12 Ensure Sustainable Consumption and Production Patterns

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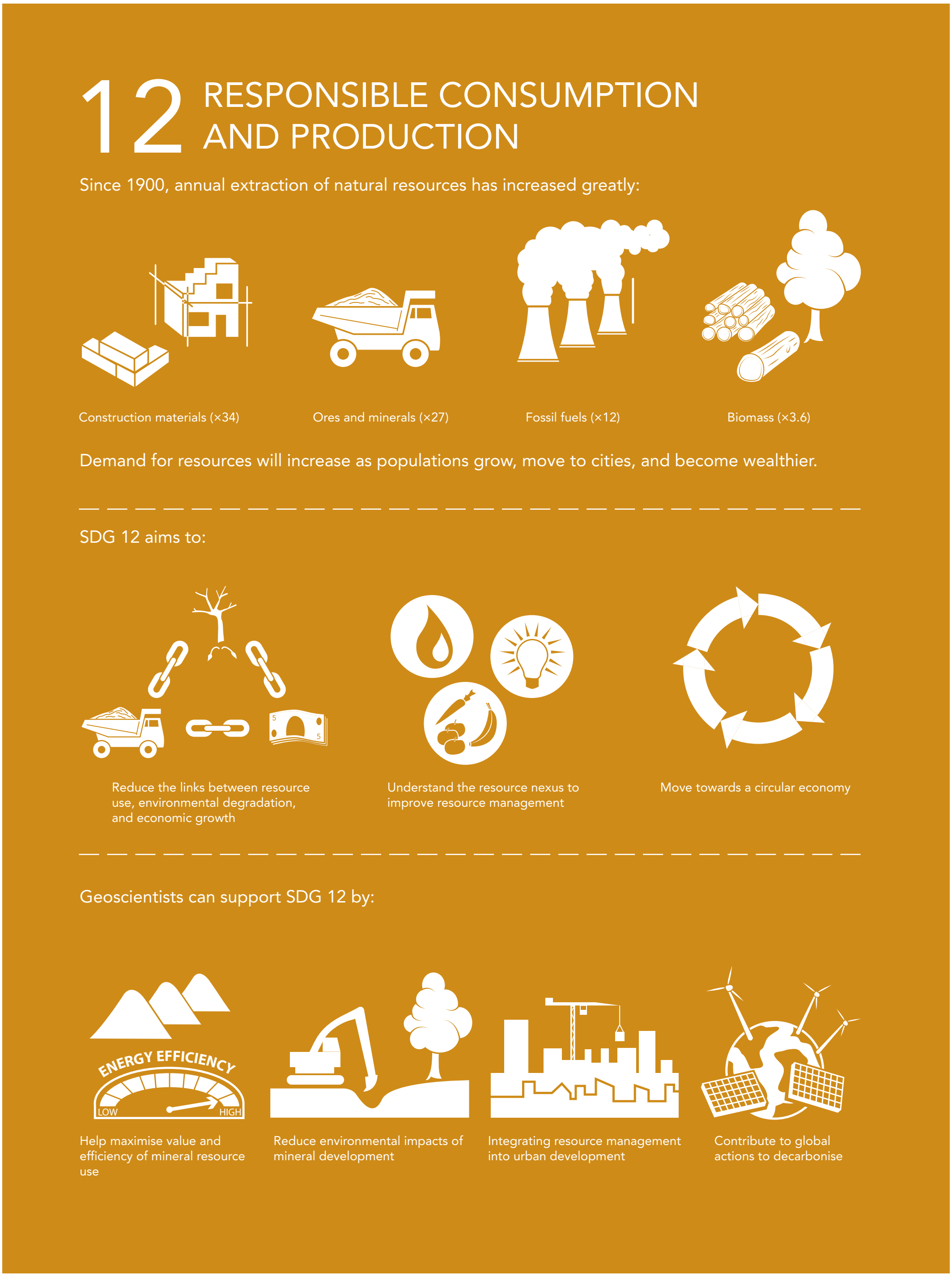
Abstract


12 RESPONSIBLE CONSUMPTION AND PRODUCTION
Since 1900, annual extraction of natural resources has increased greatly:
Construction materials (×34)
Ores and minerals (×27)
Fossil fuels (×12)
Biomass (×3.6)
Demand for resources will increase as populations grow, move to cities, and become wealthier.
SDG 12 aims to:
Reduce the links between resource use, environmental degradation, and economic growth
Understand the resource nexus to improve resource management
Move towards a circular economy
Geoscientists can support SDG 12 by:
ENERGY EFFICIENCY
LOW
HIGH
Help maximise value and efficiency of mineral resource use
Reduce environmental impacts of mineral development
Integrating resource management into urban development
Contribute to global actions to decarbonise

12.1 Introduction

Global demand for natural resources has increased greatly in recent decades as countries seek to develop their economies and enhance the standard of living of growing local populations. During the twentieth century, the annual extraction of construction materials grew by a factor of 34, ores and minerals by a factor of 27, fossil fuels by a factor of 12, and biomass by a factor of 3.6 (UNEP 2014a). Global material use has tripled over the past four decades (1977−2017), with annual global extraction of materials growing from 30 billion tonnes in 1977 to 92 billion tonnes in 2017 (Fig. 12.1). Material extraction per capita (Fig. 12.2) increased from 7 to 10 tonnes between 1970 and 2010 indicating improvements in the material standard of living in many parts of the world; however, large gaps in material standard of living exist between North America and Europe and all other world regions and, in particular, Africa (UNEP 2016).

The global population is predicted to grow from an estimated 7.7 billion in 2019 to 8.5 billion in 2030 and 9.7 billion by 2050 (UN 2019a). It will also become increasingly urban, rising from 55% of the global population in 2018 to 68% in 2050 (UN 2018a). The bulk of that growth will take place in Africa and Asia. This growth in the global population will at the same time be accompanied by a significant increase in global middle classes—from 1.8 billion in 2009 to 4.9 billion in 2030 (Pezzini 2012). While the bulk of growth in middle classes will be in Asia (Pezzini 2012), there will also be significant growth in Africa (which has already tripled over the last 30 years) to 1.1 billion (42% of the continent's population) by 2060 (Deloitte 2014).

Global population growth accompanied by the expected rise in the middle classes means that demand for an improved quality of life will drive a need to access goods and services, increasing pressure on the use of natural resources. If current resource consumption patterns were to continue (Figs. 12.1 and 12.2), it is estimated that global material use of metals, non-metallic minerals, fossil fuels, and biomass would reach between 167 billion (OECD 2018) and 190 billion (UN 2019b) tonnes per year by 2060 of which non-metallic minerals such as construction aggregates (e.g., crushed rock, sand, and gravel) will represent more than half of the total raw material use (OECD 2018).

The aim of **SDG 12**[1] (Table 12.1)—**Ensure Sustainable Consumption and Production Patterns**—is *to achieve equitable development while at the same time ensuring sustainable management of resources*. It has been recognised that delivering sustainable consumption and production patterns requires coordinated action in order to reduce unsustainable resource use, to minimise waste, and to improve the management of hazardous substances. As a result, the United Nation's 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns[2] has been incorporated into **SDG 12**. This is a global framework for action to enhance international cooperation and accelerate the shift towards sustainable consumption and production patterns in both developed and developing countries.

12.2 Global Challenges and Progress

The traditional global material footprint (the total amount of raw materials extracted to meet final consumption demands) as shown in Figs. 12.1 and 12.2 currently supports unequal standards of living. In 2017, the average person in North America required about 30 tonnes of raw materials to support their standard of living; this compares with 20.6 tonnes per capita material footprint in Europe, 11.4 tonnes in the Asia Pacific region, 10.2 tonnes in Latin America and the Caribbean, 9.6 tonnes in West Asia and less than 3 tonnes for a person living in Africa (IRP 2017). If sustainable development is to be

[1]A full listing of all the SDG targets and their indicators in MS Excel format can be accessed via https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202019%20refinement.English.xlsx.

[2]https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=1444&menu=35.

