This new report reveals, for the first time, data on resource use and resource efficiency for all countries of the world over three decades, from 1980 – 2008. The data covers the global, continental and country level, featuring illustrative case studies.

The report addresses three main issues:

1. Patterns of material extraction, trade, consumption and resource productivity in different world regions and countries;
2. Connections between material use and indicators of economic and social development;
3. Links between material use and selected major environmental problems, such as carbon emissions, land use change and water use.

The report evaluates the performances of different countries, highlighting the critical issues of current trends in resource use. It thus provides innovative input for the current discussion on green economies and poverty reduction in the context of the upcoming Rio+20 Earth Summit in 2012 and beyond.

Monika Dittrich, Stefan Giljum, Stephan Lutter, Christine Polzin

Green economies around the world?

Implications of resource use for development and the environment

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Stephan Lutter
Christine Polzin
SERI

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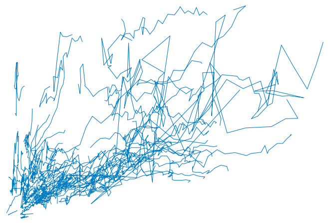
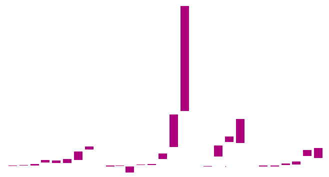
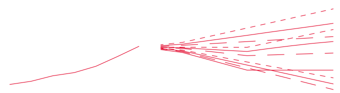






Forewords

Kandeh K. Yumkella
Director-General
United Nations Industrial Development Organization (UNIDO)

UNIDO coined the concept "Green Industry" to place industrial development in the context of new global sustainable development challenges. Simply defined, Green Industry refers to sustainable industrial production that does not damage the planet or human health. It is a strategy to create an industrial system that does not produce pollution and does not require an ever-growing use of natural resources.

Economies must strive for a more sustainable growth path by undertaking green public investments and implementing public policy initiatives that encourage environmentally responsible private investments and business. As material resources become scarcer, securing resource-efficient, low-carbon growth is more vital than ever to sustain the planet's ecosystems and the services they provide.

Business as usual is not an option. At UNIDO, we are working to encourage the decoupling of economic growth from the use of natural resources and its negative environmental impacts. By greening existing industrial activities and creating new sustainable productive activities, we create new jobs while protecting the environment, which in turn reduces poverty and raises living standards in developing countries.

UNIDO has been engaged in a longstanding and successful cooperation with the Sustainable Europe Research Institute (SERI). UNIDO recognizes the value of SERI's research in exploring issues of resource dependency and efficiency more broadly and deeply, and in helping to find alternative approaches to economic growth and development that are less dependent on resource usage than current models.

This report is the first to analyse the worldwide trends and dynamics of material extraction, trade, consumption and productivity between 1980 and 2008. Despite a growing acknowledgement of the interconnectedness between society and nature, this aspect of development is only now getting the attention that it deserves as we forge ahead with the creation of green economies and more sustainable development.

I am pleased by the innovative nature of this report, and proud that UNIDO is part of it. Now, more than ever, we must secure resource-efficient, low-carbon growth to ensure a healthy planet for future generations.

Jochen Flasbarth
President
German Federal Environment Agency

The consequences of the growing extraction and use of natural resources and the associated environmental impacts, such as climate change, are increasing. More and more, global resource use exceeds the regeneration rates of our ecosystems. Therefore, the sustainable use of natural resources has been a key issue for the German Federal Environment Agency (UBA) for years. Important goals are to reduce global resource consumption in absolute terms and to minimize the interlinked ecological and social impacts of our resource consumption. That is to dematerialise our societies in industrialised countries by a factor of 10 or more to meet the needs of all people in the future. To achieve these goals, we need a sound understanding of the different aspects of flows of materials like fossil fuels, biomass, metals and minerals, including all the relevant life cycle stages.

By providing a global picture of past and current distribution, trends and basic patterns of resource use between 1980 and 2008 around the world and illustrating their links to development and environmental issues in industrialised, emerging and developing countries, this study provides valuable support in developing and better designing effective resource policies. It clearly shows that the global resource extraction is increasing at an unprecedented rate and with it, the consumption of raw materials, land, water and energy soars ever higher. This study underlines the need for action.

Ernst U. von Weizsäcker
Co-chair of International Resource Panel
United Nations Environment Programme (UNEP)

The world faces major environmental and economic challenges caused by the growing overall scale of human's resource consumption. Resources are indispensable for human life, but the highly energy- and material-intensive development model of recent decades has clearly proven to be unsustainable, given geological and spatial limits and heavy environmental impacts.

Twenty years ago, in Rio de Janeiro, nations agreed on the new paradigm of sustainable development. Although this agreement triggered remarkable efforts at the global level and in the majority of countries, decoupling of human well-being from resource consumption is still a major challenge for policy makers and societies around the world.

This Report provides an impressive global overview of empirical trends and levels of material use over the past three decades. Furthermore, it provides essential information about links between resource use and development as well as between resource use and environmental problems. It illustrates the dramatic changes which took place over the past decades and emphasizes that reducing the overall scale of resource consumption is a major challenge not only in highly developed countries but also in many emerging and developing economies.

The report points to the urgency for policy makers and society to develop and implement strategies to enhance human well-being while significantly lowering inputs of natural resources. I, for one, remain optimistic about technological and societal *decoupling* opportunities waiting to be developed and harvested.

Michael Warhurst
Resources and Consumption Campaign
Friends of the Earth Europe

This useful and intriguing study demonstrates the scale of – and the inequalities in – humanity's resource consumption, and challenges everyone to come up with solutions for a more sustainable and equitable society.

Some will criticise the focus on tonnes of material used – but the reality is, this is the category of resource use where we currently have the most data available, and this report demonstrates that you can learn a huge amount from this approach.

Friends of the Earth Europe has been working with SERI since 2008 to develop and promote a more holistic approach to resource consumption, focussing on land footprint, water footprint, carbon footprint and material use, with each of these metrics including the "virtual" resource use used to make imported products.

We believe that using these metrics – at the level of the economy, in policy analysis, in organisations or for products, will facilitate increased resource efficiency and increased resource equity, around the world. Already, there are studies looking at the way in which carbon footprint, water footprint and land footprint are traded around the world, which expose the massive inequalities in resource use. At the same time, humanity's constant increase in resource consumption is destroying ecosystems, for example through our ever-increasing land demand – and severely damaging our climate.

We must become more resource efficient, distribute resources more equitably, and reduce the resource consumption of richer countries – focussing on quality of life, not quantity of consumption.

1 Material flows and green economies

Green economies: why material flows matter

Twenty years ago, political leaders gathered in Rio de Janeiro to discuss issues of poverty, growing disparities between the industrialised and developing world and the impact of industrial development on the environment. Together, they aimed to set the course for sustainable development worldwide.

Despite 20 years of remarkable economic development, especially in some of the most populous and dynamic emerging economies, the gap between industrialised and developing countries is still large, and problems associated with the environment have increased significantly. Resource prices are surging and competition for scarce resources has intensified. This is a serious challenge for countries around the world, but especially so for low-income countries. These social, environmental and economic dimensions are reflected in the concept of the green economy.

"Green" has become a buzzword in debates about sustainable development. A number of Green terms abound, such as "green economy", which is one of the two main themes at the Rio+20 United Nations (UN) Conference on Sustainable Development[1]; "green growth[2]", suggested as an alternative, more environmentally benign concept, to standard economic growth; or "green industry[3]", which is defined as a pattern of industrial development that is economically, environmentally and socially sustainable.

In its current working definition, the UN Environment Programme (UNEP) defines the green economy not only as an economy-environment nexus but as an economy that results in improved human well-being and social equity, while significantly reducing environmental risks[4]. Green economies can thus be a vital component enabling the overarching goal of sustainable development.

The Rio+20 summit aims at promoting the goal of creating such low carbon, resource efficient and socially inclusive economies around the world. This may be achieved by fostering investment that reduces carbon emissions and pollution, enhances energy and resource efficiency, and prevents the loss of biodiversity and ecosystem services around the world.

This report sheds light on the physical or material basis of development over the past three decades, including the distribution of resources and resource use, and asks to what extent it is possible to establish green economies around the world.

Primary resources form the material basis of all human activities, including production and consumption of goods and services. An assessment of material flows indicates how societies extract primary resources from ecosystems and the earth's crust, transform them into commodities, which are then used for different purposes, such as food, furniture, machines, buildings and roads, and products, which are part of our daily life. The amounts and types of materials used as inputs to our production systems also determine the flows of waste and emissions back to nature. Whatever materials humans extract for their socio-economic system, sooner or later become waste.

So far, the physical dimension of development has yet to receive adequate attention in the debate about green economies and sustainable development. However, the interconnectedness between society and nature has been increasingly analysed and acknowledged.

A large number of studies have investigated the implications of increasing globalisation and deeper integration of countries in world markets for the environment and development. However, only a few studies explicitly addressed the issue of material use. An analysis of material flows between different regions therefore provides an important additional perspective on development trends, which can complement prevailing economic explanations and monetary indicators.

Analysing resource flows also becomes important from the perspective of increasing resource scarcities, which lead to a growing number of environmental conflicts. Those conflicts range from local conflicts to international tensions over access to resources.

Apart from various studies by the authors of this report – many of them commissioned by UNIDO[5, 6, 7] and UNCTAD[8] – important studies with international or global scope have been published by the UNEP Resource Panel, in particular the report *Decoupling natural resource use and environmental impacts from economic growth*[9]. Other studies include the UNEP report on resource efficiency in the Asia and Pacific region[10]. *Factor Five*[11] is an example of a publication explaining the fundamental concept of resource productivity. Current scientific issues on material flow analysis are discussed predominantly in academic journals such as the *Journal of Industrial Ecology*[12] or *Ecological Economics*[13].

Global material use has reached a level that is jeopardsing the sustainable functioning of the planet's ecosystems and the services they provide. Policy debates in recent years have thus focused on ways of decoupling economic growth from the use of natural resources and its negative environmental impacts. Following the example of labour productivity improvements over the past decades, resource productivity has received increasing attention in the 1990s, as reflected in concepts such as *Factor 5*, introduced by Ernst Ulrich von Weizsäcker or *Factor 10*, developed by Friedrich Schmidt-Bleek[14].

