Catalysing Science-Based Policy Action on SCP

Task Group IRP-One Planet network

Analysis of the Construction Value Chains

Understanding the value chain & identifying hotspots

Draft 28 October 2020

The science is clear on the need to decouple economic growth from natural resource use, and the positive impacts this would have on reducing greenhouse gas emissions, protecting biodiversity and driving socio-economic development. Yet this evidence does not always reach key decisions makers in a way that is relevant and actionable. Stakeholders, whether governments or businesses, need comprehensive and tailored information to help identify priorities, implement strategies, and monitor impacts around the sustainable management of natural resources.

To meet this need, the 4th United Nations Environment Assembly, in its resolution on Innovative pathways to achieve sustainable consumption and production (UNEP/EA.4/Res.1), requested the One Planet network and the International Resource Panel form a task group. The aim of the task group is to catalyse science-based policy action on sustainable consumption and production, thereby creating the conditions to provide actionable insights on the management of natural resources in relation to the 2030 Agenda for Sustainable Development. The task group comprises experts and governments from the International Resource Panel and practitioners from all stakeholder groups (government, business, civil society, international organisations) of the One Planet network.

Following an initial assessment of the research undertaken by the IRP, the task group decided to focus on practical approaches to catalyse the science-policy action on SCP through a sectoral focus and by adopting a value-chain approach. The value chain approach aims to identify hotspots and shape corresponding actions built on existing knowledge and available data. It provides a framework applicable to different sectors, products and geographical scales. In the context of the work of this task group the data and information is analysed and discussed under three key steps:

1. Understanding the value chain and identifying the key hotspots (data source: IRP and other UNEP scientific assessment);
2. Consolidating existing action and identifying opportunities to address the identified hotspots (data source: One Planet network);
3. Defining a common agenda and prioritising action to address identified gaps (through participatory process).

The practical illustration of the benefits of the value chain approach to define SCP action that is informed by science is illustrated by its application to the three prioritised sectors of Food, Construction and Textiles.

This report focuses on the application of the first step of the value chain approach to the Construction sector. It provides an analysis and mapping of available information on natural resources, environmental impacts and the system within which the value chain operates to understand the construction value chain and to identify its key hotspots.

I. Overview of construction value chain and data availability or gaps

For the purpose of this analysis, construction will include residential buildings, institutional and commercial buildings, specialised industrial construction, infrastructure and heavy construction.
Construction is described by the International Resource Panel and UNEP as including: Planning, Design, Commissioning, Construction, Maintenance, Refurbishment and End-of-Life (IRP, 2017a; IRP, 2017b, 2018). This sequence is further detailed to integrate key actors and business processes in the construction value chain, , ranging from Investors (including banks and financial institutions) to purchasers and users of buildings and infrastructure. A simplified though operational representation of the value chain of construction includes the following key stages:

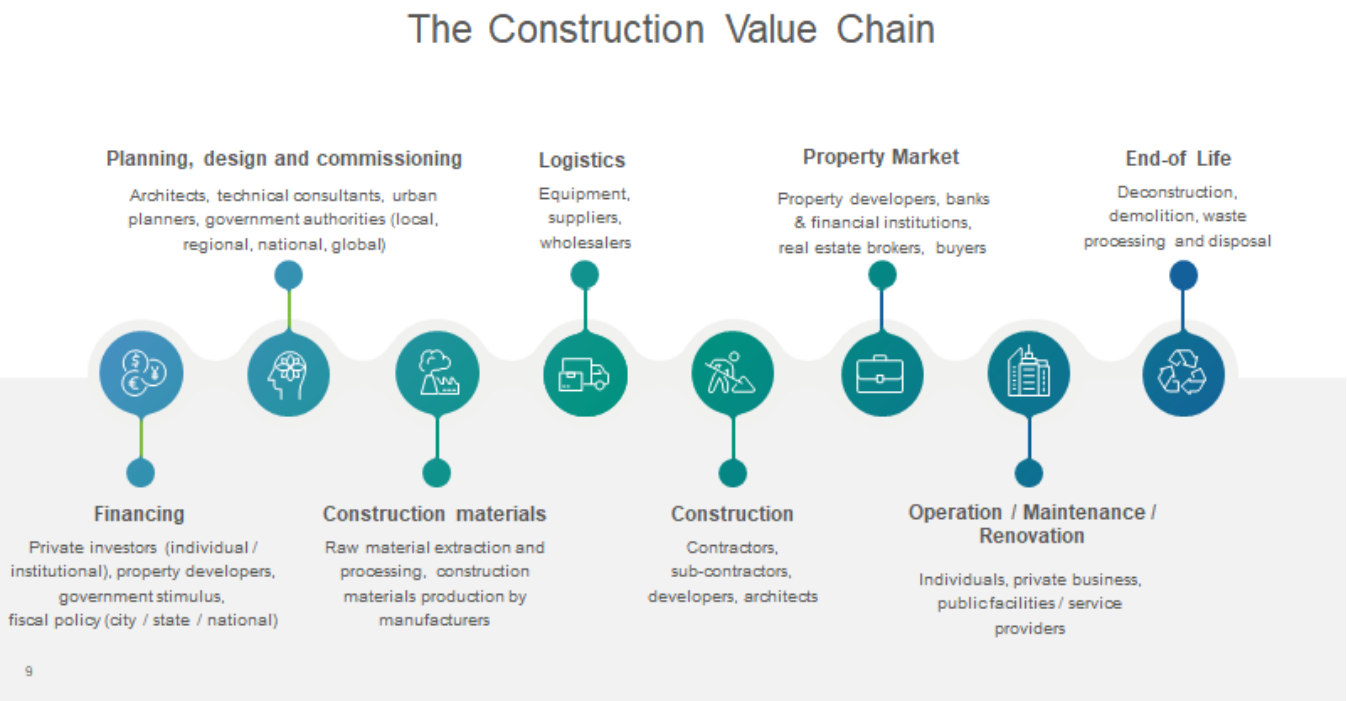


Figure 1: Stages of the construction value chain

For illustration purposes the stages of the value chain are reported as a linear sequence in Figure 1. However, some stages can take place simultaneously or with a different order (e.g. property market v. construction) and involve a mix of processes and actors in different parts of the world (e.g. for the production and supply of construction materials).Simplification and generalisation on the stages of the value chain is necessary while acknowledging that these may vary between and within types of construction, countries and region.

Data availability and gaps:

In line with the scope of the task group, the main source of information for this analysis are IRP reports, complemented by reports from UNEP and other organisations. Differently from other sectors (e.g. food systems), construction is not the object of a dedicated IRP report. Rather, the information on the construction value chain is scattered across a variety of reports. For example, the "Global Resource Outlook" report (IRP, 2019) provides an overview of material used in construction, whereas the report on resource efficiency and climate change (IRP, 2020) provides information on greenhouse gas emissions in the use of residential buildings. Further detail on the IRP reports reviewed for this analysis is provided in Annex I.

Although the analysed reports cover several aspects associated to the construction value chain, the focus tend to be more at aggregated level, as well as on energy use and greenhouse gas (GHG) emissions. More specifically:

- Broader city level data rather than sectoral level data: IRP resources take an approach which is often broader than just the construction sector. As a result there is limited specific information and data on the natural resource use and environmental impacts of this sector. Despite the focus on cities in some reports, the urban rural nexus not captured: it does not connect construction in cities to the rural "sources" of natural resources, materials and 'sinks' for waste.
- Lack of data on material stocks and flows: A data gap to highlight is relating to the availability of detailed information about material flows and stocks in constructions, e.g. the list with quantity of construction materials, assemblies, parts and components used (the so called "bill of materials"). There is limited overarching information available on the usage of materials along the global construction value chain, with different pieces of information available from individual sources often at a material-specific level such as on steel, or cement. Granularity of data on construction materials (including glass, timber, plastics and chemicals) and natural resources extracted (including minerals and metals) is lacking.This is also related to the general focus on energy-efficiency over material use in construction sustainability.
- A focus on energy and GHG emissions, rather than on materials and resources: Data focus across IRP reports is primarily on energy use in construction and operation of buildings.
- Differentiation between materials and natural resources is not systematic: materials and resources are often used interchangeably in the reports, creating confusing or difficulty in understanding what is specifically being referred to.
- Case studies and anecdotal evidence: Reports at times contains case studies and anecdotal evidence from specific cities, not necessarily quantifiable, comparable or verifiable. There also seem to be more focus on residential buildings than on commercial buildings and infrastructure. Further to this, data is mainly focussed on developed countries, China and India. This leaves a large information gap concerning informal sector, emerging economies and developing countries.
- Political economic analysis of the construction value chain: The IRP refers to the different actors along the value chain. However, there is a lack of in-depth analysis of how the value chain operates and of each of the different stages of the value chain. There is an opportunity to undertake further analysis that considers the governance and institutions that shape the operations of actors and organisations, the economic role of stages of the construction value chain and actors therein, including mapping where stages/actors are focused geographically and what they contribute in terms of types of constructions, economic activity, employment in countries and regions. A more detailed understanding of the above is essential to identify key points of intervention.

II. Natural resource use & impacts along the value chain

The mapping of available data and information to key stages of the value chain allows to filter and distil large volume of information to identify where the greatest opportunity for improvement occurs. The mapping focused mainly on natural resources and raw material use, as well as environmental impacts and known socio-economic impacts. The mapping of data and information included the following aspects:

- Construction materials (e.g. concrete, asphalt, steel, aluminium, timber)
- Natural resource use: Land, soils, landscapes; water; biodiversity and ecosystems; genetic resources; minerals (including ores and stones); nutrients; fossil fuels.
- Environmental impacts: deforestation, biodiversity loss, water scarcity and pollution, soil pollution and degradation, air pollution, GHG emissions

1. Use of construction materials in the value chain

Buildings and infrastructure can be made of a broad list of construction materials that include cement, gypsum, lime, mortar, mineral materials and products (e.g. earth, sand, clay, slates, stones), ceramics, terracotta products (e.g. roof tiles, bricks), concrete products, binders and sealing materials, thermal and insulating materials, iron and steel products, products of non-ferrous metals, timber and wood-based products, plastics products, glass, as well as other materials (e.g. textiles) (ISO). Construction material are usually manufactured using a combination of natural resources – for example steel is composed principally of iron ore and carbon and requires energy to be produced, similarly cement is mainly composed of limestone and clay (or other silica source) and requires energy and water to be produced. The following construction materials are of particular relevance to construction:

- **Concrete**: is a key product used for buildings and consists mostly of aggregates, including gravel (40.8%) and sand (31.1%), cement (10-15%), water, and burnt lime as binder. Concrete in buildings is the largest contributor to the use of sand and gravel by the sector (IRP, 2016).
- **Cement:** is key ingredient of concrete; it is made of limestone, clay, shells, chalk, shale, slate, silica sand, and sometimes even blast furnace slag or iron ore. These ingredients are crushed then heated at high temperatures to result in a material called "clinker". Gypsum is added and the whole mixture is finely ground to produce cement powder.
- **Asphalt (or bitumen)**: main material used for the construction of transport infrastructure (e.g. roads) and is mostly composed of petroleum and aggregates;
- **Metals (steel, aluminium, copper);**
- **Timber and wood-based materials;**
- **Earth:** nearly 30% of the population of the world and more than half of the population of developing countries live in earth construction. It is regaining interest as sustainable construction material in industrialised countries (Vyncke et al., 2018).
- **Chemicals, Glass, Plastics and Stones.**

Furthermore, alternative construction materials can also be sourced locally – depending on their availability – as for example wood recovered from pallets, sugar cane bagasse, bamboo, typha (invasive aquatic plant of West Africa carrying thermal insulation capacity).