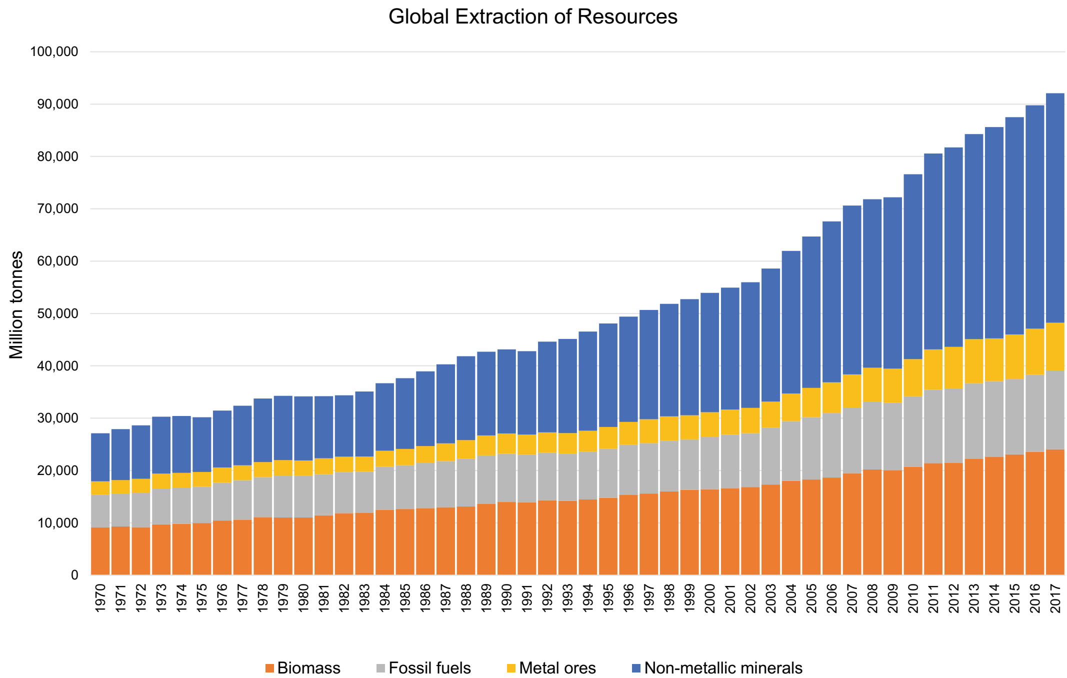


Fig. 12.1 Global resource consumption 1970–2017. Data from IRP (2019)

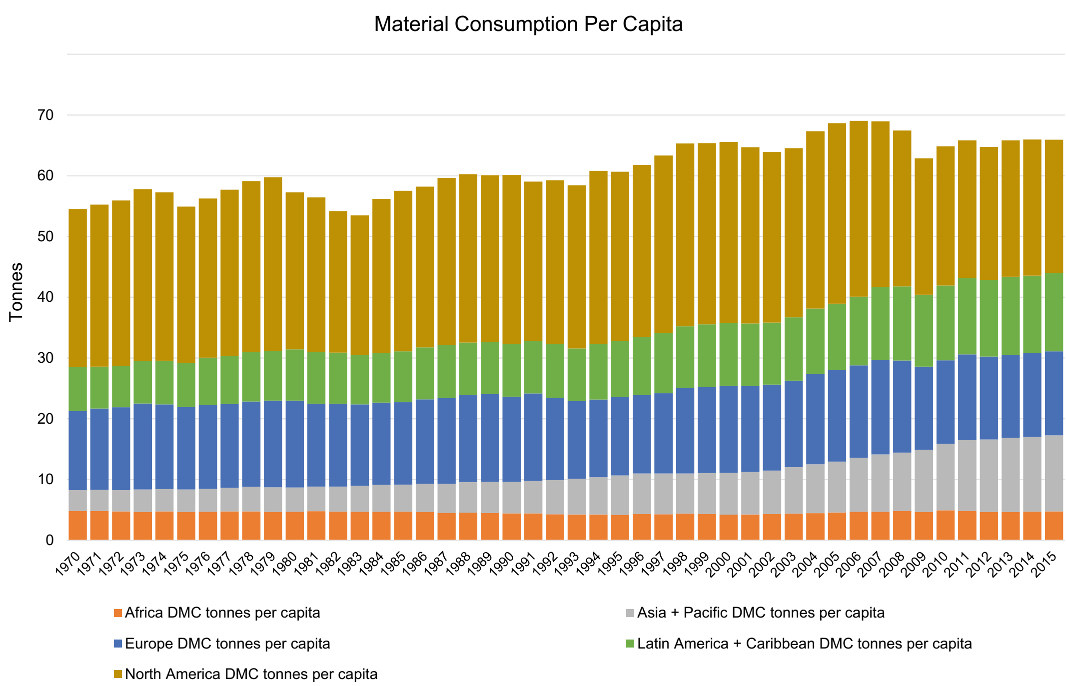


Fig. 12.2 Material consumption. Data from IRP (2019)

achieved while at the same time ensuring equitable development and delivery of **SDG 12**, there is a need to

- Reduce the intrinsic link between (to decouple) escalating natural resource use and environmental degradation from economic development.
- Recognise the critical interlinkages between different types of resources themselves by employing a systems approach and taking these into account, help to avoid burden shifting—the resource nexus.
- Move away from material supply and use within the traditional linear economy (take–make–use–dispose) to that of a circular economy (which maximises resource efficiency, innovation across the whole product life cycle, value addition, reuse, and recycling while minimising the generation of waste and negative environmental and social impacts).
- Develop and employ fit-for-purpose methodologies to monitor progress towards achieving the **SDG 12** targets.

All of the above are intrinsically linked with each other and are able to contribute to ensuring sustainable consumption and production patterns. Geoscience has an integral role in delivering them.

12.2.1 Decoupling Natural Resource Use from Economic Development

If sustainable consumption and production patterns are to be achieved while at the same time meeting the material requirements to ensure human well-being within the growing global population, there is a need for all countries (high as well as low and middle income) to break the link (to 'decouple') escalating resource use and environmental degradation from economic growth (UNEP 2011, 2014). Decoupling means reducing the amount of natural resources such as water, biomass, and minerals used to produce economic growth. While the sustainable use of natural resources and materials is the focus of **SDG 12**, decoupling resource use and environmental degradation from economic development is also targeted in **SDG 8.4**.

Enhancing resource efficiency means achieving the same (or greater) production of goods and services (economic) output with fewer inputs and delinking economic development from environmental deterioration. UNEP (2011) and Hennicke et al. (2014) differentiate between two types of decoupling as applied to sustainable development:

- **Resource decoupling**—it means reducing the use of (primary) natural resources per unit of economic activity.
- **Impact decoupling**—it means raising economic output while reducing negative environmental impacts that arise from the extraction of natural resources (e.g., groundwater pollution due to mining or agriculture), production (e.g., land degradation, wastes, and emissions), use of commodities (e.g., CO_2 emissions from transportation), and in the post-consumption phase (e.g., wastes and emissions).

While there are trends to decouple resource use and economic growth in resource-intensive mature economies, this is less the case for low- and middle-income countries (Angrick et al. 2014). However, by implementing policies which reflect the need for decoupling and by utilising different and emerging technologies, it is possible for such countries to grow their economies without following the same levels of historic resource use as those which occurred in mature economies around the world (UNEP 2014; IRP 2017). While global resource efficiency grew by around 27% between 1980 and 2009, it rose by 98% in India and 118% in China (Hennicke et al. 2014). Barriers related to, for example, technological innovation, resource-efficient infrastructure, and poor policy implementation currently disadvantage investments in resource productivity (see **SDG 9** also). The countries which are able to overcome such barriers will be able to lead the next wave of

Table 12.1 SDG 12 targets and means of implementation

Target	Description of target (12.1–12.8) or means of implementation (12.A–12.C)
12.1	Implement the 10-Year Framework of Programmes (10YFP) on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
12.2	By 2030, achieve the sustainable management and efficient use of natural resources
12.3	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses
12.4	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimise their adverse impacts on human health and the environment
12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
12.6	Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle
12.7	Promote public procurement practices that are sustainable, in accordance with national policies and priorities
12.8	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature
12.A	Provision of support to developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
12.B	Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products
12.C	Rationalising inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimising the possible adverse impacts on their development in a manner that protects the poor and the affected communities

development. It is also easier to design for resource efficiency at the start of a process or project, rather than when a specific route is already in place thus potentially offering developing countries an advantage over more mature economies. In order to both monitor and assist in the delivery of 'decoupling', the UNEP incorporated it within the mandate of the International Resource Panel (IRP) which was established in 2007. The IRP aims to improve the evidence base for monitoring and policymaking, in particular, through systems-based assessment of the resource-related challenges and opportunities supporting the transition towards sustainable development (IRP 2017).

12.2.2 The Resource Nexus

The critical and complex interlinkages between different resources have received increased recognition in recent years. As a result, the concept of the resource nexus has increasingly been adopted to facilitate an integrated approach to the assessment of the resource life cycle. Commonly adopted is the water–energy–food nexus (see Ferroukhi et al. 2015; D'Odorico et al. 2018). Others, however, have adopted a four- (see Ringler et al. 2013) or five-node nexus (Fig. 12.3) which incorporates the essential systems of water (**SDGs 6** and **15**), energy (**SDG 7**), food (**SDG 2**), land (**SDG 15**), and material resources proposing that it better captures the realities and complexities of the human–environment system and related goals as specified in the SDGs (see Bleischwitz et al. 2018).

In order to meet material demand from the present and future generations, strategic and holistic thinking about the potential factors that may affect supply and demand for resources is paramount (de Ridder et al. 2014; WEF 2014; UNEP 2015a; Wakeford et al. 2016). At present, sustainability assessments and governance frameworks aim to address issues around individual resources (e.g., raw materials or water) without taking into account potential interdependencies between them. In other words, a 'singular thinking approach' is favoured at the moment rather than a holistic or systemic one (Giampietro 2018). Nexus governance offers an opportunity to be both adaptive and innovative (Marx 2015). Bleischwitz et al. (2018) note that if the SDGs are implemented in ways that overlook the critical interlinkages between different resources, all of the SDGs (not just **SDG 12**) may well risk a further acceleration of natural resource demand and degradation, ensuring numerous knock-on effects on individuals, communities, businesses, and societies—and the ecosystems on which all depend. Table 12.2 lists some of the direct and indirect impacts related to the water–energy–food nexus.