While improvements in technologies have resulted in great progress in resource efficiency, the overall dynamics of economic growth have outstripped these achievements in efficiency. Thus, although we are getting relatively better at utilising scarce resources, the overall environmental burden has only increased over the past few decades. Improved resource efficiency may actually have served as a driver to the net increase in ecological impacts through the so-called "rebound effect" – a situation, where the financial savings resulting from reduced material and pollution costs are reinvested to expand operations and increase consumption, thus stimulating economic growth.

Therefore, a truly green economy at the global level will only be realised if an absolute dematerialisation of production and consumption can be achieved. This implies a radical reduction in the scale, volume and rate of human resource use. At the same time, it is essential that green economies satisfy the material needs of the population and achieve a high level of well-being worldwide.

Measuring resource use: a key requirement to move towards reliable welfare and sustainability

Friedrich Schmidt-Bleek
President
Factor 10 Institute

At the beginning of the 1990s, it began to dawn on me that in the West, we had managed to establish a multi-billion-dollar secondary economy – a kind of planned economy for the rich if you wish. The principal purpose of it was to stave off dangers to human health arising from deleterious emissions and wastes emanating from the real economy – the one that is responsible for creating welfare and security for people. Economists were busy translating bad symptoms in the environment into "externalities" of human activities and advising governments on how much money they should spend for correcting them. After the fact responses, fragmented policies, and compartmentalized counter measures were the hallmark of our approach, applied at the exit side of economic activities.

I had previously been deeply involved in the legal control of toxic substances in Germany, in Brussels and at the OECD in Paris. I therefore knew that internalizing externalities in monetary (or any other) terms was hopeless for hundreds of thousand different emissions, effluents, products and wastes. A single all-encompassing yardstick for the eco-toxicity of goods and services was – and remains – out of reach. On the other hand, I was convinced that the quantity of natural resources mobilized, extracted and used for creating a service by technology was related to the environmental impact potential of that service. Resource intensity,or the productivity of resource use, was therefore my choice as a basic indicator. I named the material intensity of a good ready for marketing its "ecological rucksack". It can be measured in weight units and is applicable worldwide for comparing goods with one another. The cradle-to-grave material input for creating a unit of service or benefit, I called MIPS (Material Input per Service Unit). More recently, we named it the "Material Footprint".

But what about the limits of worldwide resource use within the context of ecological sustainability? Given all the evidence available in the late 1980s, I estimated that the global overshoot in resource use was about a factor of two at that time. That meant that the world economy should be dematerialized by roughly a factor of two for approaching sustainability. Moreover, the fact that 20% rich people consumed about 80% of he world's resources, and expecting that there could be a 20% increase in world population, I arrived at 2*5=Factor 10 as a reasonable goal for the need to dematerialize western lifestyles. Only under this condition, would the poorer countries have sufficient "environmental space" available for fair development.

Some still feel that a ten-fold reduction in the use of fossil energy, water and resource use would entail a correspondingly dramatic cut in humanities' quality of life. Fortunately, that is not the case at all. Since the technologies for achieving such a reduction exist or are on the way, introducing them over a generation should, in fact, result in a steady improvement in the competitiveness of business, along with expanded possibilities for employment and increased potential for wealth creation and the quality of life of people and their communities.

Measuring material flows

This study focuses on material flows and considers both renewable and non-renewable materials. All materials are accounted for in mass units and expressed in metric tonnes. Four main types of materials are identified:

BIOMASS
(from agriculture, forestry, fishery, and hunting)

MINERALS
(industrial and construction minerals)

FOSSIL ENERGY CARRIERS
(coal, oil, gas, peat)

METAL ORES
(ferrous and non-ferrous metals)

Note that metal ores are calculated as the total metal-containing ore, not the net metal contents. Some metal ores with very low concentrations in the crude ore, such as gold, therefore have very high numbers.

While water could also be addressed as a material, it is generally excluded from analyses of material flows, as flows of water are of a far greater magnitude than material use and would thus bias the results. Additionally, high quality water related data is still scarce at the international level.

Methodologies for compiling material flow data and calculating indicators on material use and material productivity have been standardised during the past 10 years. Important international organisations in this regard are the European Statistical Office (EUROSTAT) and the Organisation for Economic Cooperation and Development (OECD). Today, many countries around the world have developed accounting systems in the field of material flow analysis in order to monitor the success of policies, aimed at increasing material productivity at the level of individual companies, economic sectors or the economy as a whole.

A large number of existing statistics can be drawn upon to calculate indicators on material use. Information on quantities of different materials being extracted, traded and consumed by different countries can be referenced from existing material, which includes:

- agricultural, forestry and fishery statistics for the different categories of biomass, energy statistics for the different fossil energy carriers,
- industrial production statistics as well as geological surveys, from which information on the extraction of minerals and metal ores can be retrieved, and
- external trade statistics, reporting on the physical quantities being imported and exported across the borders.

In some cases, estimations need to be applied in order to fill statistical data gaps, to complete indicators with figures not covered by statistics (for example, the uptake of biomass through grazing animals) or to standardise data (e.g. by water content). Estimates have been applied conservatively throughout this study. The methodological description in the Annex provides more details on data quality issues.

With material flow analysis, the flow of materials from extraction to consumption to final disposal can be illustrated. All production processes start with the extraction of materials from nature, where they cross the border to the socio-economic system. Recycling is an exception to this general rule, but it still plays a minor role for most materials. Products made from those raw materials can either be consumed domestically or exported to other countries. Due to intensified globalisation and international trade, the amounts of materials being imported and exported become increasingly important while studying the overall material flows of a country. At the end of the life-cycle, materials are discarded, and go back to nature. However, this aspect is not the focus of this report.

Glossary and methodological choices

Central terms used in this study

Resources versus materials: Often, both terms are used interchangeably, but "resources" refers to a broader range of categories (including energy, water and land) than "materials". In this study, the term materials is used for all physically present materials except water. The term resource is applied as in common usage, such as "resource scarcity" or "resource-rich".

Extraction in this study refers to the indicator "Domestic Extraction Used", which measures the flows of materials that originate from the environment and physically enter the economic system for further processing or direct consumption.

The **Physical Trade Balance (PTB)** is defined as imports minus exports measured in physical terms (mass).

Domestic Material Consumption (DMC) is defined as the total amount of materials directly used in an economy and calculated as extraction plus imports minus exports.

The term **material use** is used as a generic term, including extraction, trade and consumption.

Material productivity illustrates the amount of economic value generated per tonne of materials used. The inverse measure is termed material intensity, which shows how much material is necessary to produce one unit of GDP.

Decoupling refers to the amount of materials in relation to economic output or in relation to environmental impact. **Relative decoupling** means that resource use or environmental impact is growing slower than economic output. **Absolute decoupling** refers to a decrease in resource use or environmental impact in absolute terms.

Key methodological choices

A focus on direct material flows

This study focuses on direct flows. Indirect (or embodied, hidden) material flows associated with imports and exports are not considered, neither is so-called "unused extraction", such as overburden from mining or harvest losses. However, these flows are very important and some selected examples are included in order to demonstrate their importance. Future work should focus on the improvement of data quality regarding unused extraction and indirect flows of trade at the global level, in order to calculate more comprehensive indicators on material use.[15]

Measuring material productivity

There are different ways to measure material productivity, for example by using consumption or input indicators or by using different concepts of measuring income. In this study, material productivity is calculated as GDP (in purchasing power parity in constant terms, 2005[16]) per unit of DMC which is also the current approach for the European Sustainable Development Indicators.

Data quality

Data of comparatively weak quality (amount of estimated flows exceed amount of known flows, e.g. in various African countries during selected years) has been only integrated in the regional and global aggregates. The respective countries are not used as examples in figures.

Objectives and structure of this report

Objectives

This report is the first to analyse the development of material flows for all countries worldwide between 1980 and 2008.

With the help of indicators based on material flow data, questions such as the following are addressed:

- How has global material extraction and trade in materials developed over the past 30 years?
- Which countries have consumed most materials in absolute and in per capita terms? What are the differences between high consuming and low consuming countries?
- How has material productivity developed since 1980, and how does it differ across the world?
- How do different development paths differ in their use of renewable and non-renewable materials? How is material use linked to income, human development and well-being?
- How is material use linked to various environmental impacts?

Addressing these and other questions related to material use is essential if the potential of different countries to create green economies is to be assessed. The question whether current specialisation trends allow all countries to achieve a highly resource efficient and green development path is also addressed.

Looking at the trends in material use since 1980 thus helps to assess whether or not we are on the right track, if there are any "good practice" examples of countries that are already on their way to becoming green economies.

Structure of the report

Following the introductory Chapter 1, **Chapter 2 (Global material use: patterns and trends)** provides an overview of the general trends and dynamics of material extraction, trade, consumption and productivity and changes therein between 1980 and 2008. Trends are illustrated at the global level in different regions of the world and for the main material categories. This chapter also covers basic information on dependencies and differences in absolute and per capita consumption.

Chapter 3 (Material use and development) analyses the links between material consumption and income, two important indicators of development.