There is limited overarching information available on material flows and stocks and on the usage of materials along the global construction value chain, with different pieces of information available from individual sources often at a material-specific level such as on steel, or cement. This is also related to the general focus on energy-efficiency over material use in construction sustainability. However, some general trends can be observed around material usage in construction.

- A major shift from wood to other construction materials (e.g. concrete and steel) took place in the 20th century.
- The availability, durability and versatility of steel, iron and concrete resulted in their widespread adoption and enabled the massive construction of buildings and infrastructure that can be seen today.
- This also caused a massive consumption of non-renewable resources (mainly non-metallic minerals and to a lower extent metals) that further changed the nature and scale of environmental pressures (IRP, 2019).

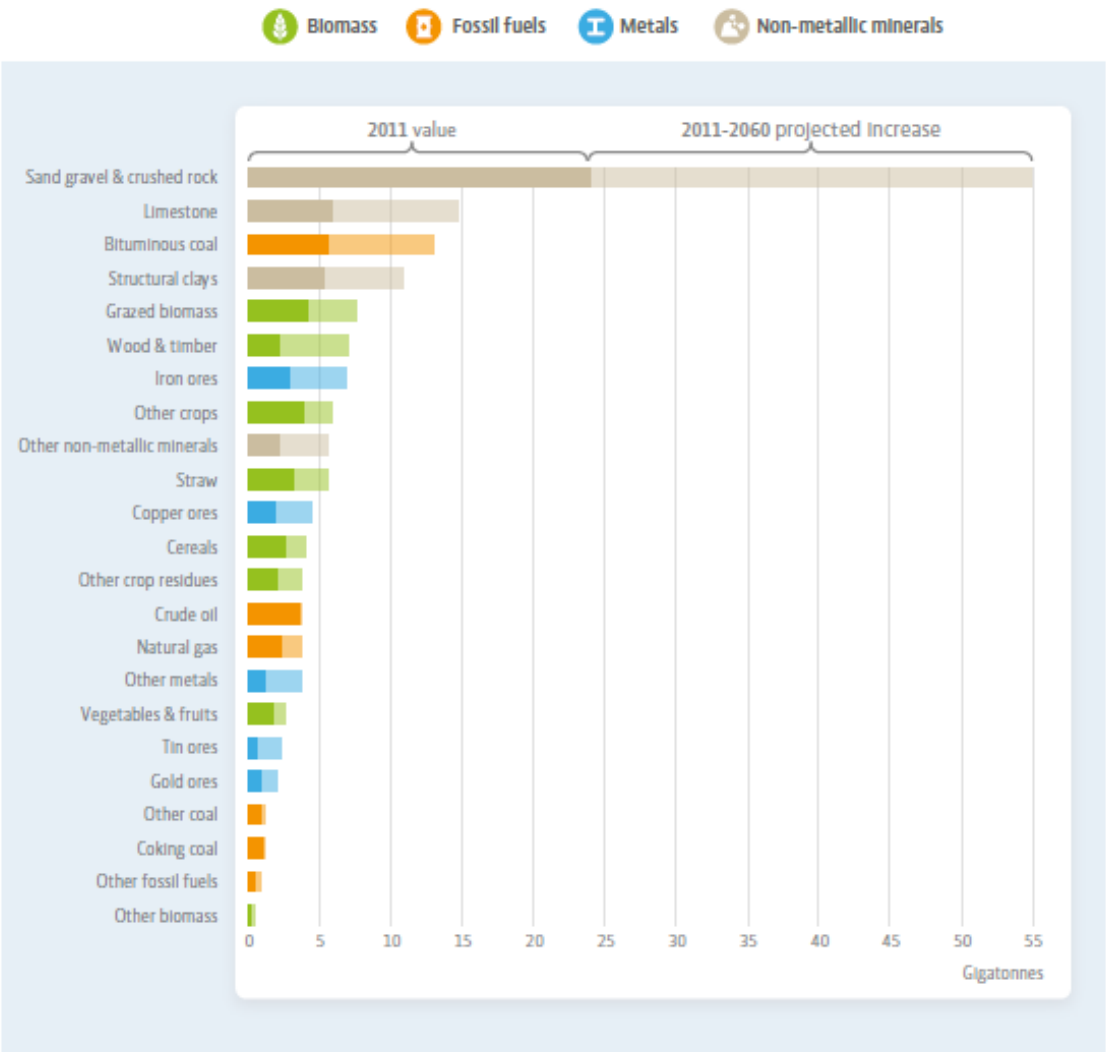


Figure 2: Global use of construction materials and other natural resources (from OECD 2018)

2. Use of natural resources

Resource	Financing	Planning, design, commissioning	Construction materials	Logistics	Property market	Construction	Operation	End-of-Life
Land			Land for extracting, processing and manufacturing materials			Land where constructions are made	Occupation of land over time	
Water			Water for extracting, processing and manufacturing materials			Water for construction	As operational water (mainly for buildings)	

Biodiversity, Ecosystem Services			Trees for timber that rely on ecosystem services					
Genetic resources			Trees for timber/wood-based products					
Minerals			Used as ingredients of construction materials (production side)			Use of construction materials		
Nutrients			Fertilisers for timber/wood-based products					
Fossil fuels			Used as ingredient of materials and as process energy	Energy for transports		Use of construction materials Energy	As operational energy (mainly for buildings)	

Table 1: Mapping of main uses of resource along the construction value chain
*(*Legend: Orange = key stage of use; Yellow = other stages with less intensity of use (data gaps may exist). Use of resources may more marginally occur also in other stages of the value chain)

Land: Construction works are physical transformation of the environment that require direct use of land. Land occupation can last 25-100 years or longer, depending on country and type of construction.
Land use is also associated with: Mining and quarrying for the extraction of minerals; Oil and gas extraction; Trees growing; Industrial areas where factories are built for processing and manufacturing materials.

Water: 25% of water and 12% of potable water used globally are associated with buildings (IRP, 2017a; IRP, 2017b). The consumption of water in the construction sector is mainly associated with construction processes and occupation of buildings s well as withthe extraction, processing and manufacturing of materials.

Biodiversity and ecosystem services, Genetic resources, Nutrients. Trees are used to produce timber and wood-based products, which thus rely on ecosystem services.

Minerals:
Non-metallic minerals and metals are the main natural resources used in the construction sector (IRP, 2019). On a global scale, the construction sector uses about 65% of non-metallic minerals, 15% of ferrous metals and 3% of non-ferrous metals (OECD, 2018b).

Non-metallic minerals are mostly used for buildings (Figure 3) andin construction these include sand, gravel and limestone. Sand and gravel are mined worldwide and account for the largest volume of solid material extracted globally: about 40-50 billion metric tons per year (IRP, 2019), of which 40.8% made by gravel and 31.1% by sand in 2010 (IRP, 2016).

Metals, such as iron, aluminium and copper, represent about 10% of global extraction of natural resources and are used for constructions, energy and transport infrastructure, equipment, manufacturing and for consumer goods.

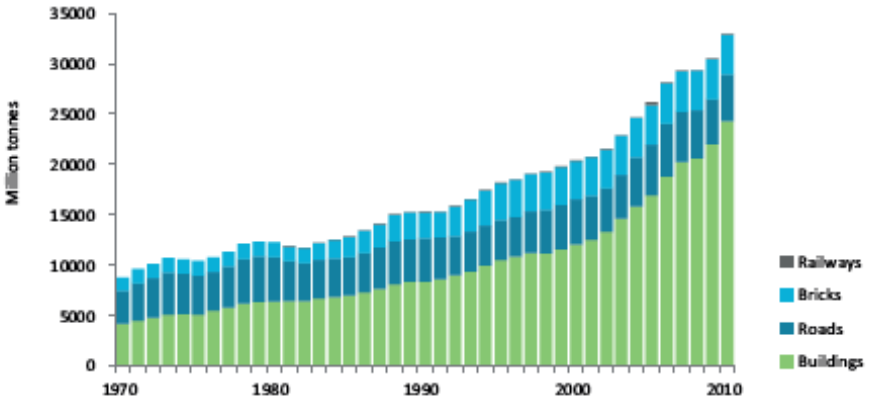


Figure 3: Global extraction of non-metallic minerals by sector of use, 1970-2010, million tonnes (IRP, 2016)

Minerals are non-renewable resources in human time scales and their extraction inevitably reduces the stocks available for use globally (IRP, 2016). While metals may face scarcity in the next 50-100 years, for non-metallic minerals no major global supply constraints is expected. For example, on the basis of recoverable reserves and global extraction levels in 2010, it is estimated that the years of available reserve are 72 for iron ore, 53 for copper ore, 124 for bauxite and alumina (IRP, 2016).

Over the last 50 years, material extraction has tripled, with the rate of extraction accelerating since the year 2000. Non-metallic minerals and ferrous metals used for construction had the highest average growth rates of extraction between 1970 to 2010. This reflected the major shift in global extraction from biomass to mineral-based natural resources (IRP 2019) and the fuelling the major build-up of buildings and infrastructure in transitioning countries (particularly China, India, Brazil and South Africa) (IRP, 2017a; 2019).

Virtually none of the massive growth in materials consumption in the new millennium has taken place in the wealthiest countries; however, not much of it has taken place in the poorest countries either, which make up the group in the most urgent need of higher material living standards (IRP 2019).

Fossil fuels

40% of energy used globally is associated with buildings (IRP 2017, UNEP 2017). Different source(s) of energy can be used along the value chain. The operation of buildings is one of the main points of consumption of energy. Traditionally, the supply of energy for electricity, heating, cooling and transport depends on fossil fuels to a large extent.

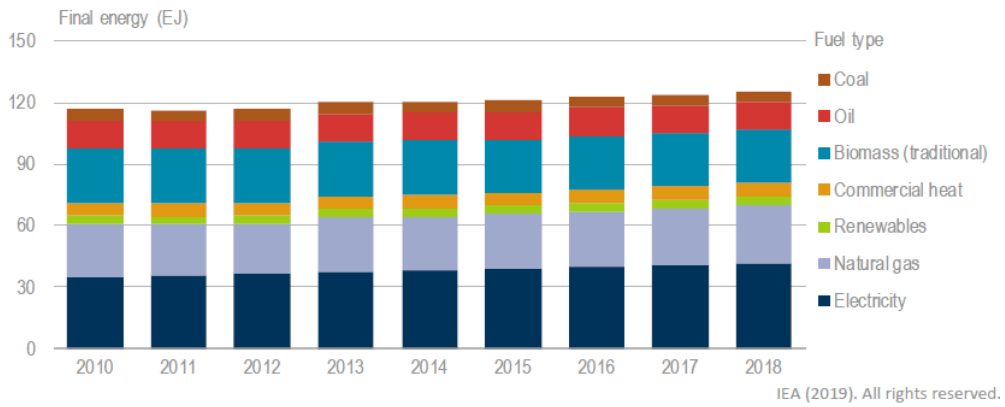


Figure 4: Global building sector final energy use by fuel type (Global ABC et al., 2019)

Fossil fuels are also used as ingredient for key construction materials and as source of energy in the processes creating such materials (also called embodied energy). For example, asphalts and plastics products are based on crude oil, while 70.7% of steel worldwide is produced predominantly from iron ore, coal and recycled steel through the blast furnace-basic oxygen furnace route (Worldsteel, 2019).Furthermore, energy is also spent for the supply of construction materials and in the construction process, although to a possible lower extent compared to the previous two aspects.