To be effective in overcoming such impacts, nexus-style solutions need to be adopted at the policy and planning levels. However, this will require a significant change in institutional thinking and working. Single-sector, top-down, and compartmentalised approaches are insufficient in tackling the challenges surrounding sustainable utilisation of water, energy, food, and other natural resources. There is a need to move away from exploring impacts in isolation and move towards a systemic approach. All too often agricultural policies (e.g., those linked to **SDG 2**), for instance, continue to be drafted in isolation of water policies (**SDG 6**) and vice versa while institutions with higher level objectives in common (such as food economic growth or socio-economic transformation) fail to cooperate, and instead compete for resources, both financial and natural (Riddell Associates 2015). For example, 29 national and county departments and agencies have responsibility for water–energy–food-related functions in a single county of Kenya (Thuo et al. 2017). The level of institutional coordination required to overcome such a silo approach is often significant. Several different stakeholder groups should be considered, including their needs and requirements when following a systemic approach (Fig. 12.4).

To date, while the resource nexus offers a promising conceptual approach, the use of nexus methods to systematically evaluate resource interlinkages or support the development of socially and politically relevant resource policies has been limited (Albrecht et al. 2018).

12.2.3 Transitioning to a Circular Economy

The global system of production and consumption has historically been predominantly linear whereby the focus has been on ensuring the supply of materials to meet demand. It has been facilitated by a century of declining commodity prices. If decoupling economic growth and the future well-being of the global population from the use of natural resources is to be achieved, there is a need to change from the historic linear economic approach (take–make–use–dispose) to that of a circular economy. A circular economy relies on sustainably sourced natural resources, and products that are designed for repair, reuse, remanufacture, and recycling (Fig. 12.5) (see Lee et al. 2012; Hennicke et al. 2014). Within a circular economy, the environmental and social consequences of primary resource extraction and processing continue to be minimised, while maximum value is extracted from resources (and their derived products) thus keeping them in use for as long as possible and minimising the disposal of materials as waste. While some aspects of natural resource use (such as forestry and agriculture) are 'restorative and regenerative' by design (Ellen MacArthur Foundation 2017), for other natural resources, in particular minerals, importance within the circular economy is placed

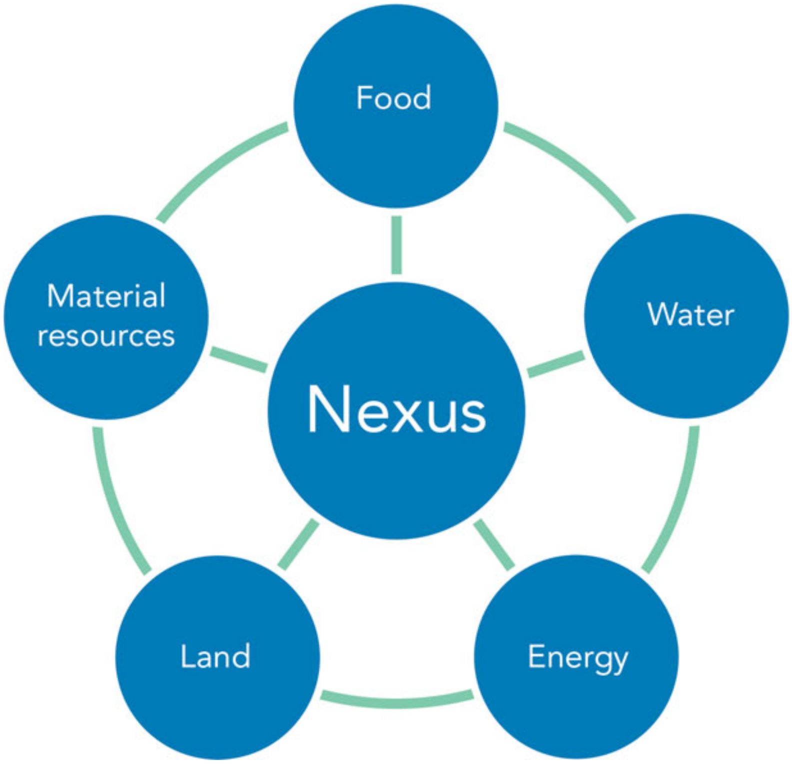


Fig. 12.3 The resource nexus

Table 12.2 Impacts of risks related to the water–energy–food nexus (non-exhaustive) (WEF 2011)

Impacts	Direct impacts	Indirect impacts
Impact on governments	• Stagnation in economic development • Political unrest • Cost of emergency food relief • Significantly reduced agricultural yields • Threats to energy security	• Increased social costs linked to employment and income loss as agriculture is negatively effected • National security risks/conflicts over natural resources
Impact on society/populations	• Increased levels of hunger and poverty • Increased environmental degradation • Severe food and water shortages • Social unrest • Food price spikes	• Migration pressures • Irreparably damaged water sources • Loss of livelihoods
Impact on business	• Export constraints • Increased resource prices • Commodity price volatility as shortages ripple through global markets • Energy and water restrictions	• Lost investment opportunities

Fig. 12.4 Stakeholder groups often involved in the nexus approach

on maximising length of use followed by reuse and recycling to enhance sustainability. Increased efficiency across the entire life cycle of resource use means more effective extraction and production, sustainable and smarter consumption as well as prevention and minimisation of negative environmental impacts (Hislop and Hill 2011; Preston 2012; UNEP 2012; IRP 2017).

In order to monitor the development of the circular economy, it is essential to quantify and understand the amount of materials flowing in and out of the economy, how they are used in society, and their level of circularity (Bloodworth 2013). Quantification of materials flowing into and out of the economy along with the stocks of materials being used in the economy is undertaken using Material Flow Analysis (see Brunner and Rechberger 2017; Nuss et al. 2017; EIPRM 2018; Allesch et al. 2018).

The circular economy has been receiving attention not only by countries with developed economies such as Japan, the European Union, and China who have all instituted high-level policy agendas (see UNEP 2016) but also by lower- and middle-income countries who increasingly look to enhance existing or adopt new circular economy approaches as a means for achieving sustainable economic growth (see Republic of Rwanda 2015; Gower and Schroeder 2016; Soezer 2016; Preston and Lehne 2017). For developing countries, circular economy policies (combined with urban planning that enables the beneficial exchange of materials and energy across different industry and infrastructure sectors in cities) are found to yield economic gains, natural resource conservation, greenhouse gas mitigation, and air-pollution reductions (IRP 2017).

As noted by Schroeder et al. (2018), while adopting circular economy practices will help to achieve **SDG 12**, they also contribute directly to achieving **SDG 6**, **SDG 7**, **SDG 8**, **SDG 9**, and