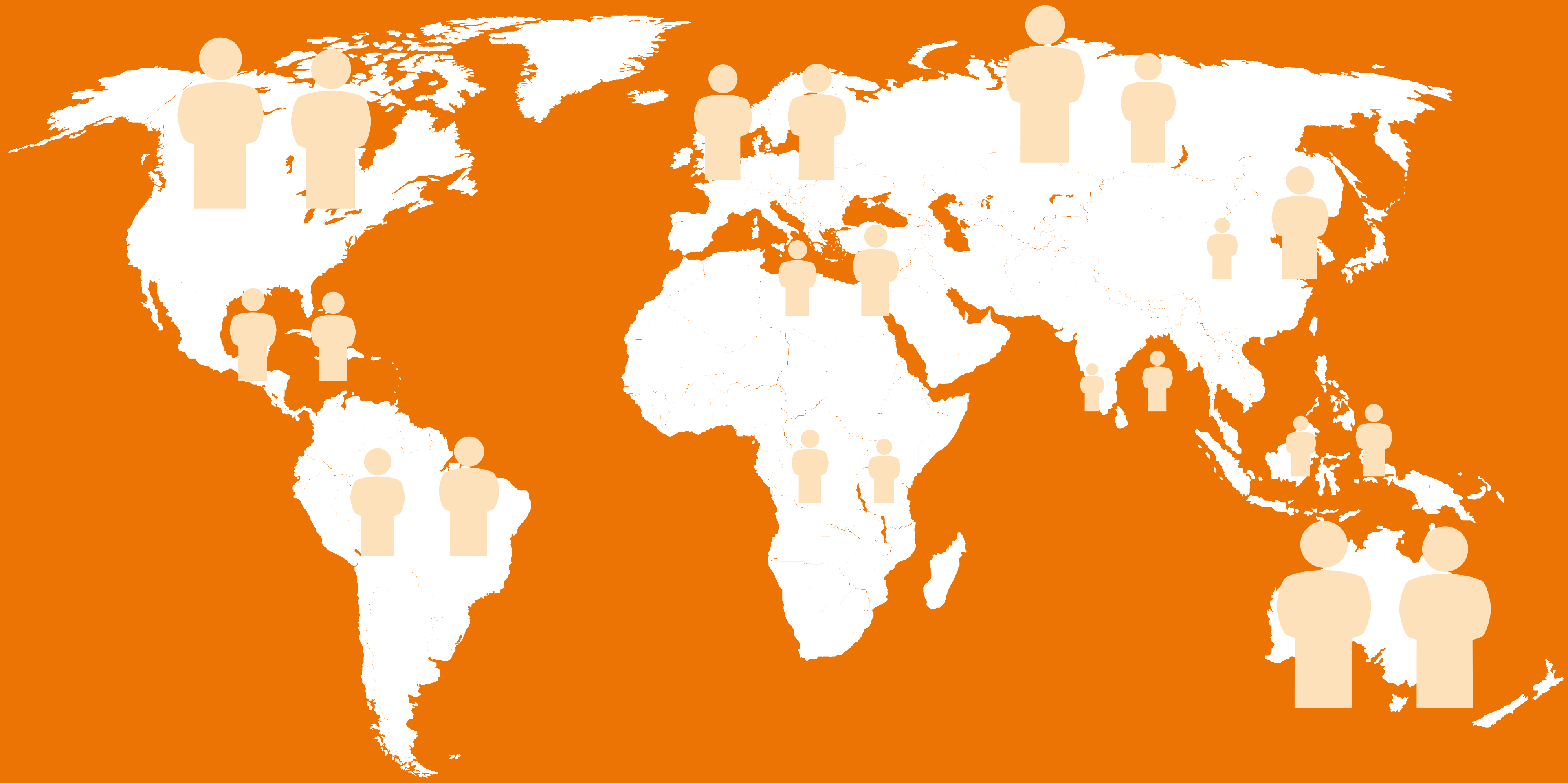
Chapter 4 (Material use and the environment) takes a more detailed look at environmental impacts of material flows. Using examples of each material category, the chapter aims to explain how all flows of materials, even of supposedly neutral ones, have different environmental impacts and how most material flows and their environümental impacts are closely related.

Chapter 5 (Conclusions and outlook) takes a look at the future and discusses "business as usual" scenarios as well as elements required for a global change towards more sustainable patterns of material use.

The **Annex** provides a methodological description and presents selected data and key indicators.

Further data on material extraction, trade, consumption and productivity are published online at **www.materialflows.net**, the online portal for global material flow data.

2 Global material use: patterns and trends



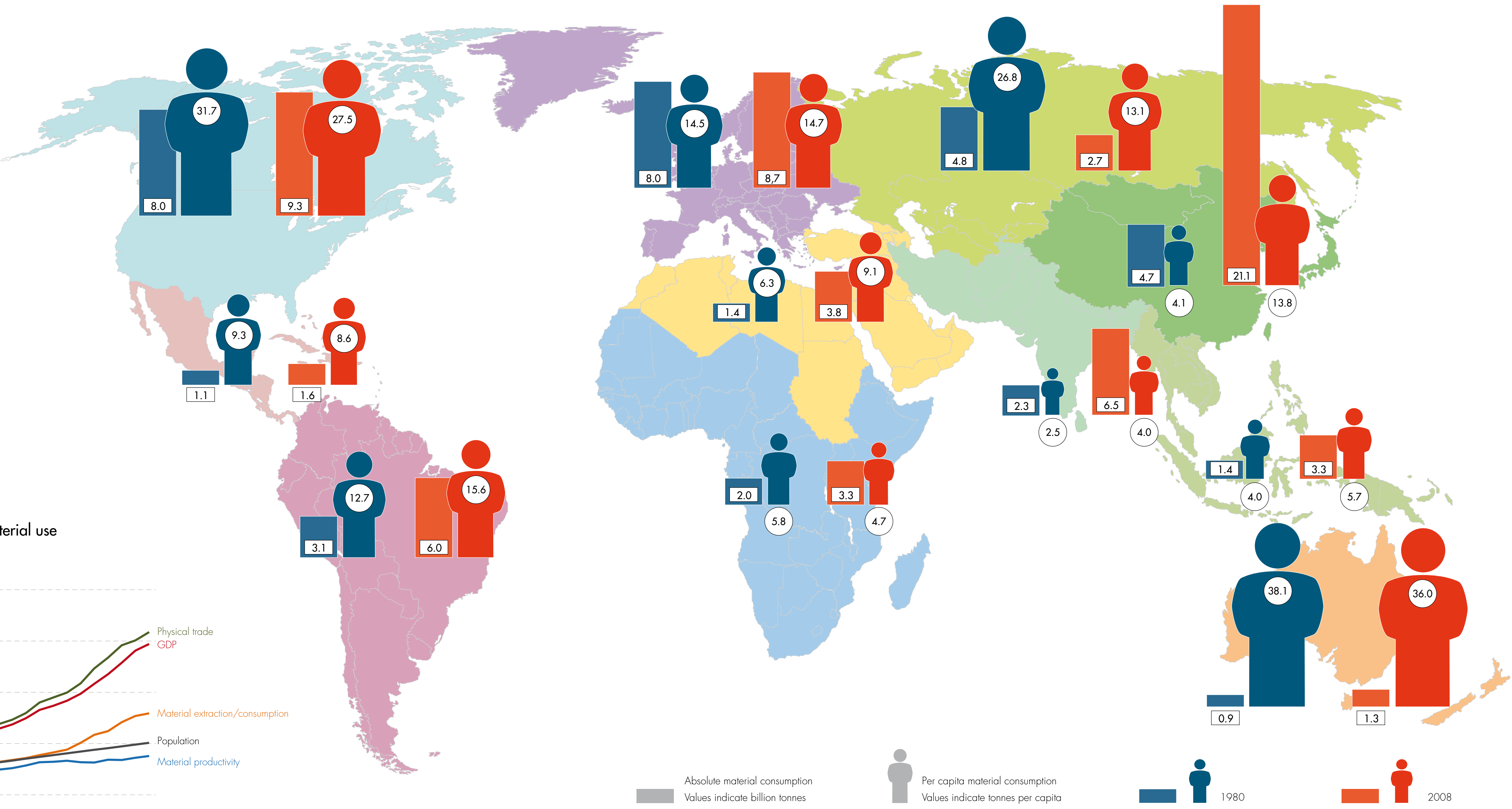
Global trends of material use at a glance

On average, each human being consumed around 10 tonnes of materials in 2008, 1.6 tonnes more than in 1980. A Factor 11 difference can be observed between the regions with the highest and lowest material consumption. At the same time, humans generate more and more economic income per unit of materials consumed, but did not even achieve a doubling – or Factor 2 – of material productivity between 1980 and 2008.

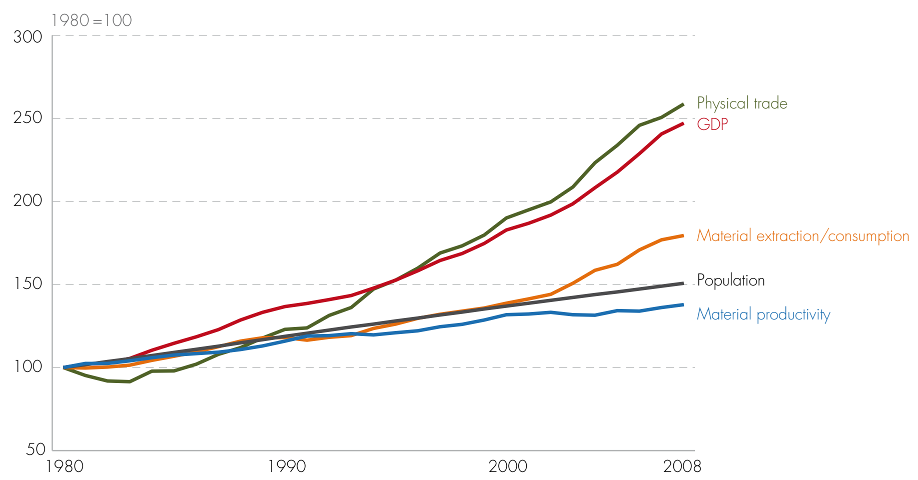
Absolute and per capita material consumption grew very unevenly in different regions. With the exception of Central Asia where the collapse of the former Soviet Union resulted in a decrease in material consumption in almost all successor states, absolute consumption increased in all regions from 1980 to 2008, most rapidly in East Asia (in particular in China). Per capita consumption, by contrast, was almost stagnant or even declined in some regions, such as North America or Africa, and increased in others, notably in East Asia.

Global material extraction, trade and consumption have increased almost every year over the past 30 years. Since 1980, global extraction which equals global consumption has been growing by an average of 2.8% annually and physical trade by even 5.6%. Global material consumption declined only in a few specific years: in 1981, after the second oil crisis and in 1990/91, after the collapse of the Soviet Union. Global material consumption increased at a significantly faster pace after 2000, mainly due to growth dynamics in China. The trade volume decreased temporarily as a consequence of the second oil crisis. Between 1980 and 2000, income grew faster than material extraction and consumption, resulting in a relative decoupling. Since 2000, material productivity has stagnated at the global level.