3. Environmental Impacts

Impact	Financing	Planning, design, commissioning	Construction materials	Logistics	Property market	Construction	Operation	End-of-life
Deforestation			Sustainability / renewability of timber Deforestation due to mining			Land transformation		
Biodiversity loss			Sustainability / renewability of timber			Land transformation		
Water scarcity			River sand extraction Data gaps				Data gaps	
Pollution (air, water, soil)			Pollution from material extraction, processing and production			Dust emissions during the construction	Indoor air quality	
Soil degradation			Mining as cause of soil degradation			Land use transformation		
GHG emissions			Embodied emissions in construction materials	GHG emissions due to transport		GHG emissions for the construction	GHG emissions from fuel combustion, electricity use	

Table 2: Mapping of main impacts along the construction value chain
(Legend: Orange = key stage of impact; Yellow = other stages with less intensity of impact (data gaps may exist). Impacts may more marginally occur also in other stages of the value chain)

Deforestation

Urbanisation and related constructions place direct pressures on land use that could potentially drive deforestation (IRP, 2019). Furthermore, other possible causes of deforestation are mining for natural resource to produce construction material and logging to produce timber. However, there is a lack of quantitative information gathered on the extent of this problem.

Biodiversity loss

The following aspects can contribute to biodiversity loss:

- Constructions imply a transformation in the use of land, as well as deforestation and land clearing associated to all land uses along the value chain;

- Different sources along the value chain of constructions can pollute air, water and land media, e.g. the use of chemicals such as caustic soda in the production of aluminium;
- GHG emissions along the value chain of constructions contribute to climate change.

Water scarcity

There is a data gap in terms of understanding water scarcity, which depends on local conditions and that is dramatically affected by climate change; this may be partially addressed through the use of the "Water Exploitation Index" (EC) and databases like the FAO's Aquastat database (AQUASTAT).

One aspect that is well acknowledged is that the boom in construction in emerging economies has created excessive demand for sand, collected from riverbeds, which is cause of the lowering of water aquifers thus worsening the occurrence and severity of drought events (IRP, 2017a, 2019b).

Pollution - air, water, soil

Pollution of air, water and soil is in general associated with the extraction and processing of natural resources and the further manufacturing of construction materials, as well as with logistic activities and construction.

Air pollution from energy supply and use in homes and industries, as well as transportation and construction sectors of cities, is associated with about 6.5 million premature deaths per year (the vast majority in cities). Indoor and ambient air pollution by fine particulate matter (PM2.5) is the dominant risk factor accounting for 96 per cent of health effects (IRP, 2017a). Indoor pollution is also caused by inefficient cooking practices and related exposure to pollutants, which also result in 3.8 million premature deaths every year according to the World Health Organization.

Furthermore, in relation to the production of construction materials:

- Energy-intensive processes and chemicals are required for the production of iron, steel, aluminium, concrete, cement, which result in the emission of pollutants to the environment.
- Highly toxic mining tailings (residues) are associated with the production of materials like copper and precious metals (IRP, 2019).
- In the primary production route of steel, the first processing steps account it is in general more impactful for the environment than the iron ore extraction phase (IRP, 2019).
- Environmental concerns are associated with the excessive demand for sand in emerging countries. Its massive collection from riverbeds is cause of water pollution and changes in pH levels and instability of riverbanks leading to increased flood frequency and intensity (IRP, 2019b)
- In general, recycling of materials considerably reduces environmental impacts because it avoids the impacts from the extraction and processing of ores.

Although general considerations are available (IRP, 2017a, 2019), an information gap is currently highlighted in terms of specific impacts associated to air, water and soil pollution along the value chain.

Soil degradation

Presumably, soil degradation can be associated with the mining stage and land use changes due to construction works. However, data gaps exist in the context of this report.

Greenhouse Gas (GHG) emissions

The construction sector is responsible for 39% of global GHG emissions, 44% of which associated with residential buildings, 28% with non-residential buildings, 28% with other constructions (Global ABC et al., 2019). Although residential buildings on average emit lower GHG emissions per square metre per year than office buildings (Rock et al., 2020), they represent a much larger destination of use in buildings. On a global

scale, 70% of the total GHG emissions in the construction sector were attributed to developing countries (UNEP, 2019).

GHG emissions are mostly associated to the operation of buildings, as well as from the production and supply of construction materials (embodied emissions). In terms of construction materials, a strong contribution to GHG emissions is associated to the use of cement and concrete (see Figure 4). The increased demand for cement has overcompensated the reductions of greenhouse gas emissions associated to its production (IRP, 2019). Although the contribution from iron and steel is the largest on a global scale, it should be highlighted that these materials are also used in other sectors.

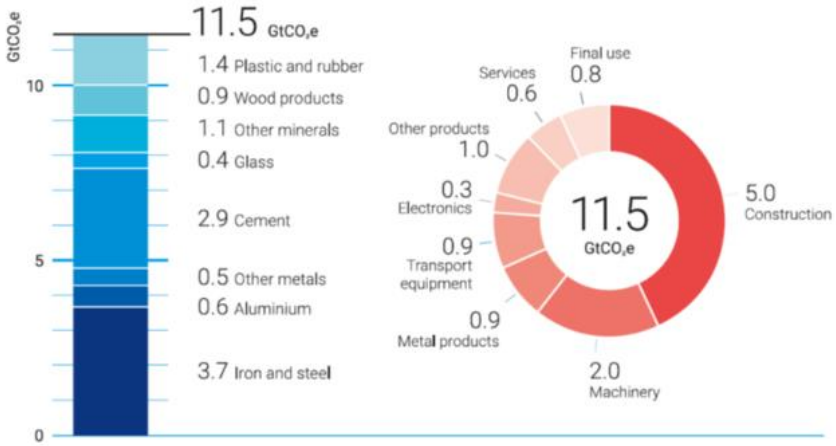


Figure 4: GHG emissions associated with materials production (left) and use (right) (UNEP, 2019)

4. . Conclusion

The review of natural resource use and environmental impacts enables the identification of 3 key stages of the value chain in which these primarily occur:

- Manufacturing of construction materials: consumption of natural resource and impacts associated with their extraction and processing (e.g. embodied GHG emissions);
- Construction: use of construction materials, water, energy and land, as well as production of GHG emissions and air pollution;
- Operation: use of energy resources (fossil fuels) and water, occupation of land, production of GHG emissions and air pollution.

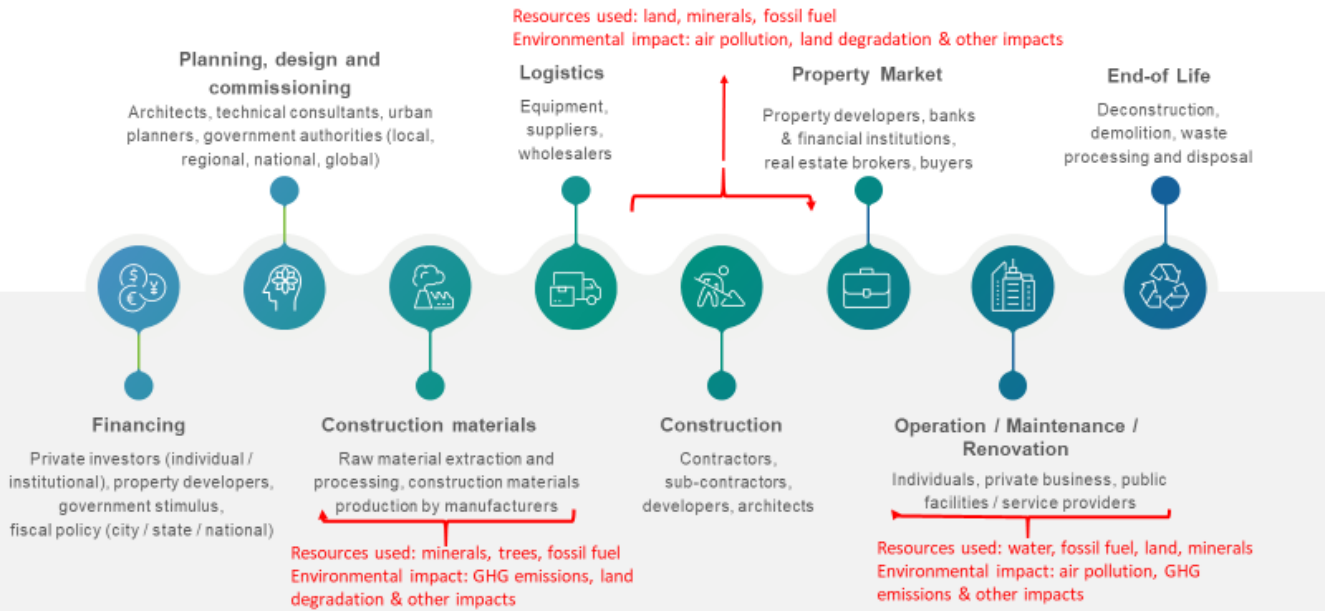


Figure 5: Stages of the construction value chain in which most natural resource uses and environmental impacts occur

II. Applying a systems lens to the construction value chain

The review of the IRP and UNEP reports demonstrates that the majority of both natural resource use and environmental impacts occur at the materials extraction and production stage, the construction stage and the use stage of the construction value chain.

However, it does not automatically follow that the solutions to natural resource use and environmental impacts are only to be found at the stages. Historically there has been a focus on energy use in the operation and use of buildings to reduce environmental impacts, however this focus alone can fail to take into account the complex drivers and feedback loops that determine and influence what types of constructions are built, how many constructions are built and how constructions are built, and the associated natural resource use and environmental impacts.

The interactions within the systems mean that the operations and behaviours of actors at different stages of the construction value chain can have a significant influence on the operations and behaviours of actors at other stages of the value chain. For example, the actions of investors and planners can shape the practices of construction companies, which in turn shape the characteristics of buildings and infrastructure available to users. It is therefore necessary to apply a systems lens to the analysis of a sector to move beyond a siloed and disconnected analysis, and toward understanding how different drivers of a given sector - such as institutions, regulation, demographics and economic factors - shape the operations of along the value chain.

Each of the drivers in the diagramme below contribute to shaping the construction value chain, influencing the behaviour of the actors along it and determining what options are available to them. Equally, each of these drivers are all possible points of intervention to positively shape the way the sector works and the behaviour of actors along the value chain.

