacturing of clay brick, tiles or blocks for construction within a radius of 300 kilometres from coal- or lignite-based thermal power plants should contain a mix of at least 25% of ash (that is, fly-ash, bottom ash or

pond ash) . Besides, every construction agency located within the same radius should use only fly-ash-based products for construction, such as cement or concrete, fly-ash bricks or tiles, or clay fly-ash bricks. Moreover, in the 2019 budget, the Indian Government reduced GST from 18% to 5% on products like fly-ash or fly-ash aggregate with 90% or more fly-ash content.

4.6 Building use phase

Circular models in the building use phase can be classified into two types: (1) circular models for building services (water, energy and sewage); and (2) circular models of space use.

Circularity in building services includes water systems, energy systems and sewage. Integrated during the design phase, double/triple plumbing systems that enable water recycling and reuse, heat exchange for space conditioning and water heating, and human excreta to compost and horticulture are now mainstreamed in architectural projects across the world, and Asia is no exception. However, these are primarily seen in institutional and commercial buildings. The integration of circular building services is not common in housing, especially mass housing.

While circularity in water and sewage services can be retrofitted in older buildings, both the expense and the facilitation of different stakeholders involved often make it unviable. However, many countries have introduced water and energy circularity as mandatory in new constructions of all building types, whether institutional, commercial or residential. It also helps that circularity in building services is recognised and awarded points in the building rating systems that are popular in different Asian countries; for example, green buildings rated by Green Rating for Integrated Habitat Assessment (GRIHA) are awarded extra Floor Aspect Ratio (FAR) and financial assistance (Indian Green Building Council, 2020). Thus, there are now a growing number of examples of circular building services in greenfield developments and new urbanising areas.

While rural and vernacular houses in many Asian countries traditionally incorporated mechanisms for heat exchange and waste to compost into their design features, these are disappearing as lifestyle changes and building styles respond to the forms and structures of industrial modern architecture. For example, in Mughal architecture, inspired by the gardens of paradise in the Holy Quran, vegetation was added to improve the quality of outer spaces and to enhance cooling by evapo-transpiration. Fountains or Nahar-i-Bahisht (water channels) were also installed in internal spaces to modify the internal environment (Ali, 2012).

Another type is seen in the circularity of services at the urban scale. This is not very popular but there are some examples of integrated development that connect extra heat, energy and treated water generated from residential to industrial and agricultural use. This brings an alignment with sustainable urban and regional planning principles.

Circular models in space use during the building use phase include the adaptive reuse of buildings, remodelling from one application to another, or space sharing within or the multipurpose use of buildings. The concept of multipurpose buildings and shared space is well known throughout Asia and can be understood as a feature of community/institutional and business model design for circular models in the building and construction sector. There are innumerable examples of community buildings being used for a variety of functions, such as schools, neighbourhood meeting places, wedding halls and common activity areas. There are also examples of community kitchens and community washing areas, where the same space is used by many, thus eliminating the need to build additional structures. The early wave of urbanisation in cities like Mumbai, Bangkok and Shanghai has involved co-living models for migrant workers employed in factories and industries. However, serviced and technology-supported space sharing as a business model is a fairly new concept. Co-working and co-living models are now fairly common across Asian cities, particularly given the high demand for affordable living and working spaces for the neo-urbanite young working population. In the

residential sector, co-living concepts have been developed more recently in high rent cities to address the need for affordable housing for young people. Community-driven shared spaces in which people cook together, eat together and launder together are key features of co-living spaces, again designed to increase density and facilitate social interaction.

4.6.1 Natural heating using the 'kang' arrangement: ancient northern China

A kang system consists of a stove, a kang (bed), channels and a chimney. It utilises the residual heat of smoke produced by a cooking stove, which burns biomaterials; uses the bed frame to release heat into the bedroom; and releases the smoke via a chimney. A kang system supports four different home functions of cooking, sleeping, domestic heating and ventilation. The ventilation is integrated into one system, which harnesses the energy from the biomass burnt for both cooking and space heating and thus reduces the use of commercial energy. This method developed out of the accumulated traditional knowledge and experience of crafts people, handed down from one generation to another; and, according to the Ministry of Agriculture, over 67 million kangs are still being used by 175 million people in China today (Sun, 2013). Figure 22 shows the plan and section layout of the 'kang' arrangement.