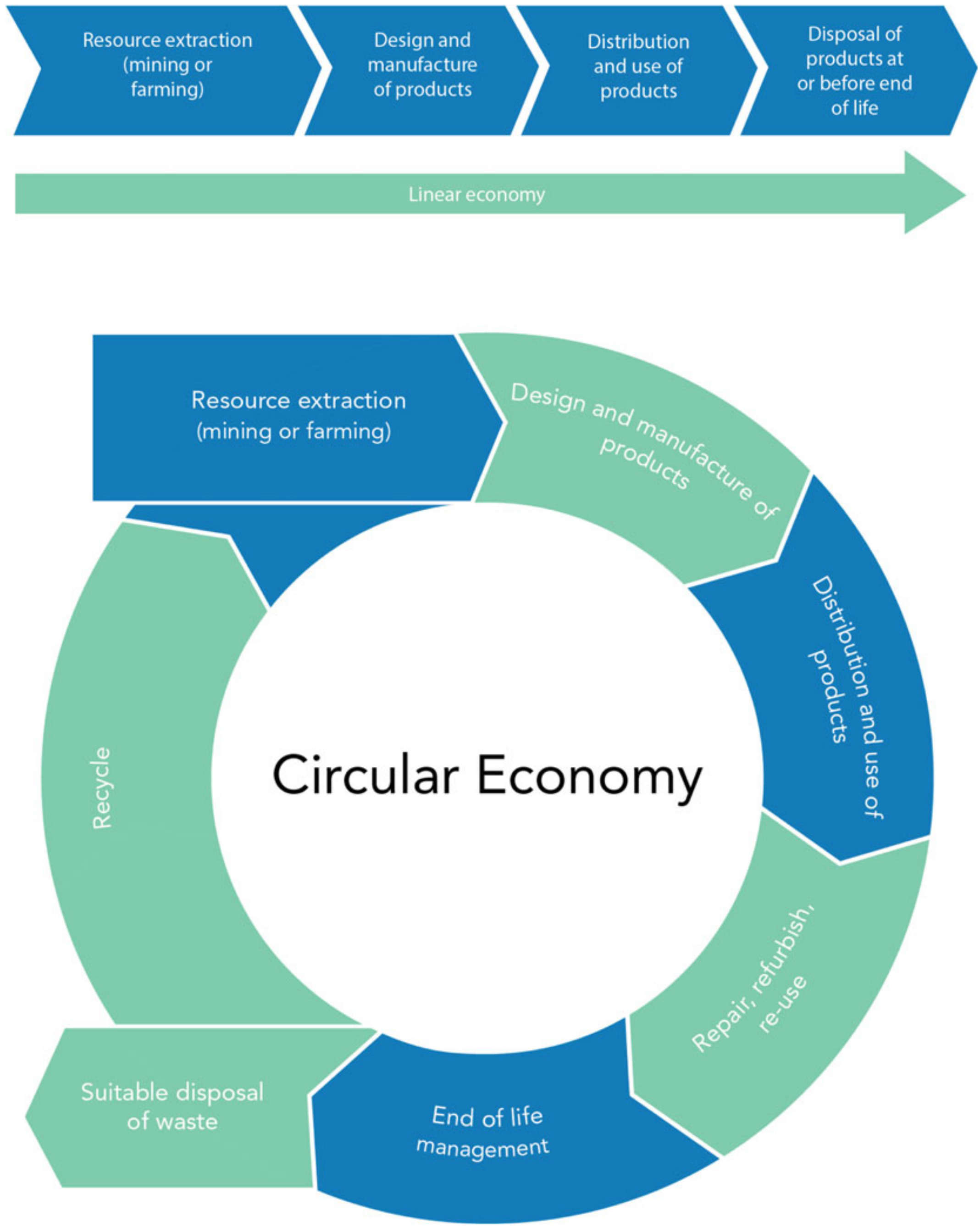


Fig. 12.5 The linear (top) versus circular (bottom) economy

SDG 15 and indirectly to many of the others. However, like all sustainable development initiatives, increasingly adopting a circular economy is likely to have trade-offs with other SDG targets. For example, while transitioning to circular economic approaches clearly delivers benefits in terms of maximising reuse and recycling of materials thus reducing demand for primary raw materials, any approaches or strategies implemented as part of the circular economy may only partially address barriers to economic and industrial development and they also should not be assumed to be optimal from a social or environmental perspective (Preston and Lehne 2017).

Whilst the drive towards achieving a circular economy is viewed as one of the key solutions to significantly decreasing demand for natural resources, it has to fit within the context of understanding the length of time materials stay in use (lifetime) within an economy along with the increasing global population and its material demand requirements. When the demand for a commodity increases over time, recycling alone cannot meet the higher demand—even if all products were collected and recycled with 100% efficiency at the end of their life. For example, global copper consumption in 1970 was about 8 million tonnes; by 2010, this had increased to 23 million tonnes (BGS 2018). If all the copper incorporated into products in 1970 were recovered at the end of their life in 2010, there would still be a supply shortfall (the recycling gap) of 15 million tonnes which could be filled only by primary production (Fig. 12.6). As long as consumption increases, the need for primary extraction of minerals to meet global demand will continue (Bloodworth et al. 2017; Wellmer et al. 2019). However, a long-term future situation where consumption begins to level off and secondary resources progressively displace mined material can be envisaged (Bloodworth et al. 2019).

Like all global industries, companies operating in the mining sector have an opportunity to contribute towards achieving not only **SDG 12** but also all the SDGs. Common opportunities for the mining sector to contribute positively to **SDG 12** include enhancing material stewardship, minimising waste, and incorporating life cycle thinking into operations (WEF 2016).

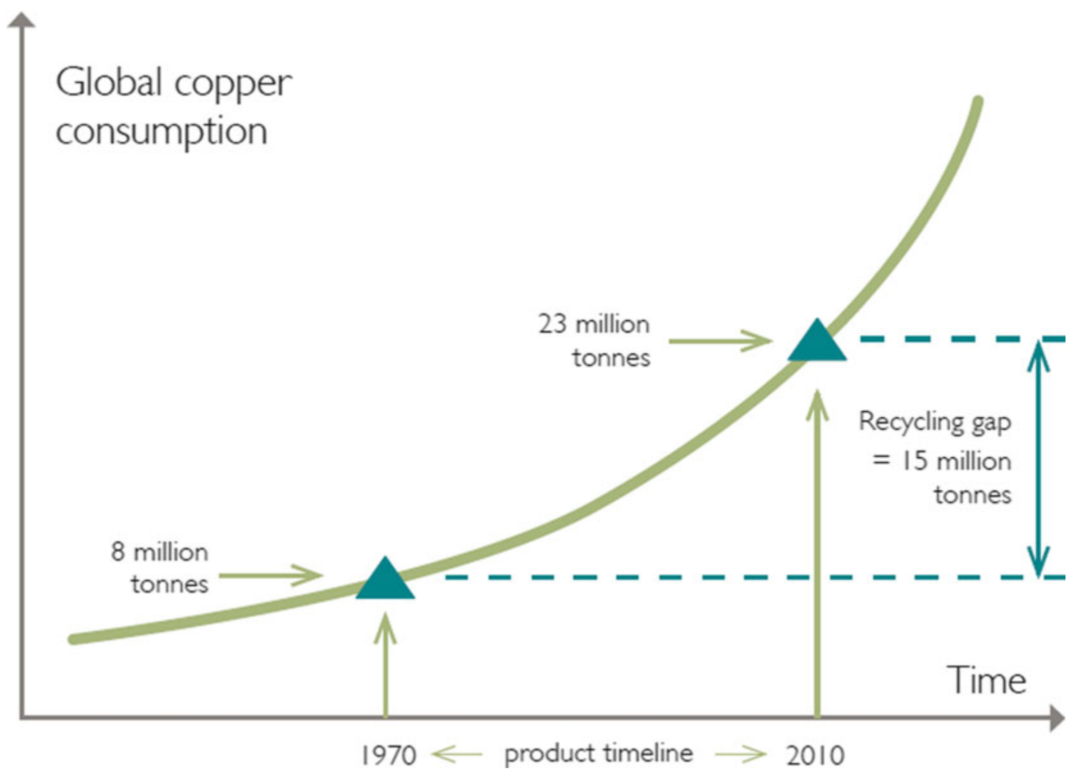


Fig. 12.6 Global copper consumption **and the recycling gap**. After Graedel et al. (2014) © British Geological Survey

12.2.4 Progress with SDG Targets

As with all the SDGs, the UN monitors progress towards achieving the **SDG 12** targets and reports this on an annual basis in the Sustainable Development Goals Report. While demonstrable progress is recognised as being made in some critical areas of the SDGs (e.g., a decline in extreme poverty, enhanced efforts to combat climate change, development of national policies to respond to the challenges of urbanisation, and positive engagement with the SDGs), many areas require urgent collective attention and more ambitious responses are required to achieve the 2030 SDG targets (UN 2019b). Specifically in relation to the progress of **SDG 12** (UN 2019b):

- The global material footprint (Fig. 12.1) continues to both rapidly grow and outpace population and economic growth (estimated to be between 167 billion and 190 billion tonnes by 2060 without concerted political action). Therefore, the efficiency with which natural resources are used to support economic growth remains unchanged at the global level and negative trends continue to be seen. There are no visible signs yet of decoupling economic growth and natural resource use at the global level. Good progress being made in sub-Saharan Africa, Central and Southern Asia, and Oceania (excluding Australia and New Zealand), mostly as a result of increases in GDP, is being offset by increased primary raw material consumption in other regions.
- There continues to be a significant discrepancy between the per-capita material footprint in high-income countries when compared with upper-middle-income countries and low-income countries.
- The material footprint for fossil fuels is more than four times higher for developed than developing countries. Decoupling the use of fossil fuels from economic growth is considered key to achieving sustainable consumption and production (UN 2018b).
- Construction of new infrastructure in emerging and transitioning economies (a pattern that many developing countries are likely to follow) and the outsourcing of the material- and energy-intensive stages of production from high-income countries to less resource-efficient countries have resulted in a significant increase in domestic material consumption in Eastern and Southeastern Asia (10 billion tonnes more or about two-thirds of the increase at the global level in 2017 than in 2010).
- Well-designed national policy frameworks and associated instruments (regulatory, voluntary, economic) remain necessary to enable the fundamental shift required towards sustainable consumption and production patterns. In 2018, 71 countries and the European Union reported a total of 303 such policies and instruments continuing the overarching positive trend in the formulation of such policies/instruments seen since 2002. The primary focus in such policies and instruments is the economic benefits offered by more sustainable consumption and production patterns with the social benefits being largely overlooked. While the formulation of relevant policies assists in the sustainable management of natural resources, the implementation of these to deliver tangible positive changes in sustainable consumption and production remains limited (UN 2018b).

To assist in implementing the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, the UN has established the One Planet Network.[3] The Network provides a platform to bring together the global community for sustainable development, and its 2018–2022 strategy outlines how it will become a leading implementation, monitoring, and evaluation mechanism for **SDG 12** (One Planet Network 2018). In addition to the One Planet Network, the International Resources Panel exists to build and share the knowledge needed to improve our use of resources worldwide and so also acts as an enabler for monitoring progress towards achieving **SDG 12**.

Table 12.3 presents a summary of the latest progress towards achieving the **SDG 12** targets.

[3]https://www.oneplanetnetwork.org/.