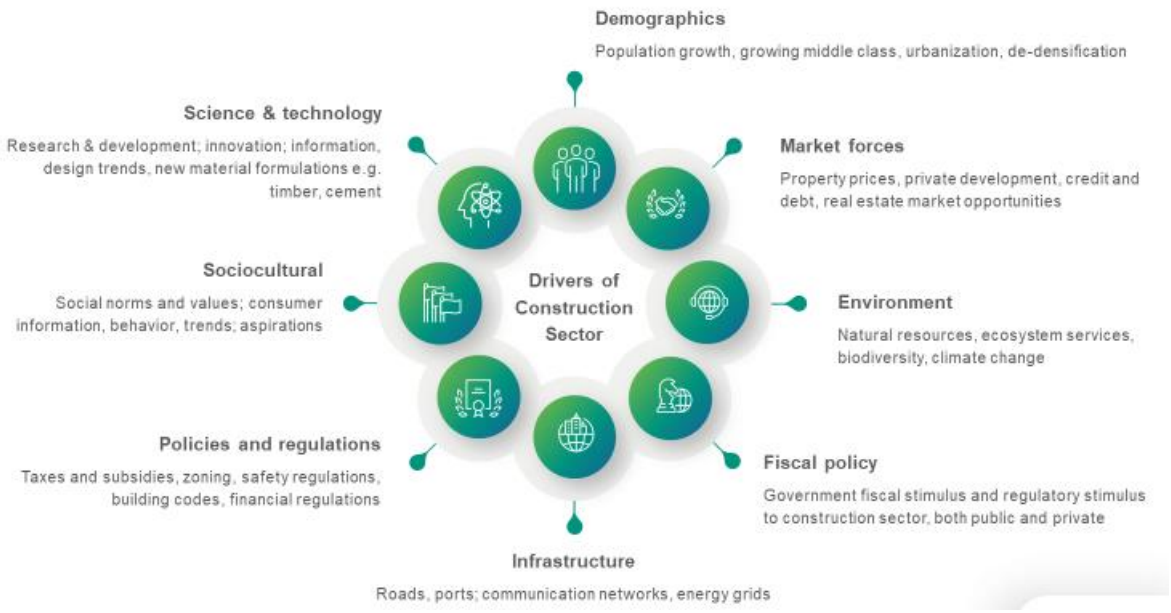


Figure 6: Drivers of the construction value chain

Understanding the what, how much and how along the construction value chain

Construction as a sector globally has the highest material consumption footprint, consuming almost 50% of the total material footprint across the global economy (SCP-HAT, 2020). As outlined, this involves the use of a range of natural resources and also results in many environmental impacts. However, the construction sector also contributes in a variety of ways to socio-economic outcomes and to meeting the Sustainable Development Goals, in particular SDG 11 which calls for safe and affordable housing; sustainable and affordable transport systems; and inclusive and sustainable urbanisation. It is therefore essential to analyse the socio-economic outcomes of the construction sector alongside the associated natural resource use and environmental impacts, to be able to balance any trade-offs.

In order to undertake such an analysis and consider these trade-offs, three questions must be applied to understanding natural resource use and environmental impacts along the construction value chain:

1. What is being built,
2. How much is being built
3. How is it being built

Discussion on sustainability in the construction sector often focuses on the third question of *how* things are being built, with an emphasis on circularity of materials, energy efficiency and material substitutes and innovations, as well as on the safety of constructions and their resilience to natural disasters and to the impacts of global warming. By changing how constructions are built through sustainable materials and practices, the associated natural resource use and environmental impacts of the sector can be reduced.

While this is a critical question, it is also necessary to ask what is being built? For example, are the constructions residential, commercial, industrial or public infrastructure? Is the sector working on new builds or renovations of existing constructions? Is the housing being built affordable? Depending on the type of construction being built, this can have different levels of impact on natural resource use and environmental impacts, as well contribute in varying degrees to meeting the SDGs, thereby influencing how trade-offs are balanced.

The other question that must be asked is how much is being built? The overall volume of constructions being built is a key determinant of the volume of natural resources that the sector is using as well as the degree of environmental impacts that are caused by the sector. The volume of construction activity is also connected to the different social and economic development pathways of countries.

The answers to the three questions above are shaped by a range of drivers along the different stages of the construction value chain, with much interaction and many feedback loops between stages. The following section applies a systems analysis to the construction value chain to highlight several important features at the different stages of the value chain.

1. Key observations along the construction value chain

1.1 A variety of construction projects involve different actors

Construction can be categorised into four main types: residential buildings (e.g. apartments and houses), institutional and commercial building (e.g. schools, hospitals, shopping centres, retail stores, etc.), specialised industrial construction (e.g. chemical industry plants, power plants, etc), infrastructure and heavy construction (e.g. roads, tunnels, bridges, railways, sewage systems, pipelines, etc).

At a global scale, residential buildings hold the largest portion of construction. In relative terms, residential buildings constitute the major part of constructions in North America and Europe. Infrastructure dominates in Asia-Pacific, Latin America, Africa, and the Middle East; while non-residential buildings makes the strongest contribution in Eastern Europe (IHS, 2013). Overall, Governments are key player in the design, execution and management of institutional buildings and infrastructure, often with the co-participation of the private sector. Private companies play a prominent role in the conception, execution and management of residential and commercial buildings.

	Residential buildings	Institutional and commercial buildings	Specialized industrial construction	Infrastructure and heavy construction
Examples of type of use	Apartments, houses, dormitories, sheds, etc	Schools, hospitals, offices, shopping centres, retail stores, stadiums, etc	Chemical industry plants, power plants, etc	Roads, tunnels, bridges, railways, sewage systems, pipelines, etc
Design	Architects, engineers	Architects, engineers	Specialized engineers	Government, architects, engineers
Execution	Construction companies, builders	Construction companies, builders	Industrial corporation or specialized companies	Government agencies and construction companies
Management	Individuals, real estate company	Retail: company / private owner. School, hospitals: local / national government	Industrial corporation	Construction companies

Table 3: Main types of construction and indicative key players in their design, execution and management

1.2 Construction activity does not necessarily correspond with development

Global construction has been on an increasing trend over the last century (IHS, 2013), to a large extent due to growing populations, increasing GDP and economic development, as well as growing rates of urbanisation across the world, that have taken place since the end of the second world war.

- Constructions were built massively in developed countries mainly between the 1950s and 1990s, whereby in Europe over 80% of residential buildings were built before 1990 (Renovate Europe, 2017).
- This was followed, starting from 1970, by the major build-up of buildings and infrastructures in transitioning countries such as China, India, Brazil and South Africa (IRP, 2017a,2019).

- In particular, China alone consumed more cement between 2011 and 2013 (6.6 billion tonnes) than the USA did between 1901 and 2000 (4.5 billion tonnes) (IRP, 2018).
- Other countries in Africa and Southern Asia are now entering into a construction phase (IRP, 2018).

However, while emerging markets are today growing in importance in the construction sector, advanced economies continue to make up a significant proportion of global construction activity.

- Emerging markets have grown from a 35% share of the global construction market value in 2005 to 54% in 2014.
- As of 2017, 31% of the emerging market share was comprised of just four countries (20% China, 5% India, 3% Russia, 3% Indonesia 3%).
- At the same time, just six high-income countries comprised 29% of the global market (12% USA, 5% Japan, 3% Germany, 3% UK, 3% France, 3% Canada).

These figures demonstrate that, while increasing GDP, population growth and urbanisation in developing countries can result in increased demand for homes, buildings and infrastructure, these socio-economic factors only partially explain the volume of activity in the global construction market.

- With just ten countries accounting for 60% of the global construction market, the majority of the world, most of which is developing and in need of buildings and infrastructure, is under-served by just 40% of current global activity in the construction sector.
- Equally, with 29% of global construction taking place in just six developed countries where population growth and urbanisation rates remain stable, and GDP growth is comparatively low, the high volume of construction in those countries does not necessarily correspond to increasing levels of development.

2. Decisions by governments & investors largely determine activity along construction value chain

2.1 Financing: Financial flows shape the construction value chain

2.1.1 A key sector for national economies and economic stimulus

The construction sector is one of the largest and most important economic sectors in the global economy.

- About USD 10 trillion is spent on construction-related goods and services every year (McKinsey Global Institute, 2017).
- The construction sector also accounts for around 10% of jobs and 10% of GDP in many countries (IRP, 2017b).

This contribution to GDP and employment makes construction a strategic and important sector for many national economies. Particularly during times of economic crisis or downturn, the construction sector is often a focus for governments when planning economic recoveries. This is due to the 'multiplier effect' that construction spending can have, increasing activity and incomes that flow on throughout other parts of the economy.

- Recent recovery packages and programmes from many national governments responding to the economic challenges of the Covid-19 crisis have included plans to stimulate the construction sector, including, for example:
  - The UK government has implemented planning reforms intending stimulate the construction sector and help revive the economy (Financial Times b, 2020).
  - The South African government is focusing on infrastructure development in its economic recovery plan (Bloomberg, 2020).
  - The Australian government announced a plan to give citizens $25,000 grants to build or renovate their homes to boost demand and maintain employment in the construction sector (ABC, 2020).
- Similarly, following the 2008 global financial crisis, the Chinese governments undertook a significant economic stimulus package with a focus on construction of buildings and infrastructure across the country which helped shield China from the worst impacts of the crisis (Lowy Institute, 2017).

Government stimulus to the construction sector can be an opportunity to direct construction activity towards achieving the 2030 Agenda in countries (IISD, 2020). However, stimulus packages and programmes can sometimes prioritise short-term economic metrics over meeting the longer-term socio-economic needs of countries.

- For example, stimulus to boost housing construction may not include social or environmental criteria to ensure that the housing is affordable, that it is built in the locations where the need is greatest, and that it is built in a way that is resource efficient with as few environmental impacts as possible.
- This can result in building more constructions than are socially necessary, building types of constructions or in locations that do not meet social needs, and these constructions being built using materials and practices that are resource-intensive or environmentally damaging.
- This can also result in harmful socio-economic consequences such as greater levels of housing unaffordability, increased inequality, and property price inflation which can be associated with economic instability.

The construction sector is integral to achieving the 2030 Agenda for Sustainable Development. Yet the importance of the construction sector to national economies can sometimes result in construction activity that serves economic purposes, without necessarily balancing social goals and environmental considerations.

2.1.2 Governments and financial institutions facilitating speculation in property market

One of the major influences on the construction sector is financialisation, which sees property, especially housing, as an investment asset rather than an essential service and a human right.

- Property market speculation sees financial capital invested in housing with a view of making a short-term profit from increasing house prices, or as a safe way to store capital, especially in more stable or higher growth markets abroad.
- Speculation has also resulted in a polarised housing market, in which the wealthy are active and the less well-off are increasingly shut out.
- This is at the time of a global housing crisis in which more than 1.8 billion people worldwide lack adequate housing, and the number of people living in informal settlements has now surpassed 1 billion, including one-third of the urban population in the Global South (IRP, 2018; UNHCR, 2019).

- According to the UN Special Rapporteur on the Right to Adequate Housing, the current global housing crisis is linked to growing socioeconomic inequality, large-scale financialisation of housing and land and unsustainable housing systems that treat housing as a commodity (UNHCR, 2019).

Governments play a key role in regulating financial and property markets, they can shape the way that these markets operate through various policy leversn, and thereby have a strong influence on the activities of the construction sector.

- According to the International Resource Panel, "governance arrangements at global, national and local levels have, in most countries, tended to facilitate financial instruments and property speculation to drive short-term growth" while "more equitable new wealth creation via innovation and skills development in the manufacturing and agricultural sectors became less important than returns from financialisation and urban property development" (IRP, 2018).
- Recent decades have seen governments facilitate and encourage the private sector's role in housing through incentives such as tax breaks to real estate speculators, tax advantages for homeowners and "golden visas" to foreign investors, as well as through deregulated rental markets and encouraging development that primarily produces housing for the wealthy (UNHCR, 2019).
- According to the UN Special Rapporteur on the Right to Adequate Housing "through legislative measures, policies and programmes, many States have treated housing as a commodity for trading and speculation, rather than as a social good and a human right" while "international financial institutions and development banks have (…) imposed deregulation, the liberalisation of housing markets and austerity measures, including the selling of social housing, and required mortgage finance programmes that do not assist the lowest-income households" (UNHCR, 2019).

This speculation and stimulus in the property market is taking place, while at the same time there is a surplus of constructions, with both commercial and residential buildings remaining unoccupied throughout major cities across the world.