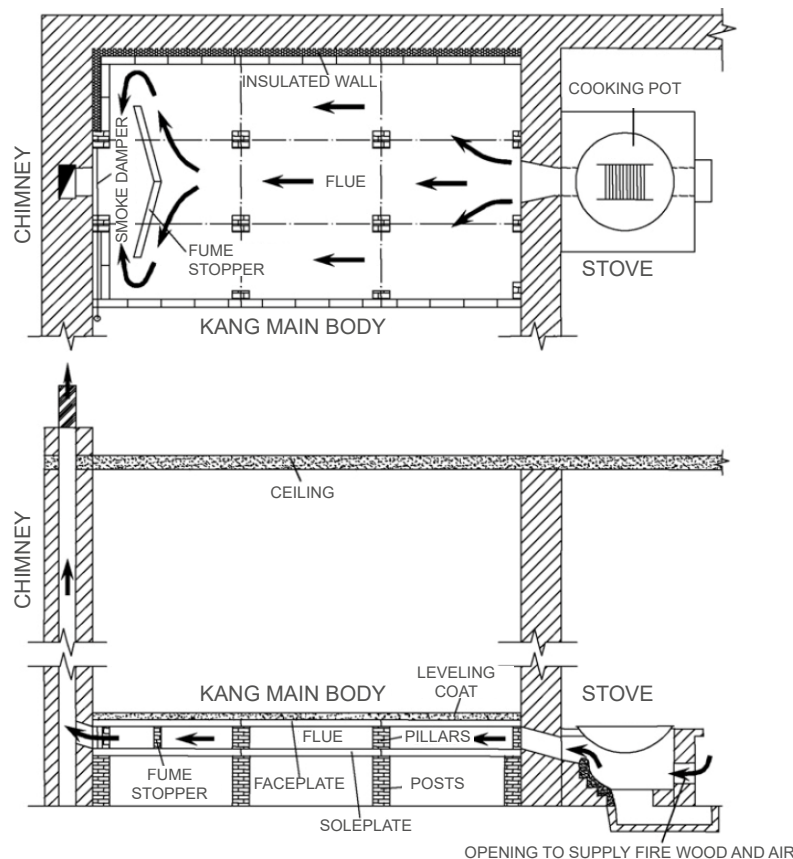


Figure 22: Plan and section of kang arrangement

Source: Zhuang & Li, 2009
Graphics modified by: Ninni Westerholm

4.6.2 Cradle-to-cradle design: Development Alternatives headquarters, New Delhi

The design, materials and techniques used in the construction of the Development Alternatives world headquarters in New Delhi (See Figure 23) demonstrate a viable alternative for the construction of comfortable, green and affordable buildings of many types. This project tests innovative, specially designed elements and components such as a hybrid air-handling unit that incorporates available components in a new way to achieve significant energy savings. Nearly all of the interior and exterior walls are built of cement-stabilised compressed-earth block and cement-stabilised fly-ash lime-gypsum block, the manufacture of which recycles plentiful local materials in processes that use local labour and low energy. Efficiently built in reinforced concrete and masonry, the Development Alternatives world headquarters uses less than half the quantity of reinforced steel used in comparable structures of conventional design. The method used holds significant potential for reducing resource consumption and GHG emissions. The building uses predominantly natural, recycled, renewable and reusable materials embodying low process energy. Some highly energy-intensive materials like aluminium are not used at all; others, such as glass and steel, are used frugally. Eighty % (by volume) of the building materials were sourced within 500 kilometres of the site, thus minimising the CO₂ emissions produced by transport. All rainwater that falls on the site is used to recharge the groundwater, while all wastewater is recycled, treated onsite and used for irrigation and flushing toilets (A. B. Lall Architects, 2015).



Figure 23: DA world headquarters

Source: Development Alternatives, 2014

4.6.3 Co-living in India

From **dharamshalas** (free or donation-based accommodation for pilgrims and other visitors) to paying guests, shared rental housing has always existed in India in various forms. More recently, co-living has emerged as a new business model that brings a fresh lease of life to India's shared rental market. The biggest driving force behind the rising popularity of co-living spaces is the influx of young renters to new cities seeking employment, who are scouting for housing options that are both convenient and affordable. Co-living is still in its nascent stages in India. In the past decade, there has been a surge in the number of unregulated operators in the shared rental accommodation sector, looking to tap into the strong demand from the migrant workforce and students across major metropolitan cities in India. Sensing the huge potential in the domestic market and taking cues from established global players, start-ups in this space are seeking to transform this line of business into a professional service-based offering. Further, the absence of a regulatory framework has led to the emergence of various business models in the market. There is a lack of clarity with respect to design specifications, and approvals and licences for properties operating as co-living spaces. Many players like Zolostays and Oyo Life operate according to the Management Contract Model. In this model, operators sign long-term management agreements with developers, investors or property owners to run their premises as a co-living facility. In this case, the owner is responsible for managing the returns from the property, while the co-living player receives a commission for operating the facility. The operator simply acts as a custodian of the property and the end users/tenants enter into a lease agreement directly with the owner (JLL & FICCI, 2019).

4.7 End of life and recycling: overview of construction and deconstruction waste in Asia

The rapid pace of urbanisation and the new housing and infrastructure requirements being introduced across the Asian region have resulted in the growth of many greenfield developments. At the same time, as discussed above, the increasing densification of cities has resulted from changes in land use and floor space index (FSI) rules, which have led to the construction of new higher rise buildings replacing low-rise, low-density developments. This phenomenon is seen across Asia. The cradle-to-cradle concept underpinning the new greenfield developments requires design for modularity in building elements. At the same time, the use of construction debris in new buildings is a great opportunity as brownfield is converted into greenfield construction. There has been an increased interest in the use of C&D waste in new building construction driven by two objectives: (1) an objective of the municipalities to better manage waste, and (2) a resource efficiency objective adopted by industry aimed at saving materials and costs. However, it must be noted that the quantity of C&D waste being generated is very small compared to the quantity of materials required for new buildings. In addition, the materiality of older buildings determines the quantity and quality of recycled new product and its application. For instance, India generated around 630 million tonnes of C&D waste in 2015, whereas the demand for sand and crushed stone aggregates was projected to be in the order of approximately 1000 million tonnes and 1300 million tonnes, respectively, in the same year (DA & GIZ, 2015).

In the Asian region, China is the top contributor to construction and demolition (C&D) waste, with a per-capita generation of 0.36 kg per day (Beijia et al., 2018). Among the countries selected for this study, Pakistan and Indonesia have a higher C&D waste generation rate than India, which is estimated to be the second most construction-intensive country in Asia. The C&D waste volume per capita per day is calculated on the basis of available data on municipal solid waste (MSW) (in terms of %) generated in 2012 in the countries selected for this study. Figure 24 and Table 7 show the C&D waste generated in selected Asian countries. Table 8 shows the C&D waste composition and volume per capita in selected Asian countries.