Material consumption by regions in absolute and per capita terms1980 and 2008



Global trends in GDP, population and material use
1980–2008

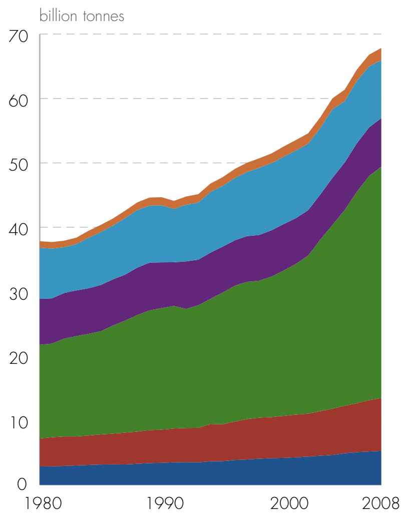


Regional trends of material use at a glance

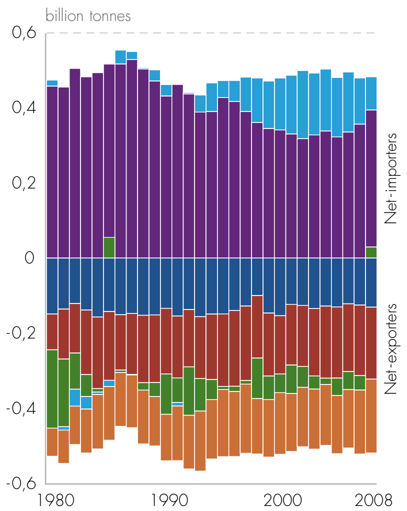
Material use has increased across regions, but Asia is by far the most diverse and dynamic region[17]. Asia extracts, exports, imports and consumes around half of all globally used materials. However, its average per capita consumption as well as its material productivity are still below the global average. With around 400 million tonnes, Europe is the biggest net-importer of materials, while Latin America and Australia are the most important suppliers of materials in the world markets.

Regional trends…

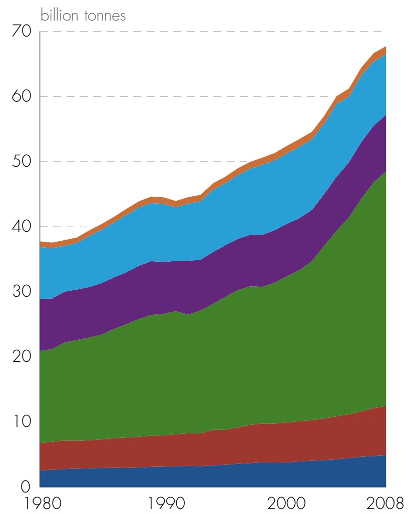
…in extraction

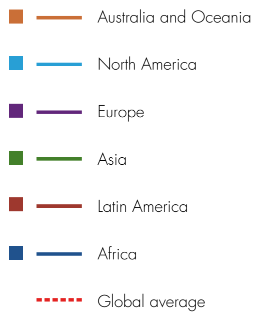


… in trade



…in consumption

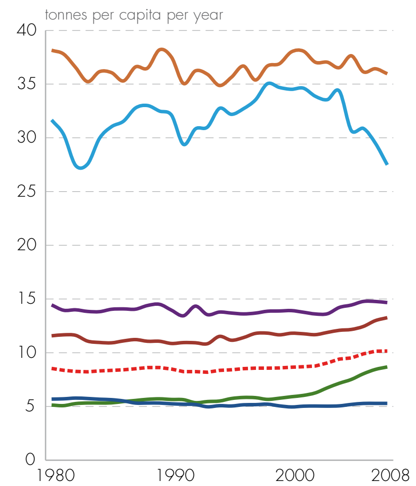




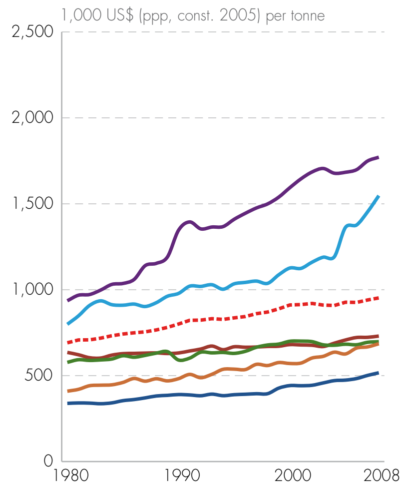
From material extraction to material consumption

All production processes start with the extraction of raw materials from nature: harvesting of biomass such as crops, timber or fish from the global ecosystems; extraction of fossil fuels, such as oil or gas; or mining of metal ores and minerals from the earth's crust. A portion feeds domestic demand. This is often the case for food products or for construction minerals such as sand, which are available in most countries. Other types of raw materials, in particular fossil fuels and metal ores, are available in concentrated form in only a few regions (such as oil in the Middle East or metal ores in Latin America) and are therefore traded to reach consuming countries.

…in per capita consumption



…in material productivity



Regional trends in extraction

Between 1980 and 2008, material extraction increased in all regions. Extraction nearly doubled in Africa, Latin America and Australia. In Asia, extraction grew by as much as a factor of 2.5. Growth in extraction was very low in Europe. In North America, extraction increased until 2005 and declined thereafter.

The drop during the 1990s is due to decreases in material extraction in Central Asia after the collapse of the Soviet Union (note: after the Fall of the Iron curtain, the western successor states are allocated to Europe). The increase in Asia after 1995 has been driven mainly by China.

Regional trends in trade

Around ten billion tonnes of materials were traded in 2008, more than ever before. About one-tenth of the total extraction is traded internationally, if volumes of materials that cross borders several times are excluded. Asia has the highest physical trade volume. The largest suppliers and the largest buyers of resources worldwide are also located in Asia, but in sum, Asia's net trade is the most balanced of all regions. In general, net-supplying regions remained net-suppliers during the past thirty years. The same is true for net-demanders, with the exception of North America, which changed from a net-supplier to net-demander during the 1980s.

Regional trends in consumption

Material consumption is the sum of extraction and net-trade. Net-importing regions thus consume more than they extract, whereas net-exporting regions consume less than they extract. As extraction exceeds net-trade by several times, material consumption mirrors material extraction at a regional level.
In 2008, Asia consumed more than half of all globally extracted materials, up from 37% in 1980. The shares of African and Latin American consumption grew slightly from 6.8% and 11.1% to 7.2% and 11.2%, respectively. Those of Europe and North America clearly decreased from 27% and 21% to around 15% and 14%, respectively.

Regional trends in per capita consumption

Average per capita consumption across regions differs by a factor of almost seven. Material consumption in Africa and Asia was below the global average of 10.2 tonnes in 2008. Increases in per capita consumption have only been observed in Asia and Latin America since the mid 1990s (+46% and +14%, respectively). The slight decline in North American per capita consumption of -6% over the past thirty years reflects, amongst other things, the decrease in construction activities after 2005. The fluctuations in Australia and Oceania are mostly driven by changes in raw material extractions in Australia.

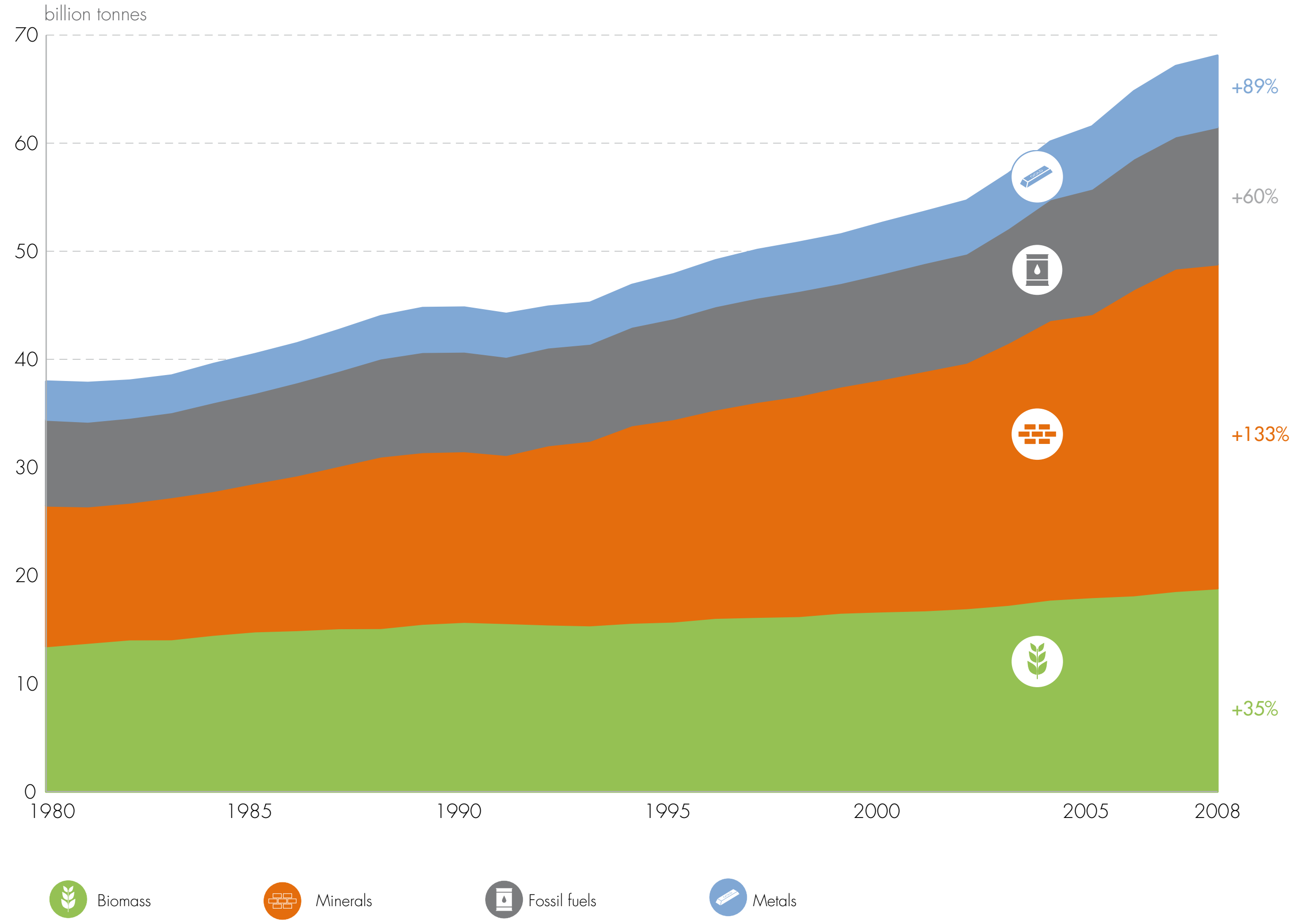
Regional trends in material productivity

Material productivity has increased across regions since 1980, by an average of +38%. In the net-exporting regions, Australia, Latin America and Africa, material productivity and productivity growth (at +67%, +15% and +53%, respectively) are minor compared to those in the net-importing regions Europe and North America (+94% and +89%).
Note that the former Soviet Union is not included in the figure due to a lack of comparable income data. The increase in Europe between 1990 and 1992 is, amongst other reasons, due to statistical changes in country territories after the collapse of the former Soviet Union.