- There are a reported 11 million empty residential dwellings in Europe (The Guardian, 2014), which would correspond to about 10% of the residential stock.
- In 2019, approximately 13% of all US commercial space was vacant (Reuters, 2019).

While housing insecurity is an ongoing issue in both developing and developed countries, and new housing supply is part of the solution, the new dwellings currently being constructed do not always achieve these goals. Rather, much of the current construction activity can result in properties that are unaffordable and inaccessible for those in need while fuelling speculation in property markets. The socio-economic impacts of this speculation can include increased inequality and financial instability, while the construction activity also results in natural resource use and environmental impacts.

2.1.3 Government a big investor in the construction sector

Governments can have major influence in the volume and type of activity in the construction sector not only indirectly through regulation of the financial and property markets, but also directly through their role as procurers of major infrastructure projects. The majority of global infrastructure project investments in 2017, 83 percent of a total US $0.5 trillion, came from the public sector including investment by government entities and state-owned enterprises (World Bank, 2017).

At a global level, international organisations and multilateral development banks also play a significant role in financing infrastructure, as do individual countries via their overseas development finance. In 2018, the total overseas development finance spent on infrastructure projects was US $77.6 billion, both from countries and multilateral development banks (OECD, 2020).

Governments also often play a role in supporting the financing of private infrastructure projects either directly or indirectly, as way of attracting investment. According to the World Bank "when governments seek private investment in infrastructure projects, they usually find themselves asked to provide grants, guarantees, or other forms of fiscal support." (World Bank, 2003).

Governments and international organisations therefore have a strong ability to influence the construction sector, through their role as procurers of public infrastructure constructions, and facilitators of funding in private infrastructure constructions. Through implementing public procurement measures that apply sustainability criteria, governments and international organisations can influence how public constructions are built to reduce natural resource use and environmental impacts, as well as ensuring that the volume and type of public constructions that are built balance development needs with environmental trade-offs.

2.1.4 Mismatch of global infrastructure investment with development needs

Despite the growing volume of construction activity taking place around the world, developing countries face a US $1-1. 5 trillion gap in financing the infrastructure necessary for social and economic development (UN IATF, 2020), with developing country governments often unable to finance the projects publicly and unable to attract private investors.

- The majority of investment funding for infrastructure is being spent in developed countries, as well as India and Brazil, while little is going to developing countries where the infrastructure gap is hardest to overcome (Mann, 2020).
- The amount of investment in developing countries and regions like Africa does not adequately meet the demand for buildings and infrastructures (IISD, 2019), including roads and electricity supply networks.
- Where infrastructure is increasingly promoted as an asset class to provide a return on private investment, the perception of risk around financing projects in developing countries can mean projects are often unable to attract funding. This results in a mismatch in terms of where funds are invested in infrastructure versus where the need for infrastructure is greatest (Mann, 2020).
- A growing proportion of global infrastructure is being driven by private investors such as corporates and investment funds (PwC, 2017). This typically takes the form of public-private partnership, where the involvement of private actors is driven on the one hand by the desire of governments to provide services to society and grow the economy while limiting public debt, and on the other by private investors seeking for long-term and stable returns.

Construction is both a key sector for national economies, as well as a critical sector for meeting the SDGs, if it is employed in pursuit of these goals. While some level of natural resource use and environmental impacts associated with the construction sector is a necessary trade-off for the socio-economic benefits that construction can bring for human development, it is not necessarily evident that the current construction activity taking place is in line with global development needs and priorities.

2.2 Planning & design: Construction value chain determined by planning and design

2.2.1 Construction value chain shaped by planning and regulation

The ways in which governments, public authorities, business and civil society shape urban areas and design and construction practices has a strong influence on natural resource use and environmental impacts, as well as socio-economic outcomes.

- Urban and territorial planning aims to realise economic, social, cultural and environmental goals through developing visions, strategies and plans and applying policy principles, tools, institutional and participatory mechanisms, and regulatory procedures (UN-Habitat, 2015).
- Traditionally, public welfare has been the primary concern in urban planning. Sustainable development was added as one of the main goals of all planning endeavours in the late 20th century when the detrimental economic and the environmental impacts of the previous models of planning had become apparent.

Territorial planning mostly occurs at multiple scales, including national, regional, local and neighbourhood level. This can help balance the challenges or decisions taken at each level, for example the deregulation or weak legal framework at one level can be balanced by legally-binding codes and sanctions for non-compliance at another level.

Proposed construction projects must comply with local, regional or national regulations on land-use planning.

- Local authorities usually assess the design of the construction project prior to authorising it, to ensure that the policies and standards are met, the potential impacts on neighbouring properties, and upon existing infrastructure (transportation, social infrastructure, and utilities including water supply, sewerage, electricity, telecommunications, etc).
- Local Authorities usually also inspect the ongoing work periodically to ensure that construction adheres to the approved plans and the building policies and codes.

Government regulation can play a role in influencing the types of materials that are used in constructions.

- This can be an opportunity for reducing natural resource use and environmental impacts such as through using regulation and building codes to improve sustainability and drive uptake of more sustainable materials and practices, such as mandating energy efficiency standards.
- In some cases government regulations can actually inhibit the uptake of more sustainable materials and practices, such as in the use of recycled building materials (Otto, 2020).

The construction value chain is heavily shaped by practices of urban and territorial planning, as well as regulation such as building codes, which are applied primarily by governments and public authorities at national, regional, local and neighbourhood levels, and are also influenced by business and civil society. These planning practices and regulations have a significant impact on what constructions are built, how many

constructions are built, and how constructions are built, and therefore on the associated levels of natural resource use and environmental impacts along the construction value chain.

2.2.2 Planning practices and regulation of construction sector not always consistent or effective

Urban and territorial planning practices and regulation of the construction sector are not equally applied across all countries, with many developing countries stills without building codes. For example, of the new buildings expected to be constructed to 2060, more than two-thirds of these will be built in countries that do not currently have mandatory building energy codes in place (WGBC 2017).

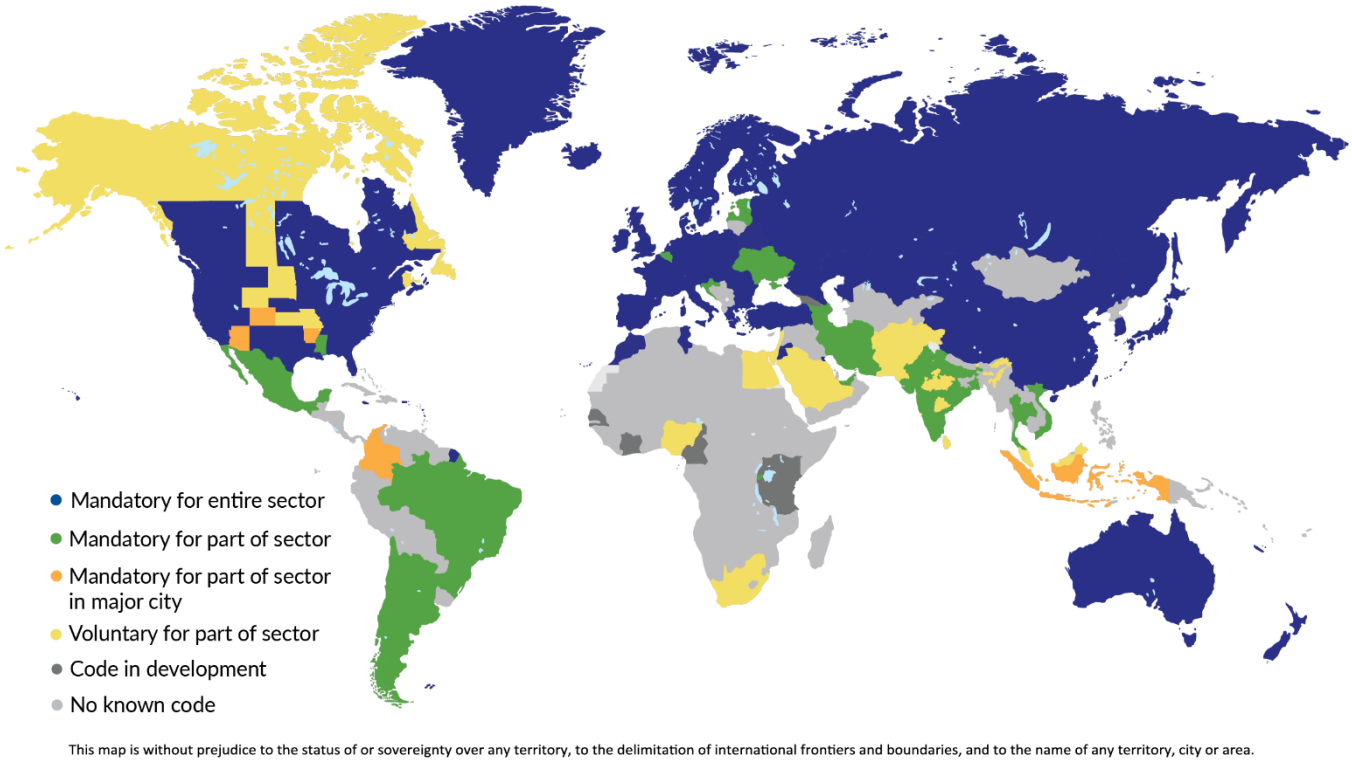


Figure 7: Existence of mandatory building energy codes across countries (Global ABC, 2020).

Due to the significance of the sector for both GDP and employment, regulation of construction can be a politically important issue for governments and economically important for private sector actors.

- Regulation of the construction sector has the potential to be used by governments to for political aims, such as appealing to certain constituencies or stakeholders.
- Governments may also choose to deregulate the construction sector or weaken planning codes as a level to stimulate the sector in order to drive economic growth.
- Key private sector players working in the construction sector may undertake lobbying activities or make political donations that seek to influence the way governments regulate the sector in ways that are favourable to private interests (TIA, 2019). This can sometimes relate to influencing the building code in order to promote the adoption and endorsement of particular building materials or technologies, which could influence the natural resource use and environmental impacts of the sector.
- In some cases, the construction industry can also be subject to corrupt dealings between private companies and politicians, resulting in regulations, safeguards or assessments overlooked to make way for developments (World Bank, 2007).

Urban planning and regulation of the construction sector by governments has strong potential to influence the natural resource use and environmental impacts of the sector, however the existence of such regulation,

as well as its quality and the degree to which it is effectively implemented, are influenced by a number of factors and interests across different countries. As a result, urban planning practices and regulation of the construction sector are not always consistent or effective.

2.2.3 Choices at design & planning stages determine sustainability in 'use' stage

Planning of buildings and infrastructure determines their construction, which in turn shapes the use phase of constructions.

- Design and planning of buildings and infrastructure determine the amount of material resources and the energy necessary to build a construction, as well as the associated environmental impacts of that construction.
- Consequently, these choices also to a large degree fix how much energy and water will be used for operation throughout the construction's lifetime, as well as how waste will be managed (IRP, 2017a).
- The design of the buildings – including size, orientation, insulation – will determine the need for lighting, heating and cooling.
- In the case of multi-residential buildings this will also include design decisions on whether electricity, water and heating is centralised.

In particular, the floor space of buildings, which is determined in both territorial planning and design decisions, influences energy and service requirements. The average floor space per capita varies with countries and tends to grow as the average GDP per capita grows in countries (OECD, 2018). In many countries, the trend is shifting towards a smaller household size, which is leading to an increase in required space as facilities are shared between fewer people (UNEP, 2019; IRP, 2020).