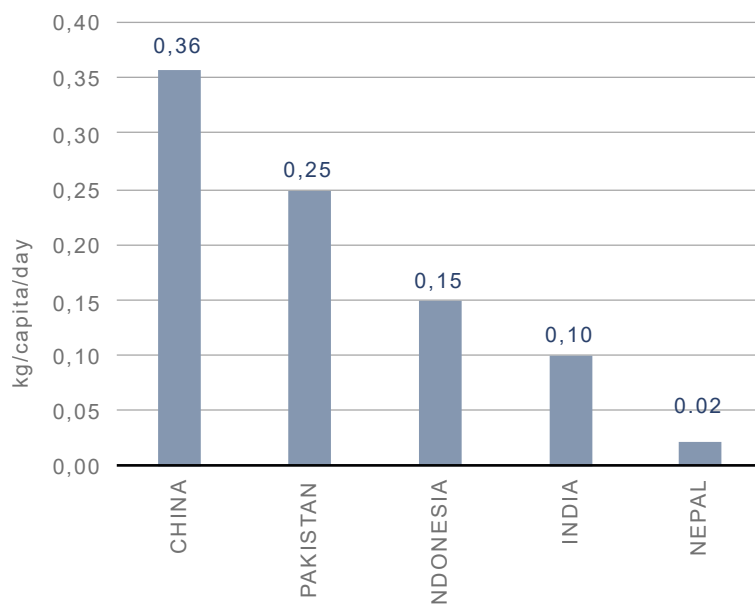


Figure 24: C&D waste generated in selected Asian countries

Source: Authors

Note: Data from Table 7 has been used to create Fig 25

Graphics: Ninni Westerholm

Table 7: C&D waste and MSW in selected Asian countries

Source: Authors

Countries	MSW generation (kg/capita/day) (World Bank, 2012)	Total MSW generation (tonnes/day) (World Bank, 2012)	C&D waste (as a % of MSW)	C&D waste generation (kg/capita/day)	C&D waste generation (tonnes/day)
China	1.02	502548	35% (Beijia et al., 2018)	0.36	179409.64
Pakistan	0.84	50438	30% (Khalid & Baig, 2016)	0.25	12710.38
Indonesia	0.52	61644	28% (Sembiring, 2018)	0.15	8975.37
India	0.34	109589	30% (Shrivastava & Chini, 2010)	0.10	11178.08
Nepal	0.12	427	17% (Dangi et al., 2011)	0.02	8.86

Graphics: Ninni Westerholm

Table 8: C&D waste composition and C&D volume per capita in selected countries

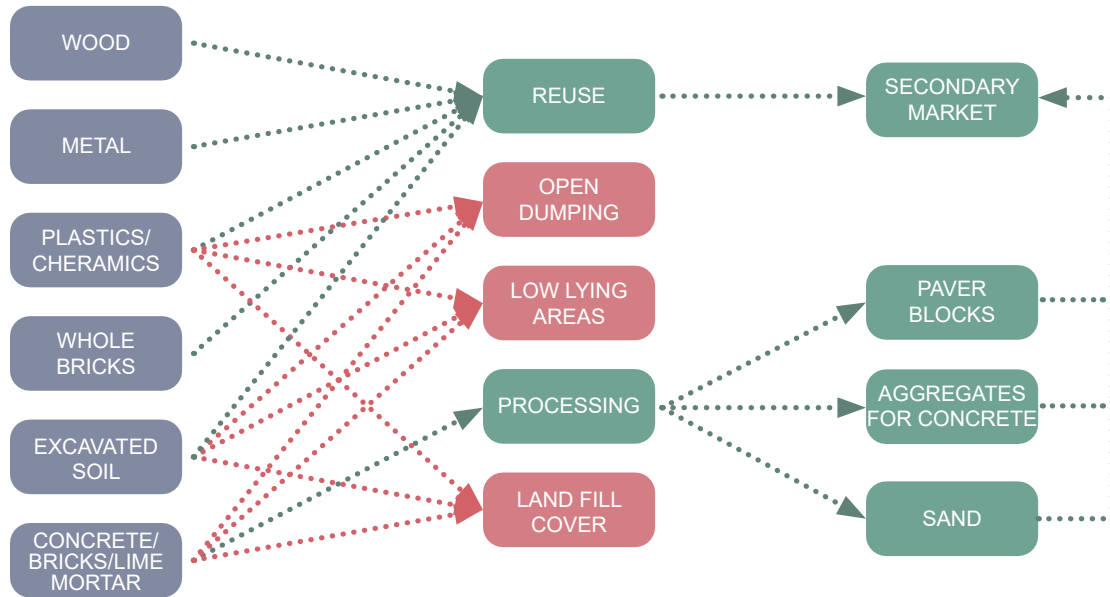
Countries	C&D waste composition	C&D volume per capita
India (TIFAC, 2001)	<ul style="list-style-type: none"> • Soil, sand and gravel: 36% • Bricks and masonry: 31% • Concrete: 23% • Metals: 5% • Wood: 2% • Others: 3% 	C&D Processing: 5% Recovery: 10–30% (Niti Aayog, 2019) Landfill: 65%
China	(Zhao & Rotter, 2008) <ul style="list-style-type: none"> • Brick & tile (48%) • Concrete (45%) • Wood (1%) • Glass (0.64%) • Plastic (0.34%) • Metal, porcelain, soil 	Recycling rate: 3–4% (Lu, 2014) Landfill: 50% (Zhao & Rotter, 2008) In coastal cities, 70–80% of the construction dregs are used for sea reclamation (Lu, 2014) Burnt/fuel for factory: 10%
Indonesia	(Faridah, Hasmanie & Hasnain, 2004) <ul style="list-style-type: none"> • Concrete (12.32%) • Metal (9.62%) • Brick (6.54%) • Plastic (0.43%) • Wood (69.10%) • Others (2%) 	Recovery: 50–60% (Sampa, 2019)
Nepal	Dirt, concrete, wood, steel, pipes, bricks, and other construction materials	C&D processing: ~ 50% (Ehler & Shresta, 2015)

Source: Authors

Graphics: Ninni Westerholm

4.7.1 Materials produced by C&D waste recycling in New Delhi

It is estimated that New Delhi generates around 5000 tonnes of C&D waste every day (BMTPC, 2016). However, as a recent initiative in New Delhi illustrates, the recycling of C&D waste can contribute to closing the material loop in India's urban construction sector. Since 2009, the local authorities of New Delhi have begun collecting C&D waste separately and recycling it. The two C&D waste processing plants in New Delhi, with a combined total processing capacity of 2500 TPD of C&D waste (BMTPC, 2016), recycle about 95% of incoming waste. An additional C&D waste recycling plant has been established by the National Building Construction Corporation to recycle C&D waste generated by the government's large-scale urban redevelopment projects (BMTPC, 2016). This waste is being converted into useful products, such as aggregates of various sizes, bricks, pavement blocks and kerbstones. The recycled products from C&D waste are found to be of acceptable quality and are up to 20–30% cheaper than conventional building materials (DA & GIZ, 2015). Several stakeholders are trying to overcome the regulatory and market challenges and close the material loop in the urban construction sector by promoting the use of recycled C&D waste for both low-and high-value applications (DA & GIZ 2015). The



material flows from C&D Waste in India is illustrated in Figure 25.