The material basis of the world economy

Today, humans extract more material resources than ever before in history. Global material extraction has grown by almost 80% over the past 30 years and is around 70 billion tonnes today. With a share of more than 70% of total material extraction, humanity increasingly relies on non-renewable materials, such as fossil fuels, metal ores and minerals.

Global material extraction and growth rates by main material categories
1980–2008

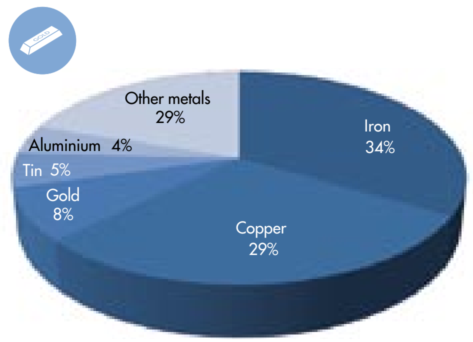


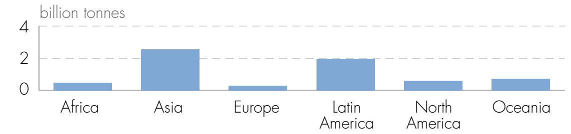
Global material extraction grew by almost 80% over the past 30 years. While worldwide extraction of biomass, fossil fuels, minerals and metal ores was around 38 billion tonnes in 1980, this number increased to more than 68 billion tonnes in 2008. Extraction has been growing constantly over the past 30 years, except in the early 1990s, when a severe economic recession hit the countries of the former Soviet bloc.

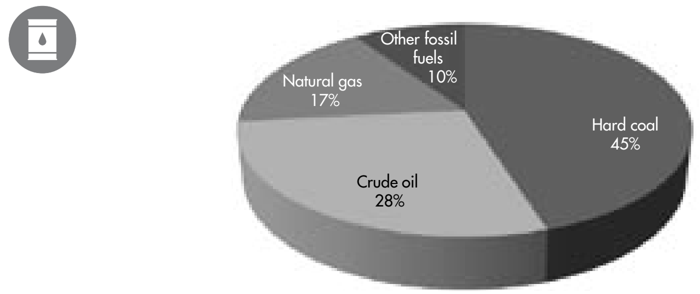
This led to a decline in industrial output and reductions in resource demand. Growth rates in 2003 are significantly higher than in any of the previous periods (+3.7% annually compared to 1.7% per year before 2003), in particular due to the rise of emerging economies, such as China, India and Brazil. Growth has been observed in all major material categories, but is most pronounced for industrial and construction minerals and metal ores. As a result, the share of renewable resources in global extraction decreased from 36% to 28%.

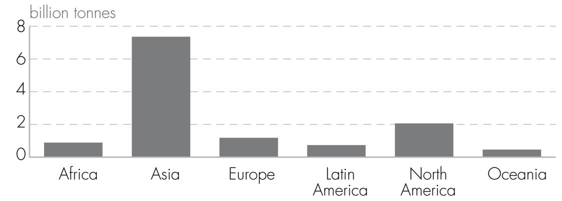
Material extraction by continent
2008

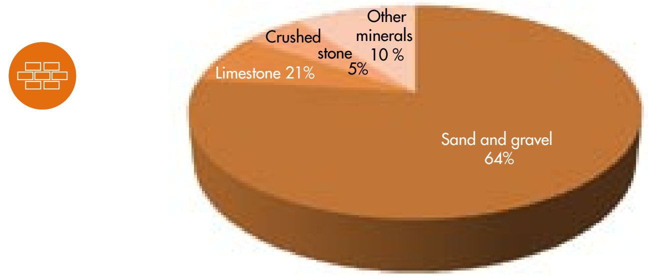
Shares of main materials extracted globally in the four material categories
2008

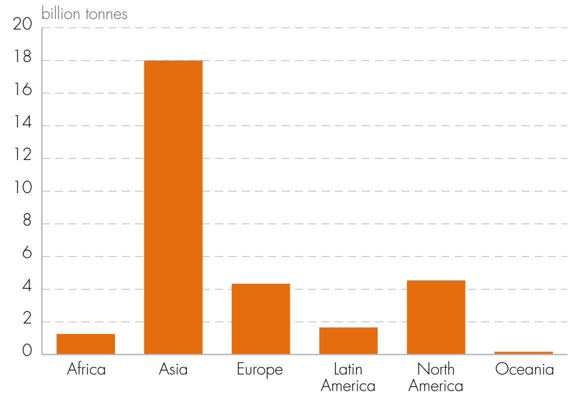


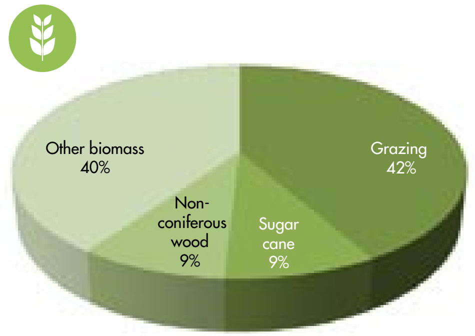


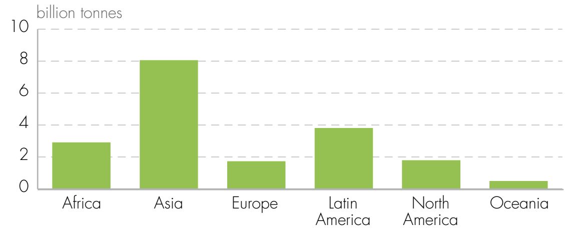












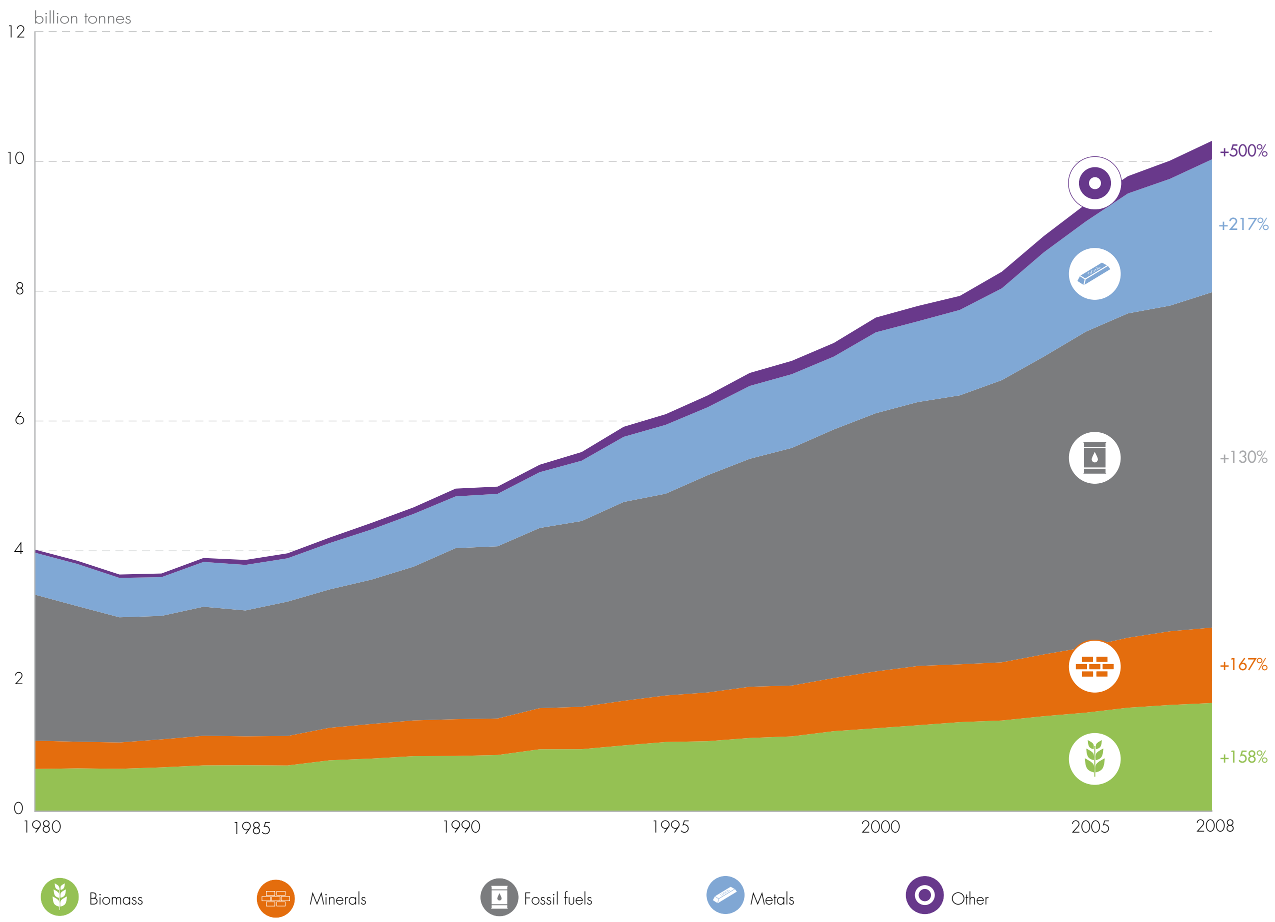
Asia has the highest material extraction levels of all regions worldwide in all four material groups. However, other continents also play a significant role. For example, Latin America (in particular, Brazil, Chile and Peru), Oceania (especially Australia) and many African countries contribute significantly to the global supply of metals.