Table 12.3 High-level summary of progress towards achieving **SDG 12**. *Sources* UNEP (2015b, 2017a), UN (2018b, 2019b)

SDG 12 target	Summary of progress
12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns (10YFP)	An increase in the number of national sustainable consumption and production policies compiled since 2002 demonstrates overarching positive trends. However, implementation of these to foster tangible changes in impact remain limited and only a few are mandated to coordinate policy implementation across ministries
12.2 Achieve the sustainable management and efficient use of natural resources	A small change in global Domestic Material Consumption has been recorded between 2010 and 2015 (from 1.2 kg per dollar of GDP to 1.1 kg). Therefore, fewer raw materials are required to produce a unit of output. However, DMC per capita and in absolute terms has continued to grow from 2000 to 2017 with consequences for global resource depletion and environmental impacts
12.3 Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	A range of interventions designed to tackle food loss and waste (e.g., research into the causes and identification of solutions, target-setting, policy formulation, legislation, and education/awareness raising campaigns) are being implemented
12.4 Achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimise their adverse impacts on human health and the environment	Mixed progress to global compliance rates for protocols and conventions relating to environmentally sound management of chemicals and wastes. Reporting of information by parties signed to the Montreal Protocol and the Basel, Rotterdam and Stockholm Conventions varies with an average of 70%. The Minamata Convention has been signed by 128 countries[a]
12.5 Substantially reduce waste generation through prevention, reduction, recycling and reuse	Information on total recycling rates is sparse and variable, with data being better at a city level. While recycling rates are highest in the high-income countries, some low- and lower-middle-income countries do collect quite reasonable percentages of their total municipal solid waste for recycling (20–40%). There is some evidence that recycling rates are lower in some of the more developed, upper-middle-income countries. The collection and management of waste electrical and electronic equipment (WEEE) heavily depends on the legislation in each country
12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	Sustainability reporting has been gaining momentum, driven by new private sector partnerships to achieve the SDGs along with growing interest from companies (especially large companies), regulators, investors and other stakeholders. 93% of the world's 250 largest companies (in terms of revenue) are now reporting on sustainability

(continued)

Table 12.3 (continued)

SDG 12 target	Summary of progress
12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities	Driving sustainability along value chains through public procurement processes that consider social, economic and environmental factors has gained increasing recognition. It is being progressively embraced by national and local bodies. The relevance of sustainable public procurement as a strategic tool to drive sustainability and transform markets is no longer questioned. However, the need to ensure that it is better integrated into broader sustainable consumption and production policies continues
12.8 Ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	Numerous on-going public engagement and awareness raising activities. Includes the UN's One Planet Network

[a] Montreal Protocol on Substances that Deplete the Ozone Layer, Basel Convention on the Control of Transboundary Movements of Hazardous Wastes, Rotterdam Convention on the Prior Informed Consent Procedure for Certain. Hazardous Chemicals and Pesticides in International Trade, Stockholm Convention on Persistent Organic Pollutants, and Minamata Convention on Mercury.

Despite recognising some broad progress made towards achieving **SDG 12**, a recent survey (which 454 sustainability experts completed) rated progress on **SDG 12** (as well as six other of the SDGs) as poor (GlobeScan-Sustainability 2019). However, respondents to the survey were also of the view that Climate Action (**SDG 13**) and Ensuring Sustainable Consumption and Production (**SDG 12**) are the most critically urgent, and noted that these two SDGs receive most attention within their organisation.

The UN (2018a, b) reports that serious concern exists in relation to the lack of an adequate monitoring framework for many of the targets under **SDG 12**. No internationally established methodologies or standards exist currently for monitoring 10 of the 13 indicators for the targets (but methodologies are being developed or tested). As an example, in its latest report on monitoring of progress towards the SDGs for the Asia and Pacific region, the UN Economic and Social Commission for Asia and the Pacific indicated that only 10% of the required data to assess progress towards achieving **SDG 12** exists (ESCAP 2019).

In order to facilitate the monitoring of progress towards achieving **SDG 12**, there is a need for better data collection and more consistent data collection. However, the qualitative rather than the quantitative nature of several of the **SDG 12** targets makes it difficult for countries to measure their achievements (Chan et al. 2018). Adopting methodologies that incorporate social science approaches for qualitative assessment may assist in overcoming some of the problems. Limited resources along with limited technical capacity and fragmented institutional systems mean that many countries also have difficulty developing monitoring processes and collecting the required data (Steinbach et al. 2016). Steinbach et al. (2016) note that substantive efforts in institutional and technical capacity development as well as financial resources are required to effectively monitor changes in consumption and production patterns, indicating that where they do exist, it is important for current international reporting systems to converge in order to assist the process.

12.3 Geoscience and SDG 12

As with all the SDGs, if the ambitions of **SDG 12** are to be met, geoscience will have an important role to play. Chosen because they utilise some of the concepts described above, the following case studies provide just some examples of where an understanding of geoscience can make a positive contribution towards achieving **SDG 12**.

12.3.1 Resource Decoupling in a Green Economy Strategy for Kenya

In Kenya, the Ministry of Devolution and Planning is mandated to coordinate the management, implementation, monitoring, and reporting of the SDGs. Within the Ministry, the SDG Coordination Department has been established with the responsibility for ensuring appropriate monitoring and evaluation of all SDG activities, and the country has reported good progress on several of the SDGs (see Government of Kenya 2017).

Like many low- and middle-income countries, Kenya's economy is heavily reliant on natural resources. For 2014, the UN estimated that 42% of Kenya's GDP and 70% of overall employment were derived from natural resource-related sectors (UNEP 2014b), many of which are acutely vulnerable to climate change and variability. In recent years, viable deposits of oil, natural gas, coal, and other minerals have been discovered. However, the prospective benefits to the economy and enhanced national energy security from the exploitation of these minerals need to be weighed against the risks of negative environmental impacts. To mitigate these impacts, the Government of Kenya is to embrace sustainable consumption and production approaches in order to transition to a green economy.

In 2016, the government published its Green Economy Strategy and Implementation Plan, 2016–2030 (Government of Kenya 2016). The strategy outlines activities to achieve a low carbon, resource-efficient, equitable, and inclusive socio-economic transformation in the country. The strategy aims to facilitate Kenya attaining a higher economic growth rate (consistent with the country's development blueprint, Vision 2030) but which firmly embeds the principles of sustainable development as the country's growth continues. The strategy is designed to guide Kenya's transition to a sustainable path in the following five key areas: sustainable infrastructure development; building resilience; sustainable natural resources management; resource efficiency; and social inclusion and sustainable livelihood.

In order to optimise the contribution of the agriculture, forestry, water, fisheries, wildlife, land use, and extractive industry sectors to the Kenyan economy, there is an emphasis on the need for decoupling economic development from sustainable natural resource management and the conservation of Kenya's natural resources. There is recognition that Kenya's natural resources are under intense pressure from global and local drivers such as population increase, over-extraction of natural resources, poaching of wildlife, urbanisation, changing consumption patterns among the population, climate change, and the use of chemicals. Intrinsically linked to achieving such decoupling is the promotion of resource efficiency. Within this area, the strategy recognises that the challenge for Kenya is to develop its resource efficiency agenda, reduce the environmental impact of production and consumption while addressing the policy and technical challenges of waste management. The country aims to optimise the contribution of Kenya's natural resources to the economy, industrialisation, and livelihoods by recognising the interlinkages of the economy–environment nexus.

Kenya sees the delivery of the green growth path outlined in the green economy strategy as a way to ensure faster growth, a cleaner environment, and higher economic productivity and is highlighted as one of the means by which the country will meet the **SDG 12** targets.

12.3.2 Maximising Value and Efficiency of Mineral Resource Use in Kenya

The Government of Kenya, through the Ministry of Petroleum and Mining, State Department for Mining, is in the process of establishing four Value Addition Centres (VAC) located in different mineral-rich regions of the country. Through this initiative, the government aims to maximise efficiency in mineral resource use by adding value to mineral products at the source while enhancing the economic growth and well-being of the local communities.

Fig. 12.7 The Voi Gem Centre. Credit: Martin Nyakinye (DGS)

Included among the VACs is the Voi Gem Centre (Fig. 12.7). This is located within Voi town in Taita-Taveta County in the south-east of the country. The area has been the main source of Kenyan gemstone production since independence. The Voi Gem Centre has been operational since 2017 and offers several value addition and support services to the gemstone mining industry. The Voi Gem Centre is expected to increase the value of gemstones at the source, reduce waste, and facilitate sustainable mining and trading of gemstones. It will achieve this by providing the facilities necessary to maximise the value of gems extracted locally. Facilities at the centre include

- An administration block offering all the essential services in a single location.
- An accredited gemology laboratory for the identification, verification, and valuation of gems.
- A lapidary providing gem cutting, faceting, and polishing.
- A jewelry-making section.
- A security safe for the secured custody of gemstones.
- The provision of export permits.
- An exhibition hall for gemstone auction and trading.
- Gemstone dealers' booths.
- A bank and a restaurant.

The other VACs are still at the feasibility stage with a tender award for construction expected by the end of 2019 and full operation by 2022. There is the Kakamega gold refinery which is to be located at the Old Rosterman mine in Kakamega County. This will include a demonstration of the mine facility for safe and sustainable mining as well as providing mercury-free gold recovery services to the artisanal and small-scale gold mining (ASGM) communities. Others include the Vihiga Granite Slab Processing Centre to be located at Emuhaya in Vihiga County and the Soapstone Value Addition Centre to be located in Kisii county. Prior to construction, all of these VACs will be subjected to Kenya's Environmental and Social Impact Assessment (ESIA) process.