Figure 25: Material flows from C&D waste in India

Source: DA & GIZ, 2015
Graphics: Ninni Westerholm

4.7.2 Construction waste to 3D printed houses, China

A company in China is using C&D waste and industrial waste as material to create 3D printed houses with a low-carbon footprint. This initiative is aimed at reducing the impact current buildings and future construction activities will have on the environment and air pollution levels in China. The company, WinSun Decoration Design Engineering, has showcased the construction of 10 houses in one day using construction waste, as well as a five-storey apartment building in Shanghai (Kira, 2015) (See Figure 26). According to the CEO of WinSun, the waste from construction and mining produces a lot of carbon emissions, but using 3D printing the company has been able to turn such waste into brand new building materials. This process also means that construction workers are at less risk of coming into contact with hazardous materials or



work environments (WinSun, 2018).

Figure 26: 3D printed houses using construction waste

Source WinSun, 2018

4.7.3 Traditional wooden housing in Indonesia using waste-wood composites

Communal longhouses on stilts with steep sloping roofs and heavy gables were the major type of the earliest Austronesian structures, evident in the traditional Batak house and TorajanTongkonan in Indonesia. Typically, a post, beam and lintel structural system is used, which transfers the load straight to the ground, and includes either wooden or bamboo walls that do not bear any load. In Indonesia, because wood is no longer affordable for local people, concrete has become the major construction material used in these traditional houses and therefore buildingthese types of houses has also become increasingly difficult.

Currently in Indonesia, most waste wood is used to produce chipboard or are burned in power stations. To achieve this, the waste wood is industrially processed and then shipped long distances, often overseas, which leavesa major carbon footprint. However, a large portion of waste wood is reusable. As an alternative to shipping the processed waste wood, four small pieces of waste wood connected with steel nails or self-tapping screws can beassembled into a rectangular waste-wood composite, serving as secondary beam, column or brace. These waste-wood composites are considered recyclable and low-cost, and provide local people with an alternative solution supporting an affordable and sustainable construction system.

4.7.4 Nepal: Citizen-led reuse and reconstruction from earthquake debris

As a result ofthe 2015 earthquake in Nepal, the Kathmandu valley generated approximately 3.94 million tonnes of debris, 'An equivalent of nearly 11 years of waste' in one day. Earthquake debris in Nepal are shown in Figure 27. In the absence of a government plan and drivenby economic necessity, the people of Kathmandu, and indeed across the whole country, took it upon themselves to sort the debris and begin the reusing, recycling and rebuilding process. Across Kathmandu city, bricks and wood havebeenseparated and piled up for reuse. Building contractors, too, have been buying up reusable bricks and wood. Since the earthquake, the demand for bricks has risen and so has the price. The Nepalese Government plans to pull down all the severely damaged buildings, sort theconcrete and bricks that cannot be reused, crush these materials and create recycled bricks or filling material for roads and other structures. Debris that is contaminated by lead-infused paint or contains asbestos, pesticides and acids is to be appropriately processed before being reused or cast away (Gyawali, 2015).

In Indonesia, the remanufacturing industry,led mainly by SMEs, remains environmentally unfriendly. Only a few large companies, like SanggarSarana Jaya PT Komatsu Remanufacturing



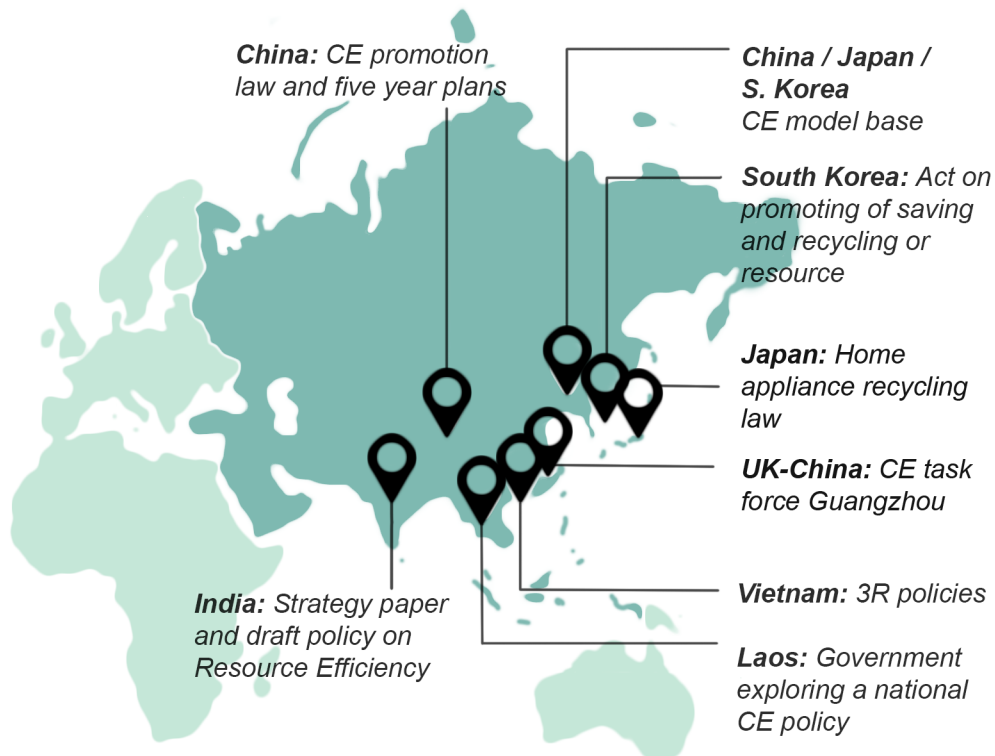
Asia, have recognised the value of remanufacturing strategies in Indonesia,specificallythe economic, social and environmental benefits.

Figure 27: Natural Disaster in Nepal

Source: Wiki Loves Earth 2016

5. Policies related to circular models in the construction sector in Asia

Over the past decade, most Asian countries have been developing policies in tune with



initiatives towards a circular economy and resource efficiency. Interventions at each stage of the construction lifecycle designed to reduce waste and enhance resource efficiency have been developed in the form of policies, guidelines and/or standards across Asia. Circular Economy policies adopted by different Asian countries are illustrated in Figure 28.

Figure 28: CE policies in Asia

Source: WEF, 2018

Graphics modified by Ninni Westerholm

5.1 Material production phase policies

In general, four materials – cement, steel, concrete and brick – are the key contributors to the environmental impacts of building materials. Interventions in the production of these materials can immensely decrease emissions within the manufacturing sector. Asian countries, heavily dependent as they are on the energy- and labour-intensive brick kiln industry, natural sand for manufacturing, and cement and concrete for construction, have introduced policies and

guidelines to drive sustainability in the construction sector.