Sustainable design practices that integrate energy efficiency and GHG emission aspects are emerging. These are driven by cost and energy saving factors, as well as by the widespread concern over climate change and other environmental aspects.

- Many national and international bodies have set targets and guidelines for improving the environmental performance of buildings and reducing carbon emissions (IRP, 2017b).
- However, the adoption and the content of building codes varies from country to country, and certifications are more widely applied to commercial buildings than to residential dwellings (UNEP, 2019).
- Sustainability is still not the major focus for design and planning of constructions. In 2018, out of the US $4.5 trillion in global spending on buildings construction and renovation, only 3% was used for energy efficiency investments (Global ABC *et al.*, 2019).
- There is growing awareness around the issue of material efficiency in construction, however the focus of sustainability in buildings remains primarily on energy efficiency.

While the natural resource use and environmental impacts of construction projects are increasingly considered during the planning and design stages of the construction value chain, these considerations are still not yet widespread and continue to compete against a range of other drivers.

2.2.4 Price as key consideration of materials, for public and private constructions

For the majority of constructions, whether private or publicly funded, whether residential, commercial, industrial or infrastructure, price is a decisive factor when it comes to what construction materials, technologies and practices are utilised, and keeping costs down is often a key objective.

- Cost considerations can often work against sustainability measures in constructions, with the cheapest options usually being those materials which are most abundantly used and easily accessible on the market. Changing to new, more resource efficient materials that have not yet achieved scale can imply additional costs.
- Keeping costs down can be of particular importance in the developing countries where many people live in informal settlements and the need to provide affordable housing is great.
- The focus on price can work in favour of sustainability, particularly when it comes to promoting certain types of building materials or technologies that will make the cost of operating the building cheaper in the long-term, such as solar panels or insulation.
- However, where the developer of a construction is not the owner, or where the owner is not the long-term occupant, these long-term cost savings may be less appealing than short-term price considerations.
- Even where sustainable options are more affordable or would imply long-term savings in operational costs, it can be difficult to overcome perceptions sustainable constructions are inherently expensive.

As price considerations and keeping costs down continue to be major drivers of activity along the construction value chain, the additional costs associated with more sustainable constructions, whether actual or perceived, continue to be a barrier against shifting towards constructions that prioritise reducing natural resource use and environmental impacts.

2.2.5 Cultural and social norms shaping construction market

Social and cultural norms around what is considered desirable in a home or building, as well as the lifestyles of owners and occupants within different cities, countries and regions, play a role in shaping choices of what type of constructions are built and how they are built. Actors along the construction value chain, including governments, private investors, construction companies or real estate agents, will seek to produce constructions that fit prevailing social and cultural norms as well as the existing lifestyles of inhabitants. Buildings and homes can also be strong symbols of modernity and therefore are often attached to collective aspirations around development.

- As referenced earlier, the trend in many countries towards smaller household sizes results in increased space and facilities to be shared among fewer people, thereby increasing the natural resource use and environmental impacts of constructions per person (UNEP, 2019; IRP, 2020).
- As populations become more wealthy, they generally also aspire to live in larger homes (OECD, 2018). Other factors such as cultural norms, country size and population density can also impact the overall density of constructions, especially residential, such as whether people live in houses or apartments, and whether homes are attached or freestanding. All of which contribute to natural resource use and environmental impacts both in the construction of a home and in its ongoing use.
- Social and cultural factors and trends can also shape decisions around what types of building materials are used, with some types being perceived as being more culturally appropriate, higher quality or more visually appealing than others.

Constructions such as homes and commercial buildings are central to social and cultural norms, as well as lifestyles, and these factors play a role in determining what types of constructions are built, how many are built, and how they are built, all of which in turn shapes the associated natural resource use and environmental impacts along the construction value chain.

2.3 Property market: Actors optimise their outcomes within the available conditions

2.3.1 Mortgage-lenders, real estate and individual buyers perpetuate property speculation

Where governments and financial institutions have facilitated speculation in property markets, especially for housing, actors downstream in the construction value chain respond to these signals and further perpetuate property speculation.

- Where governments have put in place the regulatory frameworks to facilitate financialisation of the housing sector, property developers, banks and real estate agents also act as a catalyst.
- Working within regulations set by governments, mortgage lenders can increase the amount of available credit, which can drive the number of individuals taking out loans in order to purchase properties.
- For individuals, property can increasingly become an investment plan rather than an essential service of housing. This is especially the case in the last decade where interest rates remain at record lows, which both reduces the possible return from other types of investment, as well as making it very cheap to borrow money for a mortgage.
- This is facilitated by the aforementioned tax arrangements put in place by governments, that can make it advantageous for individuals to purchase investment properties.
- Particularly in countries with limited state welfare provisions, property can be seen as a financial plan, especially for retirement, in the absence of a social safety net or public pension systems.
- The macroeconomic impacts of increasing private debt and speculation in the housing market can include rising house prices that reduce affordability and increase inequality, as well as financial instability such as was seen in the US during the sub-prime mortgage crisis in the lead up to the 2008 global crisis.

Where governance arrangements promote property as a financial investment instead of an essential service, this can direct the behaviour of actors along the construction value chain including mortgage lenders, real estate companies and individual buyers. The behaviour of these actors in turn can influence what type of constructions are being built, how many constructions are being built, as well as how these constructions are being built, all with consequences for natural resource use and environmental impacts that cannot necessarily be balanced against social needs as acceptable trade-offs.

2.3.2 Uneven access to credit across the world

Property constructions, whether residential or commercial, are long-term investments that usually require access to credit or other funding arrangements up-front before the work can commence. The access to credit

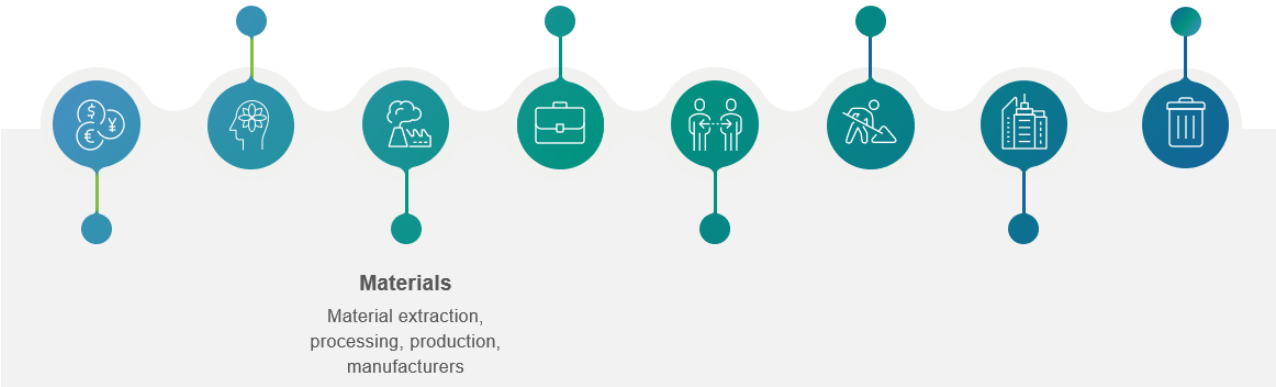
or lack of access to credit is a major influence on what types of constructions are being built, how many are being built and how they are being built.

- Many advanced economies currently have historically low interest rates and easy access to credit, especially for mortgages, which can partly explain the high volumes of construction activity taking place, particularly in housing.
- While in advanced economies the banking and finance systems make access to credit commonplace, in much of the world the banking and finance systems are less developed.
- In many developing countries, where there is a strong need for new constructions including housing, there is often very limited access to credit, especially for mortgages, which can hold back the economic and social development that is needed.
- In some developing countries, innovative financial schemes are created to facilitate access to credit such as for housing construction, including through community-based financial associations or loans provided directly to buyers through real estate stakeholders rather than banks. Other examples include schemes where people buy building materials incrementally to eventually construct their own home.

The banking and finance systems across different countries and the differential access to credit is a key driver of the types and volume of activity in the construction sector, and therefore a relevant factor in considering the natural resources use and environmental impacts along the construction value chain.

3. Limitations at points of resource consumption inhibit sustainability

3.1 Material extraction & production: Environmental and social issues



3.1.1 Increasing construction activity demands growing volumes and new sources of materials

As the total amount of construction activity grows year on year, this requires an ever-increasing source of materials which in turn drives growth of activity at the material extraction and production stage of the construction value chain.

- This increase in total volume of materials is especially noteworthy in the construction activity in China that, as referenced above, consumed more cement between 2011 and 2013 than the USA did in the whole 20th Century (IRP, 2018).
- Sand, gravel, limestone and crushed rock, primarily used in constructions, account for one-third of all materials consumed today in gigatonne terms, and this amount is set to more than double by 2060 (OCED, 2018).

- In the USA, the amount of sand and gravels used in construction is almost exactly ten times the amount of final cement produced. If this were extrapolated to the rest of the world, the total sand and gravels used for construction would be 41 billion tonnes per year (UNEP, 2019b).

Emerging economies are responsible for a growing share of resource extraction, partially reflecting their increase in construction activity. However, many countries are also exporting construction materials to other countries where the constructions are being built.

- Generally, the construction sector aims to reduce high transport costs by extracting materials for construction as close as possible to where they are used.
- China produces the most cement globally, at an estimated 2.4 billion tonnes in 2017, followed by India at 270 million tonnes, and the USA at 86.3 million tonnes in the same year, which reflects the large amount of construction activity taking place in these countries.
- China is the top steel producer, producing more than 50% of all steel produced in the world, followed by India, Japan, the USA and Russia (WorldSteel, 2019). China is also the top consumer of steel and uses more than 50% of all the steel produced in the world in 2019, followed by 10% by the rest of Asia and the 9% from the EU. In comparison, Australia and Brazil are the leading exporters of iron ore, the core raw material used in steel production.
- International trade is growing due to high demand in regions without local resources. Trade in sand and gravel is forecast to rise 5.5% a year with urbanisation and infrastructure development trends. For example, Singapore imports most of its sand from neighbouring Indonesia, Malaysia, Thailand and Cambodia.
- Material- and energy-intensive stages of the construction value chain have in recent decades been increasingly relocated and outsourced to poorer countries where production costs and environmental standards are lower (IRP, 2019).

Information on materials used in construction is generally organised separately based on the specific type of material, and its use across many different sectors, with little analysis and knowledge to date that combines an overarching view of the extraction and processing of the many different materials used along the construction value chain specifically.

In order to better understand the consequences of material usage in buildings and construction on natural resource use and environmental impacts, as well as the socio-economic implications, it will be necessary to bridge this knowledge gap around what materials are being used, where these materials are coming from and what the social, economic and environmental implications are of resource extraction to supply the global construction value chain.