North America is the second largest extractor of fossil fuels after Asia, in particular of hard coal and natural gas. The uptake of plant biomass by grazing animals is the biggest single category within the group of biotic material with particularly high importance in Asia, Latin America and Africa.

The physical dimension of global trade

Commodity trade volumes are higher than ever before. Trade volume in physical terms has increased by a factor of 2.5 over the past 30 years. Today, more than 10 billion tonnes are traded around the globe annually. The trade shares of renewable and non-renewable materials have remained almost constant over the period, at 16 % and 84 % respectively.

Global physical trade volumes and growth rates of main material categories
1980 – 2008

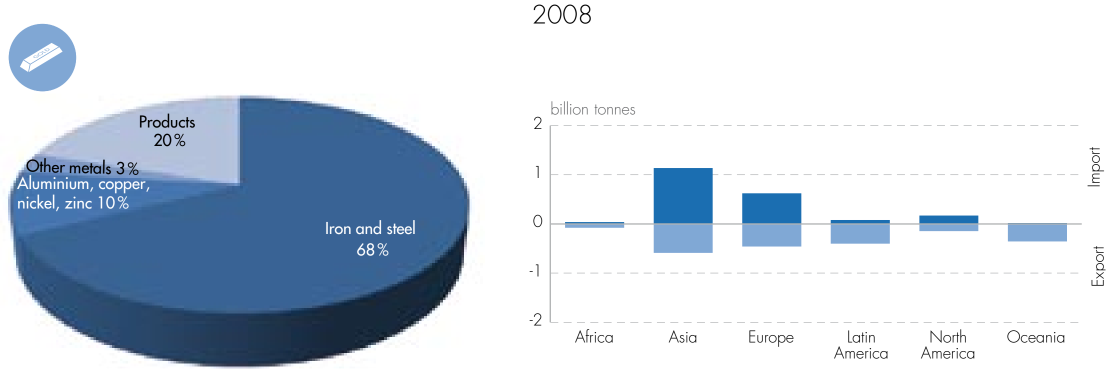


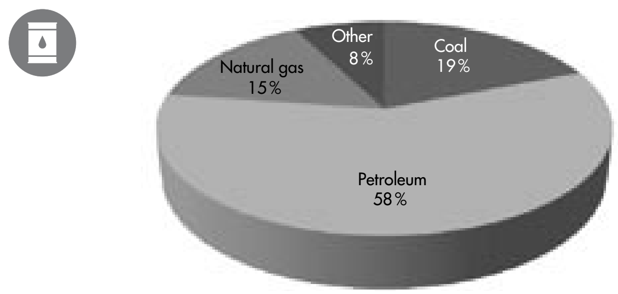
The physical volume of traded goods increased by a factor of 2.5 over the past 30 years. Trade volume increased throughout, except for the early 1980s, when it declined as a consequence of the second oil crisis. Materials that are geographically concentrated in only a few specific regions dominate trade in physical terms.

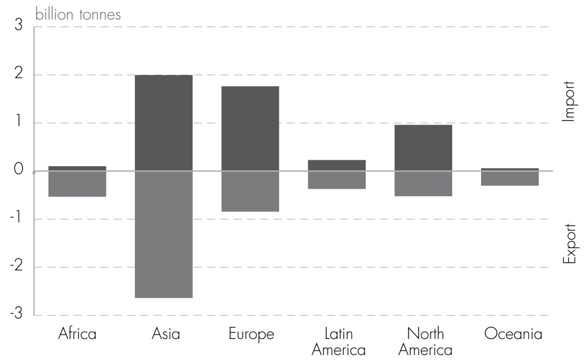
Fossil fuels, specifically petroleum, are the most important category of traded materials. Although their trade volume increased to more than 5 billion tonnes in 2008, their share in the physical trade volume decreased from 56 % in 1980 to 50 % in 2008. Today, the main importing and exporting region is Asia.

The share of **metals** in global trade increased from 16 % in 1980 to 20 % in 2008. The most traded metal, by far, is iron – in different stages of processing, from crude ore to finished products such as machines and vehicles. Precious metals, such as gold, silver and platinum, have experienced the highest growth in physical trade but their share in global trade is minor (less than 0.04 %). Asia is the world's largest importer and exporter of metals, mainly due to its rapidly growing metal processing activities.

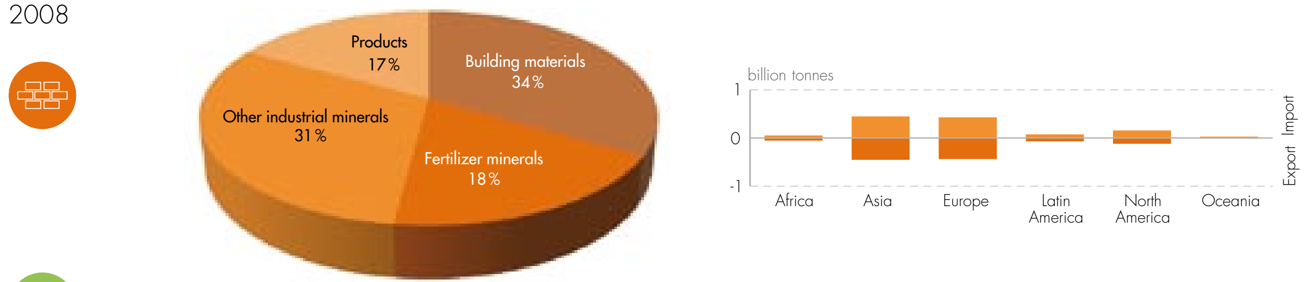
Material trade of countries by continent
2008

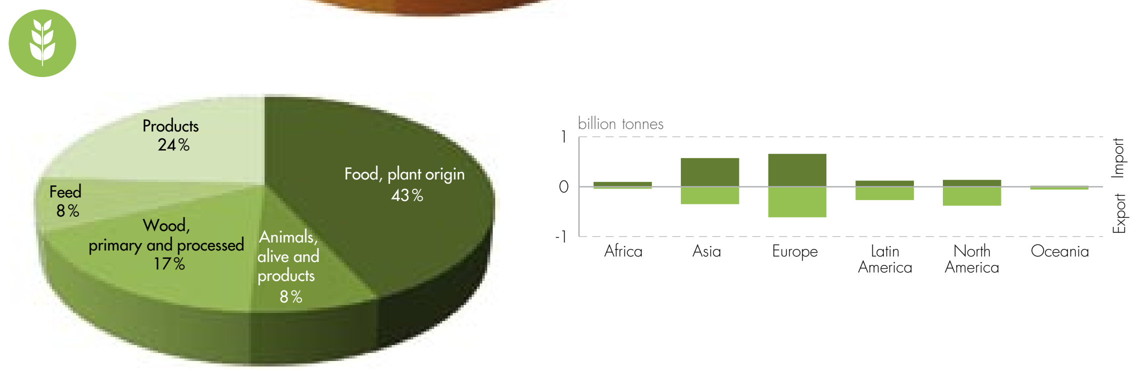






Shares of main materials traded globally in four material categories
2008





At 16 %, **biomass** has traded at a relatively constant share of global material trade. The most traded products are food (in particular cereals), followed by forestry products (timber) and finished products made of biomass, such as furniture or paper. The largest net-supplier of biomass are North American countries (United States); Asian countries are the main net-importers.

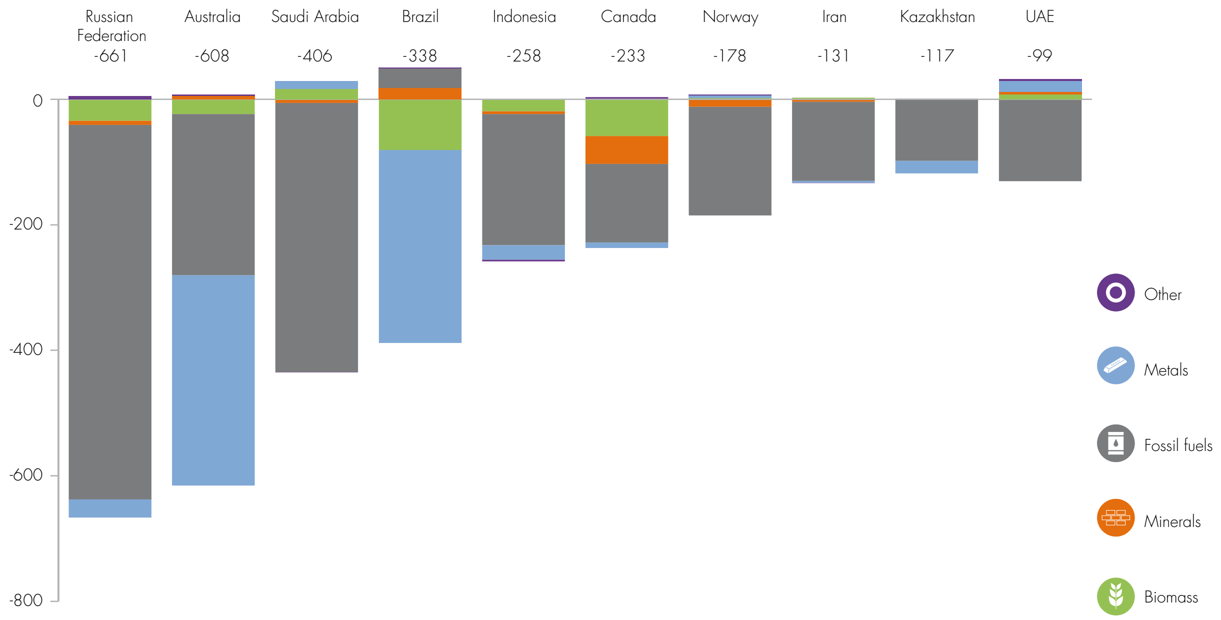
Non-metal **minerals**, in particular for construction purposes, are not traded as much, as they are more geographically ubiquitous than other commodities. Small countries and city-states are generally more dependent on imports of construction minerals. Moreover, these materials are predominantly traded between neighbouring countries such as Indonesia and Singapore.