China's 11th Five-Year Plan mandated aggressive energy-efficiency goals for the country's top 1000 most energy-intensive industries. China's cement industry was previously dominated by polluting and energy-intensive vertical shaft kilns. The Chinese Government's campaign reduced the share of these kilns to only 20% of all plants by 2010 and prompted existing plants to become more energy-efficient; but overall emissions from the sector remain high. The 13th Five-Year Plan mandated a 25% cut in the number of cement enterprises by 2020. In early June 2018, the ministry deployed 18,000 inspectors to impose new regulations on the cement industry (Schneider et al., 2019).

In India, the 1957 Mines and Minerals (Development and Regulation) Act (The Mines and Minerals, 2015) was originally enacted to regulate the mining sector in India, and was amended in 2015 and 2016. It classifies sand as a minor mineral if used for construction purposes and its management comes under the purview of state governments. Sand used to make concrete must adhere to the specifications for fine aggregates set out in Indian Standard 383:1970, while sand used for masonry mortar must adhere to Indian Standard 2116:1980. Both standards specify the use of 'natural sand deposited by streams' (river sand). The MoEFCC (2016a) also released the Sustainable Sand Mining Management Guidelines 2016, which encourage the use of recyclable materials such as quarry dust, incinerator ash and manufacturer sand (M-sand) as sand substitutes. India's National Mineral Policy (Government of India, 2019) proposes to grant the status of industry to mining activity to boost the financing of mining for the private sector and to support the acquisition of mineral assets in other countries by the private sector.

In Nepal, a national level policy has been introduced for the brick sector to achieve a substantial reduction in black carbon and other brick kilns, by employing a range of technologies and policy and market strategies (MinErgy, FNBI, 2017).

Pakistan's National Mineral Policy (2013) was established to mitigate the adverse environmental effects of mineral development through the implementation of regulatory frameworks; the implementation of post-mining rehabilitation; the promotion of the recovery, recycling and reuse of minerals, metals and mineral-based products; and the implementation of effective mine waste management measures.

5.2 Design/construction phase policies

The design of a building has major impacts on the building lifecycle stages, determining which materials will be employed, and the construction and operation of the building. While Building Information Modelling (BIM) technology is actively promoted in China, every Asian country selected for this study has enacted national building codes or standards regulating the building construction design requirements in the areas of water and sanitation, mechanical systems, lighting and structural systems, among others.

Energy building codes set the minimum efficiency requirements for new and renovated buildings in order to guarantee a reduction in energy consumption and GHG emissions throughout the building's lifecycle. By ensuring that information on energy consumption is taken into account during a building's design stage, energy codes represent a significant opportunity for savings during the building's operation.

Building Information Modelling (BIM) is widely applied in the construction industry in China. BIM refers to the 3D modelling of architectural design, structural systems and energy costs, among other aspects of the process. It advances sustainability by reducing wastage and improving efficiency at each step of the process. In China, the Development Guidelines for digitalisation in the construction industry were issued in 2011 to progress BIM implementation through the establishment of standards, and to achieve digitalisation within construction firms. Chinese BIM Standards were officially launched as part of the Engineering and Construction Standards in 2012. China's 12th Five-Year Plan for the Construction Industry, combined with the 12th Five-

Year Plan for Energy Conservation and Emission Reductions, put forward a strategic focus on and development priorities for sustainable construction in China for the five-year period (2010 to 2015) (Chang et al., 2016).

China, India, Indonesia, Nepal and Pakistan have existing energy building codes and standards

Countries	Energy building codes/standards
China	<ul style="list-style-type: none"> •Design Standard for Energy Efficiency of Residential Buildings (1986) •Design Standard for Energy Efficiency of Public Buildings (1993) •Design Standard for Energy Efficiency of Rural Residential Buildings (2013) (Xueliang et al., 2017)
India	The Energy Conservation Building Code (ECBC) 2018 (Gazette of India 2018)
Indonesia	<ul style="list-style-type: none"> •Energy conservation for building envelope – SNI 03-6389-2011 •Energy conservation for air conditioning system in building – SNI 03-6390-2011 •Energy conservation for lighting system in building – SNI 03-6197-2011 •Energy audit procedure for building – SNI 03-6196-2011 (GBPN, 2020)
Nepal	Design guidelines for energy-efficient building construction are provided in the National Building Code(NBC) 206:2015 (MOUD, 2015)
Pakistan	Building code of Pakistan Energy Provisions - 2011 (IEA, 2011)

designed to enhance energy efficiency of Heating Ventilation and Cooling systems in the building usage phase. Table 9 below summarises the existing energy building codes in these countries.

Table 9: Energy building codes in selected countries

Source: Authors

Graphics: Ninni Westerholm

Apart from building codes, certifications and ratings of green building materials guide the architects and developers in abiding by national building codes. In a few countries, green buildings are provided with incentives, which help to drive the market in sustainable green building materials. Leadership in Energy and Environmental Design, a rating tool of green buildings established by the US Green Building Council, is also used for rating new building construction in China, India, Nepal and Pakistan.

Chinese building certification systems, such as their source conservation programme (for energy and water conservation), environmental product certification and the green building material assessment label, are managed by the government ministries (Xueliang et al., 2017).

In India, the Bureau of Energy Efficiency (BEE) has developed a measure for rating energy efficiency in buildings based on a scale of 1–5 stars. GRIHA evaluates buildings based on energy efficiency, water consumption and 32 other criteria. The MoEFCC provides fast-tracked clearance for green building projects based on this rating, and local government in many Indian states provides incentives in the form of increased floor area or financial assistance and subsidies (IGBC, 2015).

The Green Building Council in Indonesia evaluates buildings and allocates the GREENSHIP rating; however, the rating is voluntary and take-up is low (ITEBuild & Interiors, 2015).The Pakistan Green Building Council has issued the Green Guideline that has four certification levels for green buildings (Hussain and Hanif, 2018).

5.3 Usage phase policies

The usage phase in the building lifecycle accounts for the majority of a building's energy and water consumption, and generation of waste (UNEP & IEA, 2017). This phase also has implications for soil and water pollution. The design and construction codes ensure the reduction of water and energy consumption up to a certain level. Solid waste management (SWM) and water management policy strategies have also been developed to deal with issues such as a system's low efficiency, the excessive pumping of groundwater and the reckless disposal of waste.