12.3.3 Reducing Mercury Emissions into the Environment and Use in Artisanal and Small-Scale Gold Mining (ASGM) in Kenya

The effects of mercury on human health are well documented (UNEP 2019 and Bell et al. 2017) yet globally, the use of mercury by artisanal and small-scale gold mining (ASGM) shows no sign of declining (UNEP 2013, 2017b). In the Kenyan context, estimates of mercury use in ASGM mining ranging 1.3–2 units of mercury per unit of gold produced (Government of Kenya unpublished report 2016). One particular study (Ogola et al. 2002) found mercury use by ASGM miners in a single county (Migori) in the west of the country ranged 60–80 kilogrammes per month. Since 2002, the area has experienced an acceleration in the growth of ASGM activity. Barreto et al. (2018) estimate that the engagement by locals in ASGM in parts of Migori and Siaya Counties could be up to 70% while the figure could be as high as 100% in parts of other counties in the west of Kenya, such as Kakamega and Vihiga. Although clear, credible data is scant; mercury use among the ASGM miners is now estimated at multiple times the figures of 2002. This points to a serious and increasing mercury use problem that needs to urgently be addressed.

Mining operations involve deep unstable shafts (Fig. 12.8), manual extraction, crushing of ore by hand followed by milling, or alternatively by panning gold directly from rivers in the region (Fig. 12.9). Mercury is mixed with the resulting heavy mineral ore concentrates forming a mercury–gold amalgam. The amalgam is then heated, vaporising the mercury to obtain the gold.

To minimise the environmental pollution and health impacts caused by the use of mercury, the government of Kenya is implementing a strategy to reduce the anthropogenic emissions of mercury by artisanal and small-scale mining activities. This will contribute to **SDG 3** (good health and well-being) and **SDG 15** (life on land). In 2018, the Ministry of Environment and Forestry issued a 'Request for Proposals' for consultants to develop a national overview of the ASGM sector in Kenya, and for the development of a national action plan for the ASGM sector in Kenya. The preliminary results from the studies (McKay 2019; ISSITET 2019) are already providing a framework for intervention by the Kenyan government to steer the ASGM sector towards greener mining. Key recommendations proposed by the studies to be implemented include

Fig. 12.8 Manual winching of ore from an ASGM gold mine. Credit: Martin Nyakinye (DGS)

Fig. 12.9 ASGM miners panning for gold. Credit: Martin Nyakinye (DGS)

- Formalisation of the ASGM sector in order to provide easier entry points for interventions.
- Enhancing capacity awareness, education, and capacity building among the ASGM practitioners about the dangers of mercury use and existing alternatives to mercury.
- Lower barriers to access for miners to finance in order to increase uptake of greener, safer technologies in their activities.
- Strengthening the human capacity and resources available to relevant enforcement agencies in order to ensure the adherence to greener production pathways.

The development of Kenya's *National Action Plan to Reduce and, Where Feasible, Eliminate Mercury Use in Artisanal and Small-Scale Gold Mining* (UNEP 2017c) will provide concrete actions and clear framework to reduce ASGM mercury emissions in Kenya, and thus contribute to the global effort to reduce overall levels of anthropogenic mercury emissions into the atmosphere and ecosystems. The end result is expected to be a reduction in the negative environmental and human health impacts of ASGM activity in Kenya.

12.3.4 Estimating Demand for Minerals Required for Future Construction in Hanoi

Between 1990 and 2016, the percentage of Vietnam's population living in urban areas increased from about 20% to approximately 35% (GSOV 2018). Such an increase in urban population is resulting in an expansion in the size of cities in the country much reflected elsewhere in the world. For Hanoi, one such city in Vietnam, current and future population trends have led to the formulation of ambitious plans for additional urban development (Iwata 2007; Leducq and Scarwell 2018) as detailed in the Hanoi Masterplan to 2030 (Perkins Eastman 2011).

Planned urban growth requires the construction of houses, schools, hospitals, roads, and other infrastructure. The Hanoi Masterplan

2030–2050 includes a major new road network, new rail links, an expanded city core, five satellite urban areas, and three eco-townships. This development all requires an input of raw materials, particularly aggregates in the form of crushed rock and sand. Without a steady supply of these construction minerals, the expansion of Hanoi cannot be delivered.

By undertaking a top-down mineral supply–demand mass balance, Bide et al. (2018) were able to estimate future demand for crushed rock and construction sand required to meet the future growth of Hanoi. The top-down approach (Fig. 12.10) estimates future supply based solely on trends in mineral production, trade in minerals, and population growth. By calculating the current apparent consumption of minerals and then using projected population growth figures, estimates were made for future demand for construction minerals. Such a top-down approach is 'simplistic' in comparison to a detailed material flow analysis (MFA) (see Bide et al. 2018). However, the methodology does lend itself to situations where data (in particular, at the relevant region or better still individual city level) is sparse or non-existent. Such is the case for Hanoi where detailed data for production and trade in mineral commodities are either not collected or are not publiclly available on either a city or regional level.

Following the methodology depicted in Fig. 12.10, the apparent consumption of crushed rock and construction sand was calculated for Hanoi for 2007–2016 (Fig. 12.11). The effects of a slowdown in the construction industry can be seen from around 2010 to 2012. Changes in policy regarding international exports of sand have also had an effect. However, despite the impact of these external forces the general trend has been one of increased consumption for crushed rock and consistent consumption for sand.

Having calculated apparent consumption over a period of time, the data were then combined with forecasts of future population growth for the city to estimate likely future demand for crushed rock (Fig. 12.12) and construction sand (Fig. 12.13) to 2030. The vertical lines are added to illustrate the potential discrepancies in the main trend line that may be observed in the future. The forecasts are based on projections using a compound annual growth rate calculation over a 10-year period.

Results show that considerable increases in demand for both crushed rock, and construction sand are to be expected as the population of Hanoi increases and homes and infrastructure are constructed to accommodate this growth. For crushed rock, there is a 2.5-fold increase in demand in 2030 (86 million tonnes), over 2016 levels (33 million tonnes) and there is a twofold increase for construction sand with 14 million tonnes required in 2030 compared with 6 million tonnes in 2016. Within a circular economy, some of this demand would be met by secondary and recycled aggregates. However, secondary and recycled aggregates are generally only suitable for lower grade applications (such as for building foundations). The degree to which aggregates are recycled in Hanoi is currently unknown. If the increased demand for the minerals is to be met while at the same time minimising negative environmental and social impacts, planned new extraction capacity is likely to be required.

Ideally, consideration of such mineral supply requirements should be considered when plans for urban development such as the Hanoi Masterplan are compiled. If due consideration is not given to future demand, issues can arise, such as high price volatility, increased informal mining with the associated negative environmental and social impacts, slow economic growth, and hindered development.

12.3.5 The Resources Impact of Decarbonising Economies

Over the last decade as the effort for the transition to a low-carbon future has increased, a variety of technologies have been developed (currently being scaled up) which rely on the availability of numerous materials, including the so-called critical metals. The growth in electrification in transport (Fig. 12.14), energy storage, and renewable energy generation is leading to increased demand for minor metals that are often