The category **other** includes predominantly finished products made of diverse materials such as footwear, toys or antiques. It also includes other, unspecified traded products.

Global allocation of materials via trade

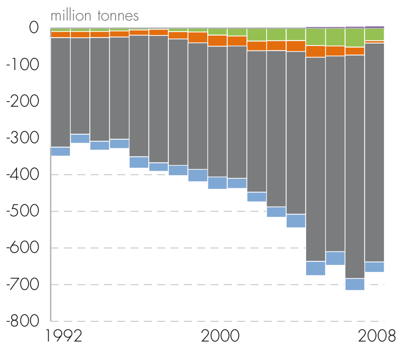
Natural resources are unevenly distributed on the planet. It is through trade that materials travel from resource-abundant countries to resource-scarce ones. This is relevant in environmental terms because abundance usually goes along with fewer environmental pressures during extraction and production. In reality, several other factors also determine trade flows, such as resource prices, demand by industries and consumers, protectionism and institutional frameworks in different countries.

Main net-exporters of materials by material categories and physical trade balances
2008



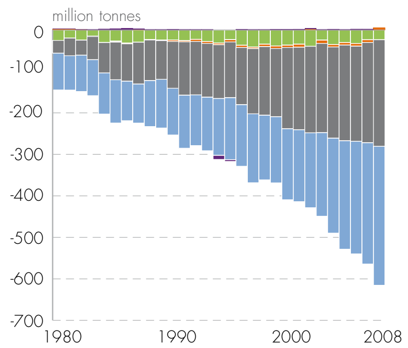
The Russian Federation

The world's largest and one of the most resource-rich countries has been the largest supplier of materials globally since 1995. Currently, the Russian Federation provides 16% of all materials worldwide which are re-allocated through global trade.



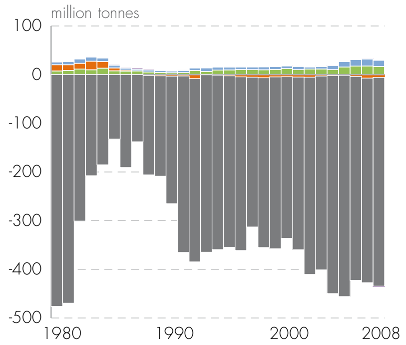
Australia

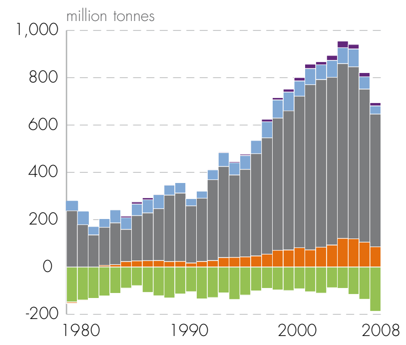
Australia is the most important metal exporter and the third largest supplier of fossil fuels in the world. Currently, Australia supplies 14% of all net-allocated resources globally.



Saudi Arabia

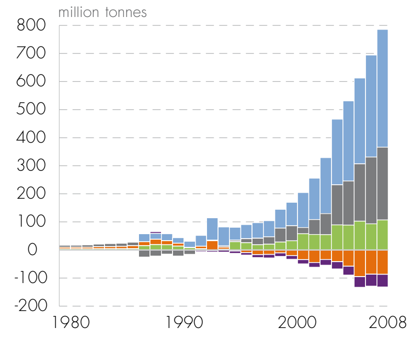
Saudi Arabia is the world's largest supplier of petroleum, although the gap to Russia's fossil fuel supply has been narrowing. The curve in the 1980s reflects the second oil-crisis. The country's natural capital is based predominantly on one exhaustible commodity; it imports nearly all other goods.





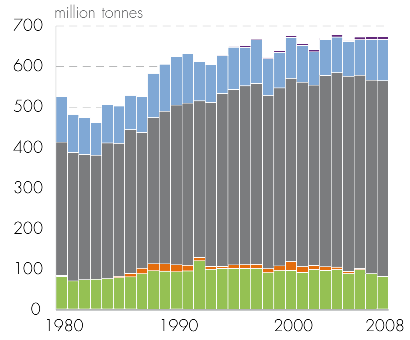
United States of America

The USA, one of the most resource-rich countries is the largest supplier of biomass (mainly maize). Until the mid-1970s, the USA had been a net supplier, but some materials (e.g. petroleum) reached their production peaks while society's demand for fossil fuels continued to increase.



China

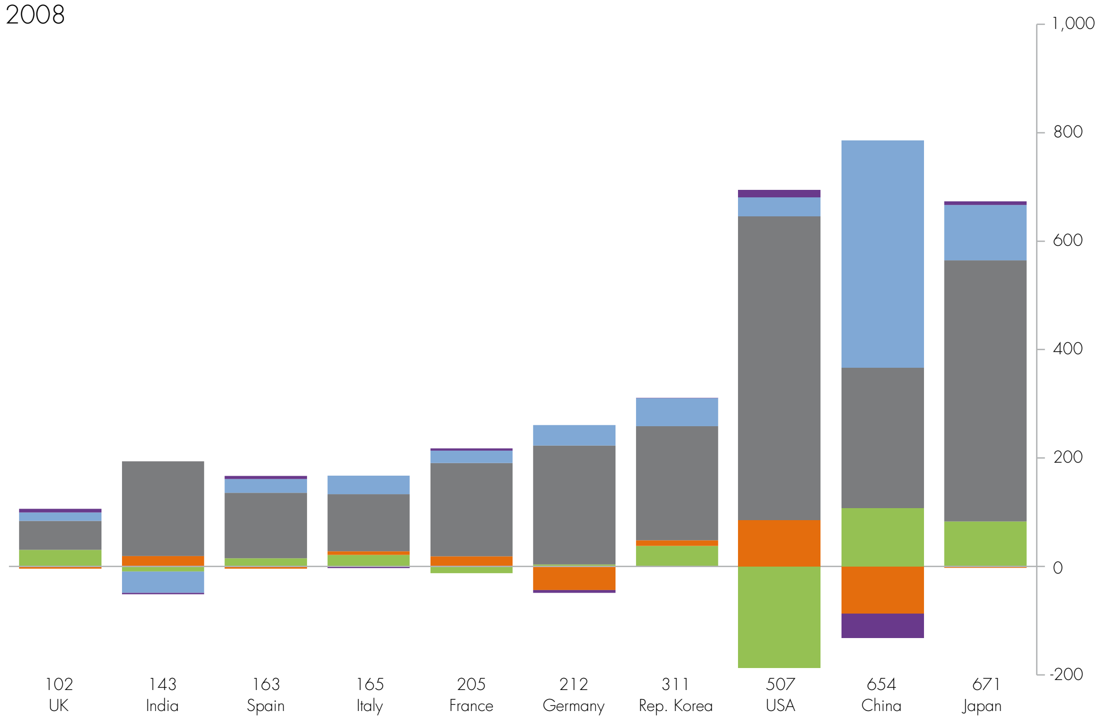
In the beginning of the 1980s, resource-rich China was barely integrated in world market. By 2008, it was the largest importer of metals worldwide and the second largest importer in sum despite its increasing exports of manufactured goods, which are mostly part of the category "other".



Japan

Since the beginning of modern trade statistics, apan has been the world's largest net-importer of materials. Japan was a net-importer of all material categories except for minerals for which it had been a net-exporter for a few years, albeit for negligible volumes, less than 5 million tonnes.

Main net-importers of materials by material categories and physical trade balances
2008



Concentration of trade in 2008

In 2008, around 85 countries imported and exported less than 10 million tonnes of resources and thus participated only nominally in world trade, whereas the ten countries with the highest physical trade volume, imported and exported 95% of all traded resources. The five largest resource suppliers exported 54% of all allocated resources; while the five largest buyers of resources imported 57% of all imports.

From export to import dependencies?

For a long time, developing countries competing in the world market have expressed concern over the low prices their raw material exports fetch from a few industrialised countries. Today, an increasing number of emerging economies process raw materials to semi-finished or finished goods. This has had a significant impact on the global demand for raw material imports, changing prices and power relations. Today, a major concern for many industrialised and industrialising countries is the secure supply of raw materials, and the increasing expense of procuring them.

Trade volume in monetary and physical terms

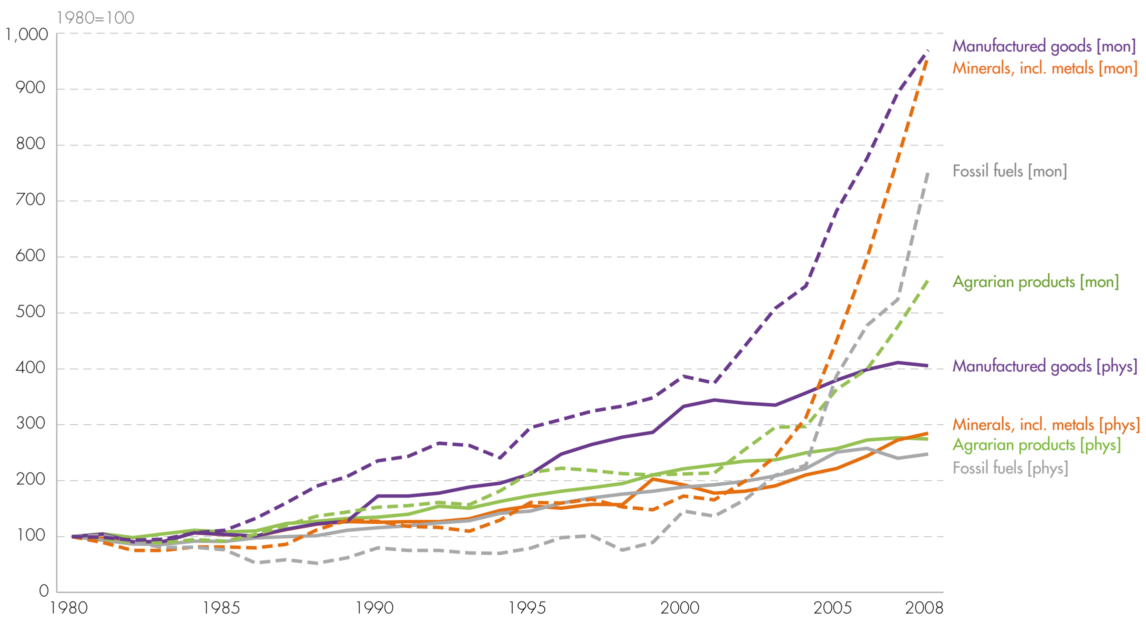
When measured in monetary terms, trade is dominated by manufactured goods; in physical terms, it is dominated by fossil fuels. Most manufactured goods have a high value but comparatively low mass, while the opposite is true for most raw materials.