China has developed comprehensive standards and labelling programmes for end-use energy efficiency. The country's 12th Five-Year Plan includes a specific section on water, with a particular focus on addressing the current challenges facing the water sector. It has set targets that include connecting the water supply in urban areas to 95% of the urban population, treating 85% of the total wastewater generated in urban areas and reusing 20% of all treated wastewater (Schneider et al., 2019).

The primary objective of India's National Energy Policy 2017 (NEP, 2017) is to promote energy conservation by business, households, transportation and agriculture. The aim is to improve the energy efficiency of all electrical appliances and apply the Energy Conservation Building Code (ECBC) to all buildings, enhance the availability of better insulation and increase investment in buildings and domestic appliances with higher energy. The Energy Conservation Act 2001 has been enacted to encourage the efficient use and conservation of energy.

India's National Water Policy 2012 (Ministry of Water Resources, 2012) highlights the importance of prioritising access to safe water for households. It states that urban and rural domestic water supply should preferably come from surface water as well as groundwater and rainwater. Should a reliable alternative source of water be available, it should be connected to the domestic water supply. Also, the reuse of urban water effluents from kitchens and bathrooms (after primary treatment) in flush toilets should be encouraged, so long as no human contact is ensured. Agencies managing the urban domestic water systems need to collect and publish water accounts and water audit reports indicating leakages and pilferages, which should be reduced albeit while taking into consideration the social issues underpinning these problems.

The Energy Building Code of Indonesia (GBPN, 2020) guides energy usage in residential and commercial buildings in the urban space. Pakistan's National Energy Efficiency and Conservation Act 2016 instituted a National Energy Efficiency and Conservation Board, which is responsible for the promotion of energy conservation, the development of energy-efficient technologies, and the certification of energy-efficient products and projects (World Bank, 2019).

5.4 C&D waste policies (recycling phase)

Asian countries are recognising the need to tackle the problem of immense C&D waste generation in the coming future. Countries like China and India, which have developed rapidly in recent years, have introduced regulation targeting the minimisation and reuse of C&D waste. However, the laws and regulations governing C&D waste management in most Asian countries are minimal and encompassed within the SWM rules/regulations of each country.

The Chinese policy and institutional system has many regulations governing the management of C&D waste. The 2005 regulation on the administration of urban construction garbage mandates the producers of C&D waste to bear the responsibility for the treatment and disposal of it. Technical specifications for C&D waste disposal and guidance for C&D waste design and management have been issued centrally by the Chinese Government. In 2014, a regulation was passed outlining technologies for building deconstruction, C&D waste classification and treatment of recycled aggregate. At the national level, China's Circular Economy Promotion Law came into force in January 2009, defines the standards and regulations for energy-efficient

design and building construction (Xuelianget al., 2017). In May 2017, the Chinese Government issued The Guiding Action Plan for Circular Economy for 2016–2020, which includes new actions to promote circular development (IRP, 2017).

In India, the C&D Waste Management Rules were introduced in 2016 by the MoEFCC (2016b). These rules apply to every waste generating construction, remodelling, repair and deconstruction of any civil structure owned/managed by an individual, organisation or authority. The government's C&D waste management and utilisation strategy is intended to help facilitate the implementation of the C&D Waste Management Rules to ensure that urban local bodies across the country are able to adopt proper C&D management practices. Further, the rules state that local authorities shall procure and utilise 10–20% of materials made from C&D waste in municipal and government contracts (MoEFCC, 2016b). India's National Resource Efficiency Policy has been drafted to enable circular approaches across the lifecycle of resource use based on the 6R principle (reduce, reuse, recycle, recover, redesign and remanufacture). The policy aims to minimise resource use and environmental impact, by adopting concepts of resource efficiency and circular economy. India has set a target to achieve a 50% recycling rate by 2025 and a 75% recycling rate by 2030. Moreover, by 2025, 30% of all public procurement of materials for construction will be from recycled materials. Municipalities in Tier 1 and Tier 2 have to start inventorising C&D waste by 2022.

In Indonesia, there are two Acts regulating waste management practices: Act 18/2008 (Act, 2008) regarding SWM, and Law 32/2009 concerning environmental protection and management (Environmental Protection and Management, 2009). The SWM Act, based on the 3R principles (reduce, reuse, recycle), stipulates policies around waste minimisation and the handling of all types of solid waste, not only C&D waste.

In Nepal, under the Solid Waste Management Act 2011, local bodies in the country, such as municipalities, have been made responsible for the construction, operation and management of infrastructure designed for the collection, treatment and final disposal of MSW. The Act mandates local bodies to take the necessary steps to promote reduce, reuse and recycle (3Rs), including segregation of MSW at the source. It also provides for the involvement of the private sector, community-based organisations and NGOs in SWM through competitive bidding.

Policies and regulations regarding C&D waste management have not been explicitly enacted in Pakistan; however, the country does have infrastructure for handling other specific types of solid waste. Pakistan's Environment Protection Act 1997 (PEPA, 1997) the Hazardous Substances Rules 2003 (ILO, 2003) and the National Environment Quality Standards Rules (NEQS, 1999) guide the safe and proper disposal of waste. Many organisations do convert waste for reuse; however, these efforts are limited and these organisations act in silos without the support of concrete policy (State Bank of Pakistan, n.d.).

5.4.1 Examples of C&D waste management policies from other countries of Asia

5.4.1.1 Legislation on waste disposal in Japan

Since the 1970s, C&D waste management in Japan has been governed by the Act on Waste Disposal and Cleaning. Nevertheless, this has not been effective in resolving the country's waste problems. A series of policies have subsequently been adopted to reformulate waste management, including C&D waste management, since 1991. This reform has proven to be more effective in addressing C&D waste problems, with the Environmental Basic Act of 1993 and the Basic Act on Recycle-Based Society of 2000 also making significant steps towards the goal of zero waste. These Acts embody some important environmental policy principles, and have shifted the paradigm of waste management away from disposal towards recycling. In

addition, other legal tools have been developed, including the Resources Recycle Act of 1991, which provided the legal basis to facilitate recycling (Crocker et al 2018).