3.1.2 Material extraction and production in developing countries often informal, unregulated and sometimes illegal

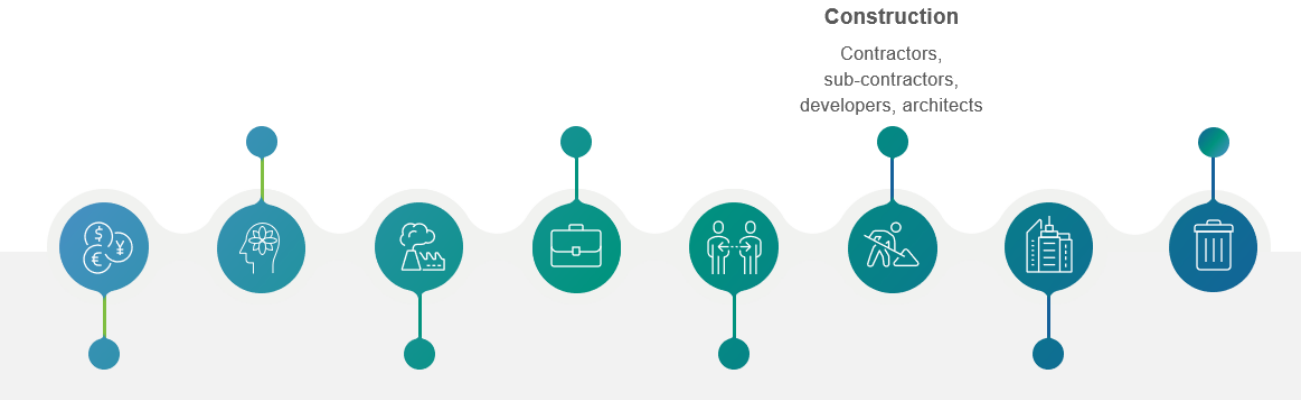
The material extraction stage of the construction value chain is often informal and unregulated, especially where it is taking place in developing countries, and can be associated with negative social and environmental consequences.

- The extraction, production and supply of construction materials can also be associated with poor working conditions and labour exploitation, with cases of child labour reported in the brick making industry of developing countries (ICED, 2018).
- In particular, the huge demand for sand to make essential construction materials concrete and glass is often informal.

- Many sand extraction operations in emerging and developing economies are not in line with extractives and environmental management regulations (UNEP, 2019b).
- Uncontrolled extraction comes at the expense of other economic sectors, local livelihoods and biodiversity. Direct safety risks for those working in the sector and living in the communities where this takes place including drowning, subsidence and landslides in extraction areas.
- Illegal sand extraction is becoming an issue, with "Sand mafias" in places such as India and Morocco threatening local communities and their livelihoods as well as the environment (UNEP, 2019b).
- The people working in unregulated sand extraction, and those living in and around these sites, risk their safety and even their lives when they try to stop uncontrolled extraction (UNEP, 2019b).
- Where regulation does exist, it is either insufficient or not enforced adequately due to corruption, the absence of monitoring, or resources to prosecute offenders (UNEP, 2019b).

As global construction activity grows and demand for construction materials increased, ensuring governance, oversight and regulation of materials extraction and production will be crucial to reducing natural resource use and environmental impacts.

3.2 Construction: Complexity, informality and fragmentation



3.2.1 Different levels of size and power among construction companies globally

The size and makeup of the companies that undertake constructions various significantly across the globe as well as within countries, as well as depending on whether construction companies work on residential, commercial, industrial or infrastructure developments.

- Construction companies range from large enterprises employing up to 100,000 people and engaged in the design and construction of major building and infrastructure projects, to large number of small-scale sub-contractors of sometimes 5-6 people, undertaking specific tasks such as plumbers and electricians (McKinsey Global Institute, 2017).
- The overall majority of global construction activity is undertaken by small and medium sized companies.
- Larger companies have the means to cover both design and construction, while smaller enterprises are usually limited to the construction.
- Large construction companies can influence local administrations to grant construction permissions and award contracts for construction works, due to the size of investment that they bring and the employment they can generate in communities.

- However, most construction companies will be limited by land use regulations and construction policies on the one side, and the property market on the other side, leaving little margin for transformative decisions.

A small number of very large construction companies dominate a comparatively large share of the global market, with global sales of 100 top companies in 2018 at US $1.39 trillion (Deloitte, 2019). In terms of market capitalisation, 40% of value from top 100 construction companies in 2018 was held by Chinese and Japanese companies, with European and North American companies holding a similar percentage of total (Deloitte, 2019). This provides an indication of where the economic and financial capacity of construction companies is stored.

The 10 top construction companies in the world based on total sales are included in table 4 and indicate:

- Five of the companies with the most sales in 2018 are based in China, with Chinese construction companies making up 37% of the top 100 companies' sales.
- Chinese companies are followed by globally important but smaller players based in high-income countries: 13% in Japan, 9% in USA, 8% in France, 7% in Korea, 5% in Spain, 4% in the UK.
- Whereas sales of Chinese construction companies were primarily domestic, international sales made up a significant proportion for construction companies from France, Spain and South Korea.
- Of all international construction company sales in 2018, 57% were attributed to European companies, with the largest income made by ACS (Spain), Vinci (France) and Bouygues (France).
- However, international sales of Chinese companies (e.g. CCCC, CSCEC) are also significant in absolute terms.
- International sales are likely to refer to participation in major construction projects worldwide, partly deployed in emerging markets (eSUB, 2020).

Company	Country	Total sales in 2018 in USD million (% of sales from top 100 companies)	International sales as % of total sales
CHINA STATE CONSTRUCTION ENGINEERINGCORP. LTD. (CSCEC)	China	181,467 (13%)	8%
CHINA RAILWAY GROUP LTD. (CREC)	China	112,026 (8%)	6%
CHINA RAILWAY CONSTRUCTION CORP. LTD.(CRCC)	China	110,473 (8%)	5%
CHINA COMMUNICATIONS CONSTRUCTIONCOMPANY LTD. (CCCC)	China	73,939 (5%)	19%
VINCI	France	51,378 (4%)	43%
METALLURGICAL CORPORATION OF CHINALTD (MCC)	China	43,809 (3%)	8%
ACTIVIDADES DE CONSTRUCCION Y SERVICIOS,S.A. (ACS)	Spain	43,279 (3%)	86%
BOUYGUES	France	41,975 (3%)	39%
DAIWA HOUSE INDUSTRY CO.	Japan	34,260 (2%)	0%
SAMSUNG C&T CORP.	South Korea	28,342 (2%)	32%
Total of top 100 companies	-	1,393,173	

Table 4: Top global construction companies in 2018 based on total sales (Deloitte 2019)

The great variation between types of construction companies presents different challenges and opportunities for reducing natural resource use and environmental impacts along the construction value chain, and will require different tools, levers and incentives targeted to the various types of actors.

3.2.2 Construction SMEs face a range of challenges

Construction companies deal with many competing obligations, drivers and barriers that can result in particular characteristics within the construction industry, many of which can limit the ability to transition to more sustainable activities and mean environmental considerations are often at the bottom of the list.

- Construction companies, especially SMEs, generally work with low profit margins, meaning keeping costs down is of prime importance which can limit the scope for using more sustainable materials and practices.
- At the same time, construction SMEs must often abide by complex building codes, leaving them squeezed between regulation and costs.
- The construction industry is characterised by a low labour productivity (the added value by construction workers per hour of work) compared to other industrial sectors, with a worse condition for smaller companies.
- A low productivity can mean inefficient use of resources and can be due to factors such as market fragmentation, re-negotiation of contracts and missed transparency on costs, inefficient design that does not take standards into account, insufficient time dedicated to plan how to manage and execute projects, lack of skills and access to innovation, informal and low wage work (McKinsey Global Institute, 2017).

The construction industry is also highly complex and fragmented, with a large number of different actors operating at a small-scale.

- Workers directly employed by construction companies include construction workers, carpenters, electricians and, to a lower extent, managers, architects and engineers, equipment operators, providers of legal and administrative services.
- Innovation in the construction industry is slow moving because of the time dimension of construction projects and because various actors and experts address different aspects often in isolation.

Informality in the construction sector is also a major problem, especially in many parts of the developing world which lack building codes, formal regulation of the construction sector and effective implementation of labour rights and conditions.

- In most countries, construction companies outsource elements of the project to various subcontractors and other intermediaries.
- Many developing countries rely largely on informal and non-standard employment that include part-time, casual and temporary contracts.
- Migrants are frequently employed in non-skilled and semi-skilled jobs, especially where the sector is not heavily regulated.
- Informality in the construction industry can result in a number of negative consequences such as poor conditions and safety of workers, as well as unsafe and unsound constructions.
- Informality in the construction industry can also impact the types of building materials used and result in increased natural resource use and environmental impacts along the construction value chain.
- For example, where construction is informal, the production of concrete is also informal, often being mixed onsite and not controlled by any authorities. Informal or on-site concrete mixes in Costa Rica

and Colombia can consume nearly 30-40% of more cement per cubic metre, producing more CO2 emissions in the same construction (Asocreto, 2020).

While construction companies are a key actor along construction value chains, the various challenges and limitations faced by the sector reduce its ability to transition more sustainable materials and practices, and to decrease natural resource use and environmental impacts.

3.3 Operation & Use: Opportunities & barriers for end-users to influence resource use and environmental impacts

3.3.1 Final users face limited choices and awareness of sustainable construction options

Individual users of constructions, especially occupiers as homes as either buyers or renters, face limited choice in the types of constructions available to them, particularly as regards the sustainability of these buildings and the natural resource use and environmental impacts involved in either the construction to the use phases.

- Few end users of constructions have the opportunity to contribute to the design or planning stage of a building, with most needing to choose from the existing building stock that is available or purchase a new building for which the design and planning has already been determined.
- In many cities, people have no choice but to live in rundown areas or in informal settlements, highly depending on fossil fuels for transport (IRP, 2018).
- Although users have limited choice at the time of deciding where to live, they can have some influence on the water, energy and materials consumed in buildings through their lifestyle choices.

Another factor that influences natural resource use and environmental impacts of constructions at the use and operations stage is that a large part of the housing stock is either rented or undergoes regular changes in ownership. Investments that result in long-term benefits are often not a high priority for short-term renters and temporary homeowners (IRP, 2017b).

Furthermore, a share of population lack of awareness on environmental issues associated with constructions. For example, despite the colossal quantities of sand and gravel being used and the environmental impacts related to their extraction, the issue is largely unknown to the general public and policymakers (IRP, 2019).This can make it difficult for users to make more sustainable decisions in regard to the constructions that they own or occupy.

While the use and operations stage of the construction value chain makes a major contribution to natural resource use and environmental impacts along the construction value chain, the actors at this value chain often lack the ability and awareness to make a change.

3.3.2 Renovation can improve the performance of buildings and constructions

The ability to reduce natural resource use and environmental impacts at the use and operation stage of constructions is to a degree pre-determined before the construction is built by decisions that are taking at the design and planning stage of the value chain. Many buildings were originally designed without taking energy efficiency aspects into account.

However, opportunities do exist to renovate existing buildings to make them more efficiency, such as through renovating windows, doors and insulations. Although technologies and methods to reduce environmental impacts exist, their investment cost could be prohibitive for certain population categories, especially low-income groups (IRP, 2017b).

Financial support is vital to develop new technologies and methods and to facilitate their uptake.

- This requires collaboration of building owners and users, businesses and governments, as well as alignment with long-term sustainability goals.
- Examples of forms of financial support are government-sponsored cost-efficient loans for homeowners to renovate or retrofit their homes.
- It is possible to ensure that such loans are affordable and accessible for all through programmes specifically targeting low-income households (e.g. as done in Mexico or Boston).

While natural resource use and environmental impacts of the use and operation stage of value chains is to a large degree determined at the design and planning stage, renovation of existing buildings presents an opportunity to improve sustainability at this stage, however barriers will need to be overcome to bring this about.

IV Conclusions

1. Construction is integral to achieving the SDGs, but direction is needed

Construction is the sector with the largest global material footprint and is responsible for 50% of total global material consumption (SCP-HAT 2020), and the materials used in construction are associated with significant natural resource use and environmental impacts. Natural resource use primarily occurs at the material extraction and production stage, at the construction stage, as well as during during the use and operation of buildings and infrastructure. Associated with the consumption of natural resources and the production and consumption of building materials, there are significant environmental impacts along the construction value chain, including climate change and air pollution.