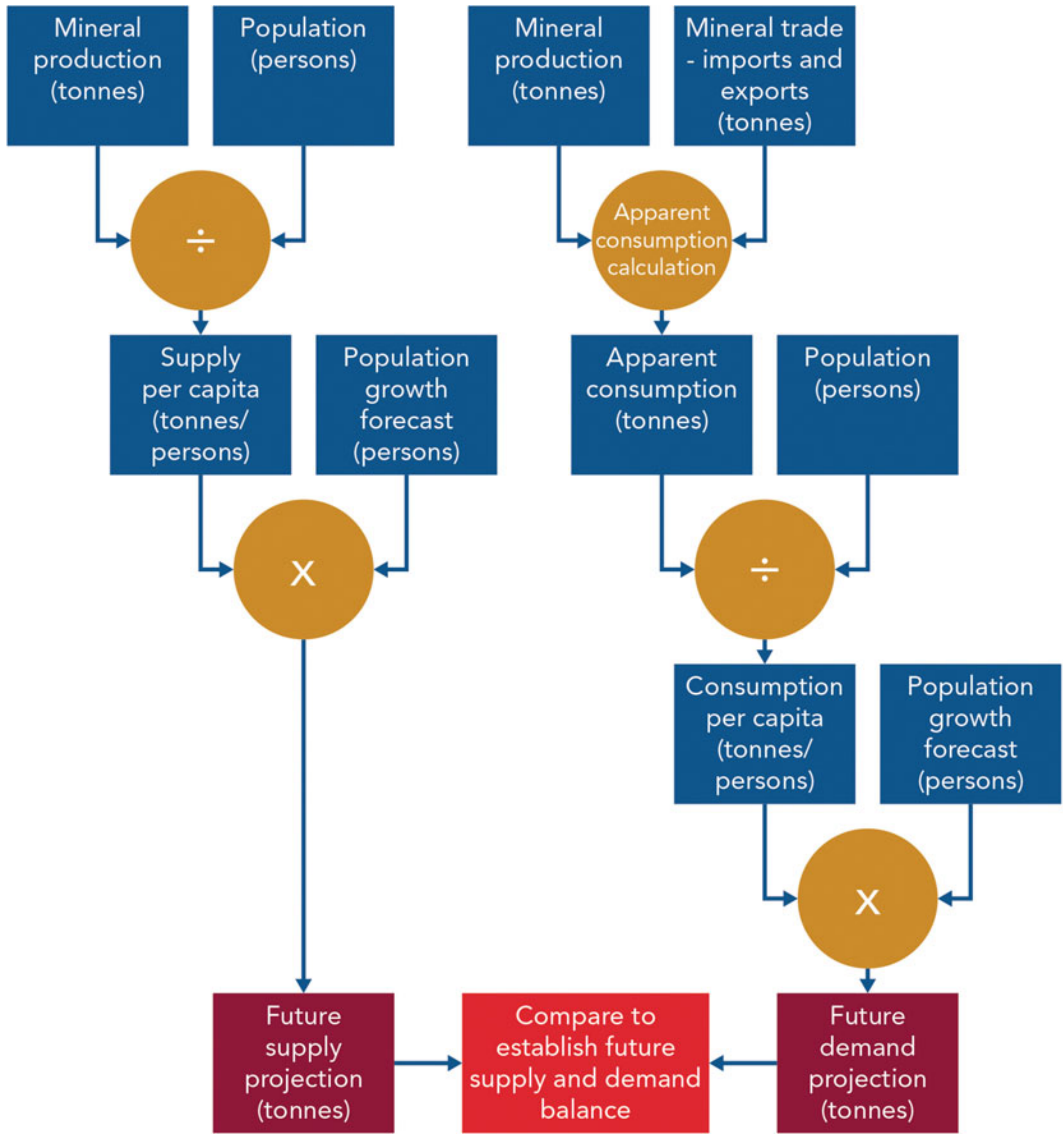


Fig. 12.10 Schematic diagram explaining the steps involved in the top-down future mineral supply and demand calculation. Adapted from Bide et al. (2018)

deemed critical, due to their associated supply constraints. The demand for many of these minor metals is expected to rise significantly in the coming years. For example, for cobalt and lithium (both used in batteries), the International Energy Agency projects that cobalt production will have to triple and lithium production will have to increase fivefold by 2030 in order to satisfy anticipated growth in the number of electric vehicles (International Energy Agency 2019). For other metals, such as tellurium (used in photovoltaics) and neodymium (used in wind turbines), similar upward growth is expected. Developed scenarios are suggesting an increase in production from a few hundred tonnes in 2017 to over a couple of thousand tonnes in 2030 and for neodymium a doubling in production by the same year (Watari et al. 2018).

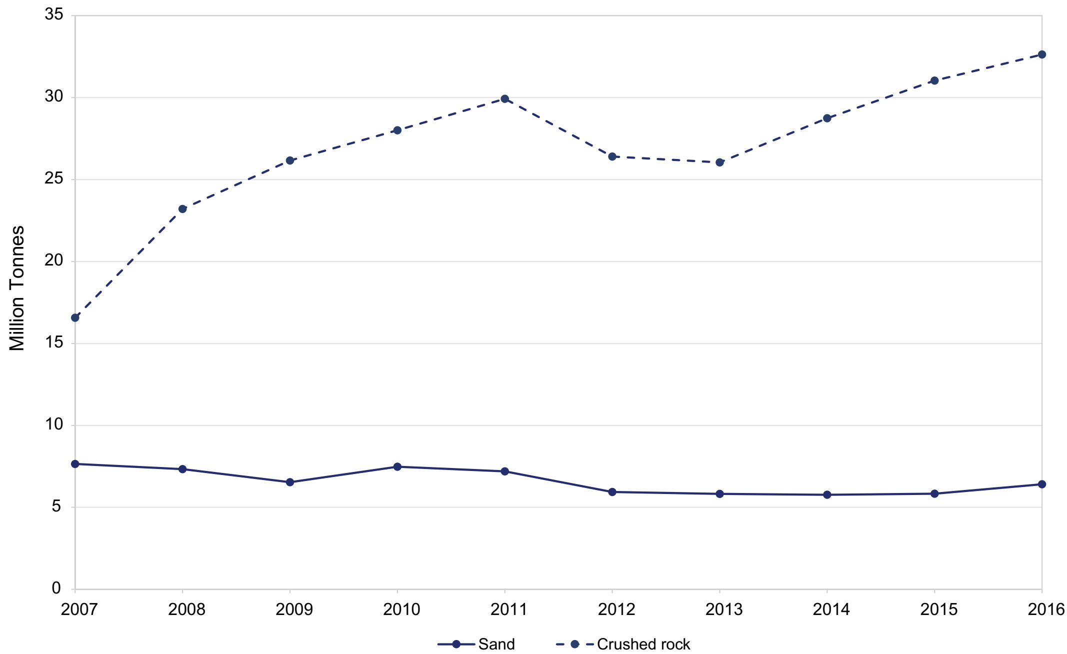


Fig. 12.11 Material consumption **for Hanoi.** Consumption of crushed rock (dashed line) and construction sand (solid line) for Hanoi, 2007–2016. Credit: Bide et al. (2018)

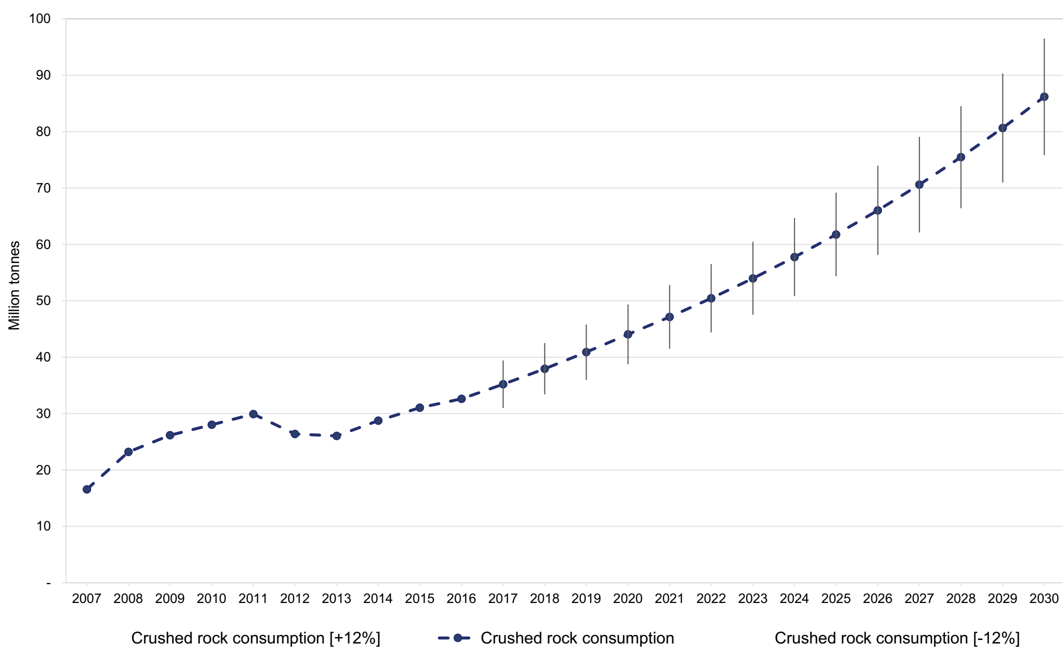


Fig. 12.12 Hanoi consumption **of crushed rock (2007–2016) and estimated future consumption (2017–2030).** Estimated via material flow analysis, with 12% (one standard deviation) error bars on projected years. Credit: Bide et al. (2018)

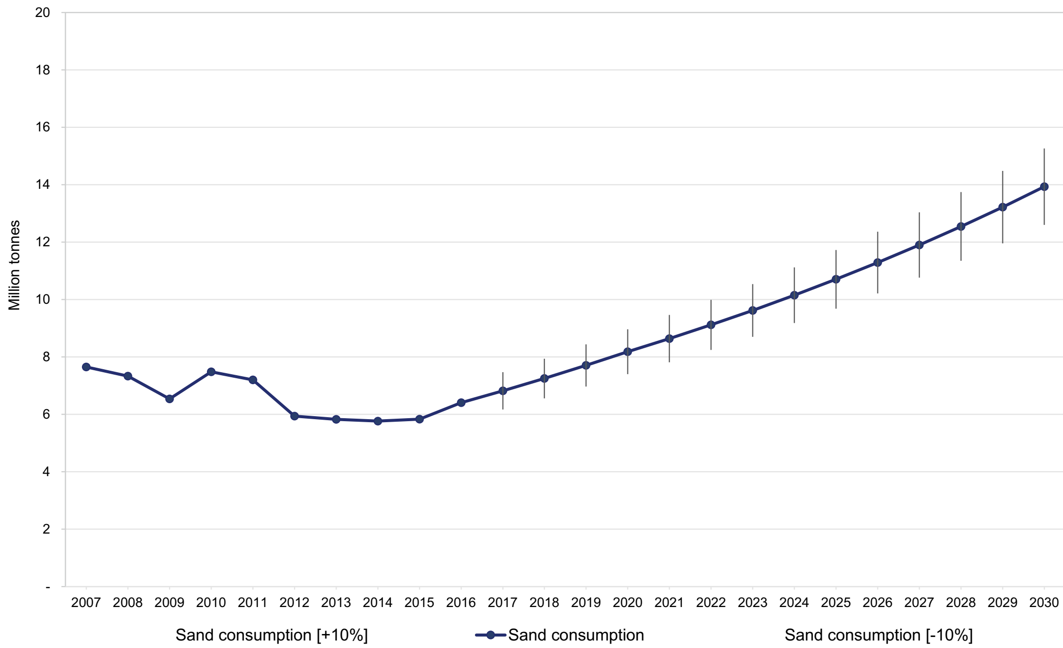


Fig. 12.13 Hanoi consumption **of construction sand (2007–2016) and estimated future consumption (2017–2030).** Estimated via material flow analysis, with 10% (one standard deviation) error bars on projected years. Credit: Bide et al. (2018)