5.4.1.2 Construction waste regulations in the Philippines

The Philippines Government implemented a National Solid Waste Management Strategy between 2012 and 2016. This strategy was intended to establish sustainable waste management through financing mechanisms that could help create economic opportunities for advancing the reuse of waste. The government then created the Republic Demonstration 9003, or 'Natural Strong Waste Administration Unmaking Waste in Construction in the EU and the Asian Circular Economy Demonstration of the Philippines', to decrease the generation of waste at the source, encouraging its reuse. Three years after this demonstration was established, the extent of reuse had increased by no less than one-quarter of wastes generated across the country.

5.4.1.3 Construction Waste Charges Ordinance in Thailand

In Thailand, in 2000, it was estimated that between 16% and 34% of MSW sent to landfill could be reused; however, only 7% (or 2360 tonnes/day) was actually being reused. In 2004, around 78% of 425 waste storage areas were open dumps and the remainder were landfills. Several critical factors have contributed to the development of a more sustainable waste management system in the country: financial support, effective administration, and clear goals and targets. The Thai Government introduced charges for the accumulation, transportation and transfer of industrial and C&D waste in order to lessen the incentive to send this material to landfill. As a result of these waste dumping charges, close-looped materials usage is now being encouraged.

5.5 Incentives

Under the Interim Regulation on Financial Subsidy Funds for Production and Usage of Renewable Energy-saving Building Materials (Xueliang et al., 2017), the Ministry of Finance, China, provides funds to support the production and use of renewable energy conservation building materials, which includes the subsidised loan interest rates for expanding the use of renewable energy conservation building materials, reward for the promotion and application of renewable energy conservation building materials, and research and development to inform relevant technical standards and specifications. Under India's C&D Waste Management Rules 2016 (MoEFCC, 2016b), it is mandated that the local governing authorities shall offer incentives to waste generators for salvaging, processing and/or recycling C&D waste, preferably insitu. In Indonesia, Act 32/2009 (Environmental Protection and Management, 2009) which governs industrial and hazardous waste management, stipulates that the polluter pays and that the waste generator is fully responsible for their waste.

5.5.1 Incentives in C&D waste management from other regions of Asia

5.5.1.1 Extra funding incentive in Singapore

Although each Singaporean generates over 1330 kg of waste every year, a high recycling rate (62%) has successfully increased the Semakau Landfill's lifespan to about 35–40 years. Since it is costly to collect and handle waste for recycling, incineration plants have become necessary for the remaining 38% of waste (Bohong, Li & Yang 2015). The Singapore Government charges approximately USD57 per tonne of waste from construction sites, a charge that motivates construction firms to reduce the volume of waste they send to landfill. The government has

also launched an Innovation for Environmental Sustainability Fund, which is available to construction companies to set up recycling facilities and plants. The plan is for more than 90% of all waste to be recycled (Crocker et al., 2018).

5.5.1.2 The ‘polluter pays’ principle in Hong Kong

In Hong Kong, a charging scheme for construction waste disposal, implemented by the Hong Kong Government, has been in effect since 2005 and has reduced the volume of construction waste generated. The government adopted the polluter pays principle to provide the construction industry with an incentive not to dump waste in landfill. Nevertheless, as Hong Kong’s land space is very limited, land prices are high and storing waste is only feasible on some construction sites – those that are very large. The high storage costs deter many contractors from storing waste onsite. In many circumstances, it may even be cheaper to dump waste to landfill than retain and store it for future use. This is a different problem to that encountered in Thailand, where waste management practice is more conventional.

5.5.1.3 Summary of existing formal institutions that motivate zero waste in the construction industry throughout Asia

Incentives provided by formal institutions:

- Japan – Government subsidises a quarter of construction costs.
- Malaysia – Government has implemented regulations to alleviate the environmental impacts: the Ministry of Works via the Standard Specifications for Buildings Works (2005), the CIDB via its Pembinaan Malaysia Act 1994 (Act 520), the Ministry of Housing and Local Government via its Solid Waste and Public Cleansing Management Act 2007 (Act 672), and the Ministry of Natural Resources and Environment via its Environmental Quality Act 1974 (Act 127)
- Thailand – The BMA Ordinance on Service Charge B.E.2543 sets charges for the collection, transportation and disposal of C&D waste. It is aimed at reducing the amount of waste sent to landfill.
- Hong Kong – The polluter pays principle is adopted to charge construction companies that dump waste.
- Singapore – USD57 per tonne is charged for construction waste disposal.

6. Analysis and recommendations

This report reveals the following important findings in relation to the Asian situation:

1. Rapid urbanisation and rising demand for new infrastructure and housing, which need materials, are in turn placing significant strain on natural resources. Considering the criticality of resources, the need to service the growing demand for materials not only requires greater efficiency, but also the substitution of these critical materials with secondary materials from other sources such as industrial by-products, bio-waste and C&D waste.
2. Industrial and mining waste streams are available in many countries in Asia. These secondary resources are being used to replace virgin minerals such as sands, soils and aggregates.
3. Many countries in Asia have rich traditions of biomass use in construction, especially bamboo. The regeneration of bio-resources provides a replenish-able resource.
4. The increasing densification of cities and urban transformation are resulting in an increase in the volume of construction debris. Many countries are recycling C&D waste into new building materials. Despite the potential to reuse this waste in new construction, a much larger amount of material is needed to replace virgin materials

- and reduce eco-system stress.
5. The greenfield construction of new cities, housing and infrastructure has the potential to ensure the future adoption of circularity through the use of modular assembly-based construction systems.
 6. There is tremendous resource diversity across Asia and also a large construction workforce, which is largely informal and unskilled. Circular models of construction in Asia have the potential to respond to this resource diversity, but there is also a need for new materials and technology, reskilling and new business models that will provide economic opportunities.