Construction also plays an integral role in meeting Sustainable Development Goals. Construction is critical to achieving the human right to adequate housing; to building essential infrastructure necessary to provide mobility, energy, drinking water and sanitation; as well as to building the commercial and industrial infrastructure necessary to support economic development, all the while providing opportunities for employment and decent work.

The importance of construction to meeting the SDGs means that there may be some trade-offs when it comes to natural resource use and environmental impacts of the construction sector, though it is also imperative that the sector transitions as much as possible toward resource efficiency, circularity and a smaller environmental footprint. However, the analysis has also shown that not all constructions contribute to sustainable development, and some activity in the construction sector can even result in harmful socio-economic consequences, making the natural resource use and environmental consequences difficult to justify.

2. Key decisions are made far from where natural resources are used

The analysis in section one identifies that the majority of natural resource use and environmental impacts along the construction value chain take place at the material extraction and production stage, the construction stage and the use stage. However, the systems analysis in section two highlights that there is limited scope at these stages of the value chains to make changes to reduce natural resource use and environmental impacts for a number of reasons, including the informality, fragmentation, complexity at these stages, as well as limitations in knowledge, awareness and available options.

In contrast, the systems analysis demonstrates that the most influential actors along the construction value chain are governments, international organisations, financial institutions and major market players, who are primarily acting at the financing stage and the planning and design stage of the construction value chain. The key decisions made at these stages largely determine what types of constructions are built, how many constructions are built, and how constructions are built, and thereby shape the activity along the rest of the value chain.

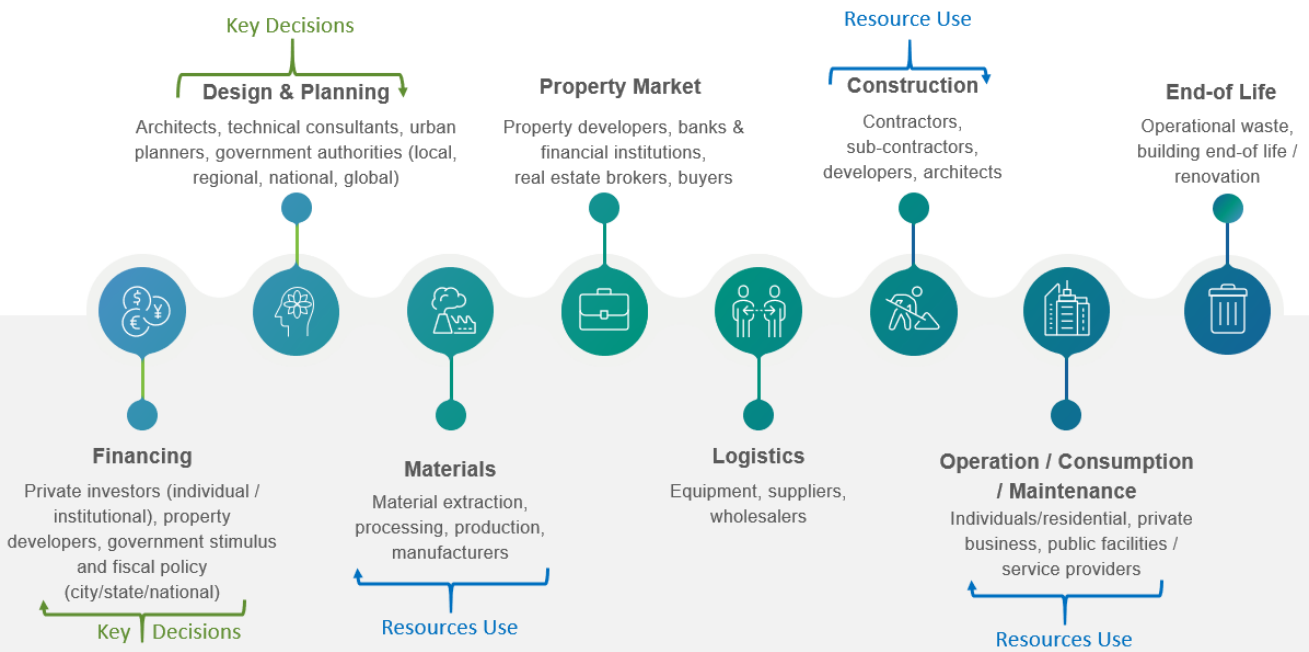


Figure 9: Key stages of the construction value chain where decisions are taken

2. Governments exert significant influence along construction value chain

Compared to other sectors, the role of governments and multilateral organisations in shaping activity along the construction value chain is significant, and occurs in three key ways:

1. As **regulators of financial markets**, the **banking system**, and **tax systems**, governments influence how much and what type of constructions are built, especially for housing, particularly at the financing stage and property market stage of the construction value chain.
2. As **investors in the construction** sector through the **public procurement** of buildings and infrastructure, governments can directly influence what is being built, how much is being built and how constructions are being built through the procurement criteria they apply and the vendors they choose to engage.
3. As **urban and territorial planners**, and **regulators of the construction sector**, governments also indirectly determine what is being built, how much is being built and how constructions are being. How governments regulate the construction sector through tools such as building codes and zoning laws can influence the operations of actors along the construction value chain, especially at the planning and design stages; the construction material stages; the construction stages; and, as a result, the use stage.

Through the above three levers, governments have a major influence along the construction value chain on shaping what is being built, how much is being built and how constructions are being built, and it is these three levers that governments already use a combination of when stimulating the construction sector to boost economic activity or promote recovery during times of economic downturn or crisis.

Governments therefore have a strong opportunity to reduce the natural resource use and environmental impacts of the construction sector through using these three key levers to drive resource efficiency in the sector and ensure construction activity is directed towards meeting the 2030 Agenda for Sustainable Development.

V Challenges and Opportunities

Addressing the three challenges outlined below of what type of constructions are being built, how many constructions are being built, and how constructions are being built can contribute to reducing natural resource use and environmental impacts along construction value chains.

Importantly, while each of the below opportunities may target other stages along the construction value chain, they can all influence the use of natural resource use and the environmental impacts that takes place at the material extraction and production stage, the construction stage, and the use stage.

Challenges	Opportunities
1) What type of constructions are built and used? Different types of constructions contribute in different ways to meeting needs of societies and achieving the sustainable development goals, and can cause different pressures on use of resources and environmental impacts depending on, For example - residential/commercial/industrial/infrastructure - affordable/luxury	**Promote and enable adequate and sustainable constructions:** Examples: - Reshape regulation and planning of the territory to ensure the participation of different actors and the adequate allocation of urban and rural spaces to different activities without reducing spatial density (and increasing consumption of resources); - Public authorities working with real estate, construction companies and financial institutions for prioritising investments

- private/public - utility/commercial and related service provision - multi-residential v. mono-residential buildings	in sustainable construction projects (e.g. renovation of existing buildings v. construction of new buildings); - Promote sustainable constructions through public procurement processes. - Ensure economic stimulus programmes are designed to meet social needs and deliver on the SDGs.
2) How much is being built? The construction market is growing worldwide, which causes pressures on resources and environmental impacts. However, constructions do not necessarily follow demand. For example, empty buildings and property speculation is registered in many developed countries, while there is a construction gap in developing countries.	**Align development needs with supply of constructions worldwide** Examples: - Capital investments made by governments and privates are the engine determining what, where and how much we build. There is a strong opportunity to focus investments where there is a deficit of constructions, rather than oversupply constructions where not needed. - Continued and better use of buildings, which would limit the demand for new constructions, can be promoted through financial and fiscal incentives for the renovation of the existing stock. - Taxation of additional properties, especially in case of empty property, acts as a disincentive to property speculation and as mean for the redistribution of welfare. - Although constructions are planned and approved by public authorities, territorial planning must ensure that new constructions do not harm the environment and meet real demands of society (e.g. through regulations).
3) How are constructions built and used? Impacts of constructions are associated with: - Type and amount of construction materials used: a construction can be made using different combinations of materials that come with different "embodied" impacts (e.g. if sustainably sourced, an increased use of timber can be a promising option); - Consumption of resources in the operation of buildings: water and energy resources are consumed in buildings, which vary depending on design and users; - Construction and demolition processes: they make 40% of solid waste production in developed countries, less than one third of which is recovered. Changing design, construction and use practices is fundamental to use resources more efficiently and reducing environmental impacts.	**Adopt more sustainable practices relating to the manufacturing of construction products and the design, construction and use of buildings and infrastructure** Examples: - Rethink design: design, and to a lower extent construction, are key phases to determine the environmental impacts of buildings and infrastructures. Sustainable design practices promoting material and energy efficiency are emerging on the market. - Develop and apply building codes and certifications: sustainable design concepts such as material and energy efficiency can be integrated in existing regulatory and market instruments such as building codes and certification systems. - Understand and improve the procurement of construction materials: more sustainable construction materials options can be identified based on certification and labelling systems (e.g. type III environmental labels), and their management in construction projects can benefit from digitalisation opportunities such as Building Information Modelling. - Recover construction and demolition waste: while recycling rate targets are set in some countries, there is the need to promote the reduction and reuse of waste, as well as incentivize their recycling (e.g. through taxation or fiscal incentives). - Develop and implement innovations: technical options are available that can allow a more efficient use of resources in the construction and operation stages.

	- Exploit catalytic actions by governments (e.g. public procurement, investment and incentives on eco-innovations) and civil society (public awareness campaigns).

Annex I: Key International Resource Panel reports addressing Construction

The table below lists the main International Resource Panel reports that address an aspect of the construction value chain.

Report	Content
"Global material flows and resource productivity" (IRP, 2016)	Description of key materials used in **buildings and constructions**, impacts and material efficiency strategies
"Resource efficiency: potential and economic implications" (IRP, 2017)	Overview of impacts associated with **buildings**, and discussion on drivers, material efficiency strategies and other improvement options from a **system perspective**
"Assessing global resource use" (IRP, 2017)	Overview of impacts associated with buildings and constructions, and discussion on drivers, material efficiency strategies and other improvement options from a **system perspective**
"Resource efficiency for sustainable development: key messages for the group of G20" (IRP, 2018)	Indication of key improvement options for **buildings**
"The weight of cities: resource requirements of future urbanization" (IRP, 2018)	**System approach** to the analysis of resource consumption and efficiency in **cities**, with a focus on **urbanism, transport, commercial buildings and building heating/cooling**
"Emission gap report" (UNEP 2019)	Information about global greenhouse gas (GHG) emissions in buildings and constructions, as well as strategies to improve material efficiency in **residential buildings** and quantitative indications about the related GHG savings in G7 countries, China and India.
"Global resource outlook" (IRP, 2019)	Description of key materials used in **buildings and constructions**, impacts and material efficiency strategies
"Resource efficiency and climate change: material-efficiency strategies for a low-carbon future – Summary for policy-makers" (IRP, 2020)	Information about global greenhouse gas (GHG) emissions in buildings and constructions, as well as strategies to improve material efficiency in **residential buildings** (the most important category in terms of climate change impact within the construction sector) and quantitative indications about the related GHG savings in G7 countries, China and India.

Furthermore, the following databases were consulted for a preliminary analysis of data on use of resources and impacts occurring along the value chain:

- http://scp-hat.lifecycleinitiative.org/methods/
- http://www.materialflows.net/visualisation-centre/
- https://www.resourcepanel.org/global-material-flows-database

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