Fig. 12.14 The introduction of electric buses is helping to reduce emissions and pollution. © Andrew Bloodworth (BGS), used with permission

Such an increase in demand for these minerals will have an impact on global consumption and production patterns. The markets of industrial metals such as iron, aluminium, copper, and others will also grow as they comprise essential parts of decarbonisation technologies. If the availability of metals is constrained, then the upscaling of technologies essential for decarbonising our economies will slow down, with corresponding negative impacts on climate change mitigation. The supply risk is particularly high for minor metals that are often produced as by-products of industrial metals. They are not mined on their own, they are dependent financially on the recovery of other metals, and their market dynamics are influenced by the market of the major metals they are connected with.

For many of the metals needed in decarbonisation technologies, their extraction and production are linked with environmental consequences and they are carbon intensive. Between seven to eight per cent of the global energy production is consumed for extracting and refining metals (Wellmer et al. 2019). Lower ore grades of extraction and continuous demand growth for raw materials have led to huge amounts of waste rock being produced. If decarbonisation is the aim, then it is important that the extraction and production of minor and critical metals to be consumed by green technologies are responsibly sourced and follow the principles of sustainability. Successful interventions will have to consider the whole material cycle and should be based on the systemic understanding of the interaction between the economy, environment, and society.

12.4 Conclusions

Achieving many of the SDGs will ultimately depend on the responsible stewardship of the Earth's finite natural resources. Natural resource management is directly tied to at least 12 of the 17 Sustainable Development Goals (SDGs) and therefore achieving the targets of **SDG 12** will help deliver the other goals (IRP 2017). Despite showing some positive progress in several targets of **SDG 12** in recent years, overall the need to significantly modify current trends to ensure sustainable consumption and production patterns remains if the goal is to be achieved by 2030.

Demand for raw materials from emerging and transitioning economies as a result of their growing populations and the drive to enhance the quality of life will continue to grow into the future. Achieving the **SDG 12** targets will require a fundamental shift in how natural resources are managed and used. The concepts of resource efficiency, resource productivity, decoupling, resource nexus, and circular economy have entered mainstream science and policy development, and having gained traction they are now increasingly being implemented into practices. All have a role to play in supporting this shift. The need to improve natural resource management continues as does the requirement for agreeing and implementing mechanisms of data collection needed to monitor progress towards achieving **SDG 12**.

Geoscience with its inherent links to the understanding and management of natural resources has and will continue to have an important role in helping to achieve sustainable consumption and production patterns. With an understanding of the links between natural resource (or raw material) supply and demand, geoscientists can contribute by

- *Assisting in the development of relevant policies and ensuring that decision makers are informed of the likely material demand impact of emerging policies*. The Green Economy Strategy and Implementation Plan for Kenya as summarised in this chapter is just one example where governments around the world are increasingly adopting the concepts outlined in this chapter in order to better manage and utilise their natural resources as their economies develop. Likewise, undertaking analyses such as the supply–demand mass balance assessment for Hanoi to better understand likely future raw material needs as cities around the world grow in size is important if better development plans for such cities are to be implemented.
- *Participating in initiatives such as the establishment of value addition centres and*

mercury reduction strategies. The examples from Kenya show how this engagement can assist those working in the informal/small-scale mining sectors to maximise the value from the minerals they extract while at the same time reduce the use of chemicals harmful to the environment and human health. This supports **SDG 3** (good health and well-being), **SDG 8** (decent work and economic growth), and **SDG 15** (life on land).
- *Alleviating some of the supply risks associated with minor and critical metals essential for low-carbon technologies.* For many of these metals, our understanding of where they are found, how we can explore for them, and how we can enhance existing geological data to promote new discoveries is limited, as their historic use was small or non-existent. Competitive geoscience data into deposit formation, new exploration techniques, and geological mapping will be essential to ensure risk-free supply chains for low-carbon technologies supporting **SDG 7** (clean and affordable energy) and **SDG 13** (climate action).

The last point in the list above can be considered as being along the lines of the 'traditional' role of a geoscientist—understanding the formation, location, and viability (environmental, social, and economic) of extracting and utilising the natural resources required for manufacturing the goods we need or producing the food we eat. The other examples indicate the much wider contribution geoscience, however, can make towards achieving the targets of **SDG 12**.

12.5 Key Learning Concepts

- Global demand for natural resources (e.g., construction materials, ores and minerals, fossil fuels, and biomass) is rapidly increasing as countries seek to develop their economies and enhance the standard of living of growing local populations, many of whom are getting wealthier.
- Responding to this increased demand, **SDG 12** aims to help the world transition to sustainable consumption and production patterns, so as to achieve equitable socio-economic development while also protecting resources for future generations, minimising waste, and reducing pollution of the natural environment (i.e., decoupling development from environmental degradation). This requires appropriate policies, technological innovation, and the development of resource-efficient infrastructure.
- The resource nexus recognises that there are critical and complex interlinkages between different resources (e.g., water, energy, food, land, and material resources). Sustainability requires the consideration of what may affect the supply and demand of each resource, recognising these interlinkages. Institutions should work together to develop coherent and comprehensive policies for resource management, recognising that a diverse ecosystem of stakeholders can inform planning and practice.
- A circular economy relies on sustainably sourced natural resources, and the use of products that are designed for repair, reuse, remanufacture, and recycling (so as to reduce the disposal of materials). Increases in efficiency across the entire life cycle of resource use means more effective extraction and production, sustainable and smarter consumption, and preventing or reducing negative environmental impacts.
- Geoscientists are part of the complex ecosystem of stakeholders that can deliver **SDG 12**, given their comprehensive knowledge of the formation, location, and viability (economic, social, and environmental) of extracting and using natural resources. Geological data and expertise can inform policymaking and implementation of measures to decouple resource extraction from environmental damage, and decarbonise societies.

12.6 Educational Resources

In this section, we provide examples of educational activities that connect geoscience, the material discussed in this chapter, and scenarios that may arise when applying geoscience (e.g., in *policy, government, private sector international organisations, and NGOs). Consider using these as the basis for presentations, group discussions, essays, or to encourage further reading:*

- Consider the social and environmental impacts associated with the development of a standard smartphone. Start by determining what minerals they contain, and consider where these may have originated and the energy and water resources required to extract and process these. How well does a standard smartphone fit on a model of the 'circular economy'? What changes would you recommend to make smartphones adhere to ambitions of SDG 12?
- Walk around a local urban environment, close to your institution or place of learning. What natural resources that you can observe or deduce were required to develop the built environment you see? Reflecting on your local and national geological setting, where do you think of these resources came from? What do you think this urban environment will look like in 20 years, and what are the implications on the types and quantities of materials used?
- Earth Overshoot Day (www.overshootday.org/) is focused on the exhaustion of biological resources that the Earth can regenerate in a year, showing excessive consumption. Review the solutions offered (www.overshootday.org/solutions/), and in small groups choose one of these, consider what contribution geoscientists can make, and present this to the class. Calculate your own environmental footprint (https://www.footprintcalculator.org/) and think what steps you personally can take to reduce consumption.

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Recommended Reading and Websites

One Planet Network. The UN's hub for **SDG 12** with the aim of being a platform to bring together the global community helping to make this happen. www.oneplanetnetwork.org

Further information on **SDG 12** from the UN. https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

Food and Agricultural Organisation of the United Nations. http://www.fao.org/sustainable-development-goals/goals/goal-12/en/

Information on monitoring of progress of **SDG 12**. https://sustainabledevelopment.un.org/**SDG 12**, https://sdg-tracker.org/sustainable-consumption-production and https://unstats.un.org/sdgs/metadata/

The International Resources Panel. www.resourcepanel.org

African Circular Economy Network. https://www.acen.africa/

Extractives Hub. https://www.extractiveshub.org/main/default/

The Responsible Minerals Initiative. http://www.responsiblemineralsinitiative.org/

The Elsevier Journal specifically for Sustainable Consumption and Production. https://www.journals.elsevier.com/sustainable-production-and-consumption

Taylor & Francis Sustainable Development Goals Online. A curated library to support the United Nations' SDGs. https://www.taylorfrancis.com/sdgo/goal/ResponsibleConsumptionAndProduction/all

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