6.1 Potential benefits of circularity

a. Economic benefits: The circular economy has been gaining traction with business and government leaders alike. Their imagination is captured by the opportunity to gradually decouple economic growth from virgin resource inputs, while encouraging innovation, increasing economic growth and generating more robust employment. If we transition to a circular economy, the positive impact will be felt across society (Ellen MacArthur Foundation, 2017), and will include the following:

- **Economic growth** – Economic growth, defined by GDP, would be achieved primarily through a combination of increased revenue from emerging circular activities and lower costs of production. The changes in input and output production will affect economy-wide supply, demand and pricing, adding to overall economic growth.
- **Material cost savings** – The material and energy cost saving potential of the circular economy is high since circularity allows for the conversion of potential waste into system inputs, thus reducing manufacturing and production costs.
- **Job creation potential** – A significant number of studies report the potential for the circular economy to generate employment (European Environment Bureau, 2014, Friends of the Earth, 2010, Government of Scotland, 2019). New jobs will be created in the development of innovative design and business models, research, recycling, remanufacturing and product development. The high degree of informality in the construction sector in Asia can be directed towards the development of new skills for repairs and refurbishment, new production manufacture, recycling materials and skills for new assembly-based construction systems.
- **Business models** – The circular economy in the context of building and construction offers a range of new business opportunities, from small-scale onsite production or conversion of C&D wastes to micro, small and medium enterprises (MSMEs) or industrial-scale product manufacturing units. Waste exchange platforms, complete refurbishment services, and space share and co-living models based on internet technology are all emerging.
- **Innovation** – The high rate of technological development, arising from the demand for energy-efficient technology, and more durable materials have enormous potential in the area of innovation in terms of shifting from a linear to a circular metabolism.

b. Environmental benefits: The concept of circularity focuses on zero waste production from the lifecycle of the building and the built environment. It also calls for durability, thus addressing the need to keep materials in the production and use lifecycle for as long as possible and then directing these either to a reuse/refurbish or recycle process (if non-biotic) or, if biodegradable, back to the source for regeneration. Clearly, this has a net positive impact on the environment. Further, circularity significantly reduces the volume of waste that is disposed of in landfill. It is estimated that reducing the volume of organic waste sent to landfill will lower landfill gas (LFG) production (LFG is composed of roughly 50% methane(the





primary component of natural gas), 50% carbon dioxide (CO₂) and a small amount of non-methane organic compounds).

- **Reduced stress on ecosystems and competing sectors:** Efficient design that supports the use of fewer raw materials and the substitution of critical primary mineral resources by industrial and agri-wastes and biomass reduce the stress placed on ecosystems and on primary sectors such as agriculture.
- **Material and energy recycling and reduced emissions:** Reusing processed waste in the value chain results in a reduction in the use of primary materials, and therefore in decreased GHG emissions. However, it must be noted that the conversion of C&D waste into aggregates and concretes requires energy and water. Thus, the embodied energy of these reconstituted aggregates is higher than that of the virgin material. Given the very local impact of sand and aggregate extraction, location-specific decisions regarding the balance between energy and material efficiency will be required.
- **Biomass regeneration and CO₂ sequestration:** A move towards the use of bamboo and timbers would lead to inter-sectoral synergies. Plantation, sustainable extraction and application in buildings resulting in biomass regeneration and CO₂ sequestration

Table 10: Considerations for different lifecycle phases of the built environment

Source: Authors
Graphics: Ninni Westerholm

C A P I T A L C O S T S

<p>MANUFACTURE</p> 	<p>Use of industrial wastes and by-products as resources</p>
<p>DESIGN</p> 	<p>Higher value for green design</p>
<p>CONSTRUCTION</p> 	<p>Reduced use of expensive resources, and tax and interest benefits</p>
<p>OPERATION AND USE</p> 	<p>Reduced true costs due to recycled water and energy services</p>
<p>RENOVATION</p> 	<p>Assembly-based products and spaces enable cheaper renovation</p>
<p>DECONSTRUCTION END OF LIFE</p> 	<p>Value of C&D waste and building elements that can be used in a new building</p>

O P E R A T I O N A L C O S T S

MANUFACTURE



Water and heat recovery

DESIGN



Passive design, renewable energy, water harvesting, design for durability

CONSTRUCTION



Reduced maintenance, rapid and cheaper construction of modular and assembly-based elements, reduced onsite waste

OPERATION AND USE



Lower energy and other utility expenses, better return on investment

RENOVATION



Cheaper and easier renovation of assembly-based elements, a recycled material market to access second-hand building elements

DECONSTRUCTION END OF LIFE



Easy deconstruction of assembly-based products, cost reduction and new products sourced for next building from onsite recycling of C&D waste

ENVIRONMENTAL IMPACTS

MANUFACTURE



Reduced or no waste from manufacturing, reduced emissions from manufacturing processes, reduced mining of virgin minerals and lower ecological impacts on ecosystem, increased use of renewable materials leading to reduced dependence on mineral resources, carbon locking and increased CO2 sequestration

DESIGN



Reduced material and energy footprints of buildings, reduced or net zero emissions

CONSTRUCTION



No debris to landfill, low or no critical virgin material used

OPERATION AND USE



Longer life, no emissions or pollution, closed water loops, domestic nutrient recycling

RENOVATION



Keeping energy and materials in the value chain, reduced waste to landfill, reduced emissions

DECONSTRUCTION END OF LIFE



C&D debris use, CO2 locking and regeneration, no waste to landfill

N E W B U S I N E S S E S

MANUFACTURE



MSME material production businesses, material aggregation platforms, secondary resources available for production

DESIGN



Green design services, green certification and valuation services

CONSTRUCTION



Green building business – affordable housing, higher value of real estate, green construction services

OPERATION AND USE



Rental and shared ownership models, space sharing platforms, energy and water sale to the grid

RENOVATION



Repair and renovation service providers, second-hand product suppliers

DECONSTRUCTION END OF LIFE



Secondary resource aggregation services, new resource streams, waste aggregation and exchange platforms

G R E E N J O B S A N D S K I L L S

MANUFACTURE



Green skills for production workforce, new skills for application of new green materials

DESIGN



Certification and rating consultants, green design skills

CONSTRUCTION



New assembly skills, green construction skills

OPERATION AND USE



New management skills for material aggregation platforms, rental and space sharing businesses

RENOVATION



Retrofitting and repair artisans

DECONSTRUCTION END OF LIFE



Recyclers and assembly workforce

can lead to net zero carbon buildings.

- **Water conservation and recycling:** Urban areas are water stressed due to over-extraction, particularly from groundwater sources. Water recycling across individual buildings, neighbourhoods and between housing and industry or agriculture can lead to reuse and considerable savings of this precious resource.

The following table, Table 10, provides a summary of the potential benefits emerging from good practice examples and policy strategies in the Asian region.

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