Since 1980, trade in manufactured goods has grown tenfold in monetary terms and quadrupled in physical terms, while the physical trade volume of agrarian products, fossil fuels, minerals and metals has only tripled. Due to rising resource prices, their traded value grew from sixfold to ninefold since 2000.

Changing trade relations

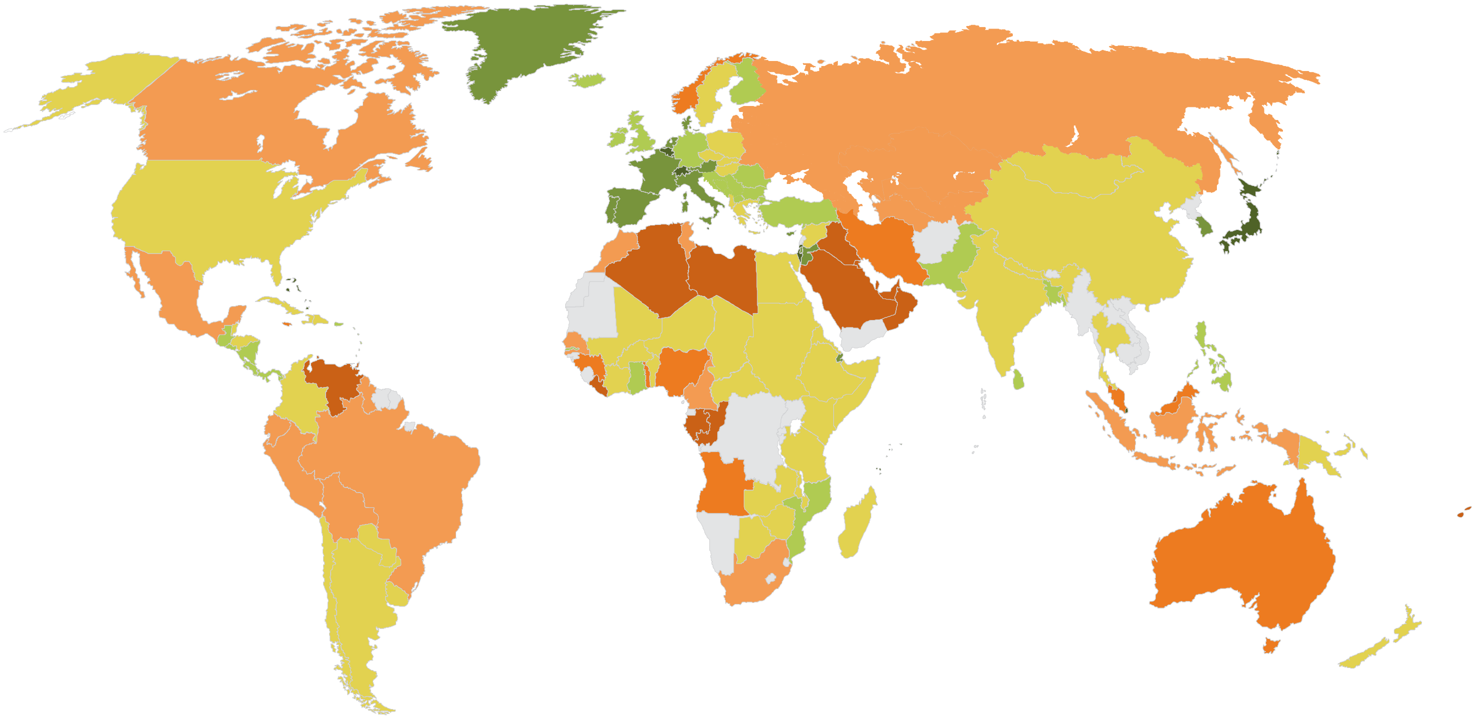
The number of countries that have significant net imports was always higher than the number of countries with significant net exports, mainly due to island and city-states. However, a major change has occurred in the ratio between both groups: In 1980, 55 countries net imported 3% or more of their consumption, and 39 countries exported a significant amount of their extraction. By 2008, the ratio was 110 to 45. Thus, more countries are competing to import resources from a rather constant number of countries that export an increasing share of their domestic extraction.

Trade volume in monetary [mon][18] and physical [phys] terms of different product groups
1980–2008

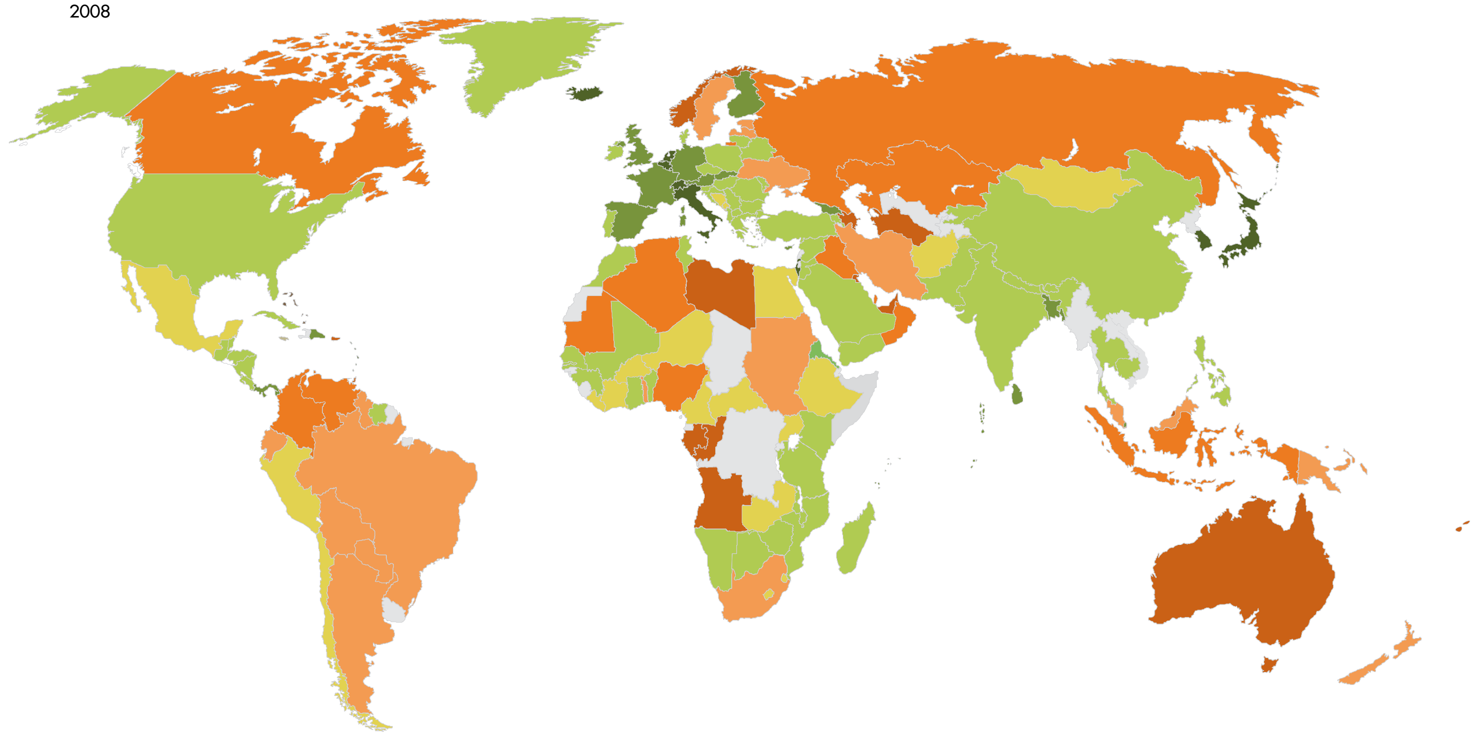


Net-exporters and net-importers of materials
1980 and 2008

1980



2008



Net-exporting countries
% of extraction which is net-exported
3–14%
15–29 %
>30%

Net-importing countries
% of consumption which is net-imported
3–14%
15–29 %
>30%

Balanced trade: +/- 2% of extraction/consumption is net-traded

Data not available in acceptable quality

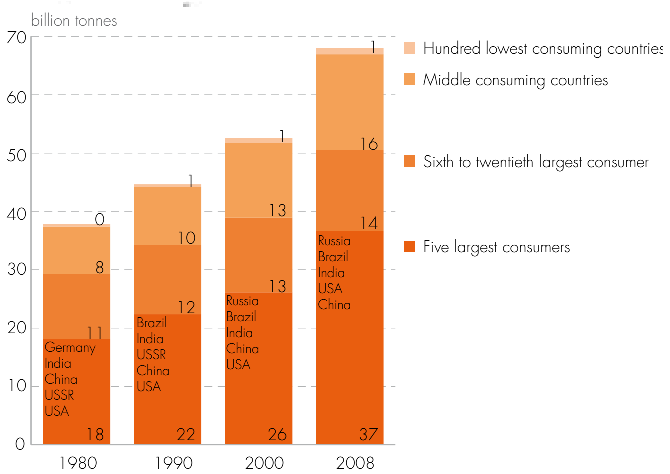
"Large" and "small" consuming countries

If the "big five" material consuming countries – China, the United States, India, Brazil and the Russian Federation – were to enter into a global resource management agreement, together, they would be deciding how more than half of all globally consumed materials would be used. Further, combined with the 15 high consumer countries that follow them, this group of 20 countries could influence about three quarters of global material consumption. By contrast, the 100 countries with the lowest absolute material consumption together consume only around 1.5% of all globally consumed materials.

Absolute resource consumption is very unequally distributed across countries. Populous, high income and resource rich countries generally consume more materials in absolute terms than others. Since 2002 China has been the top global consumer of most materials in absolute terms. In 2008, it consumed twice as much as the United States.

Absolute material consumption of high and low consuming countries

1980–2008

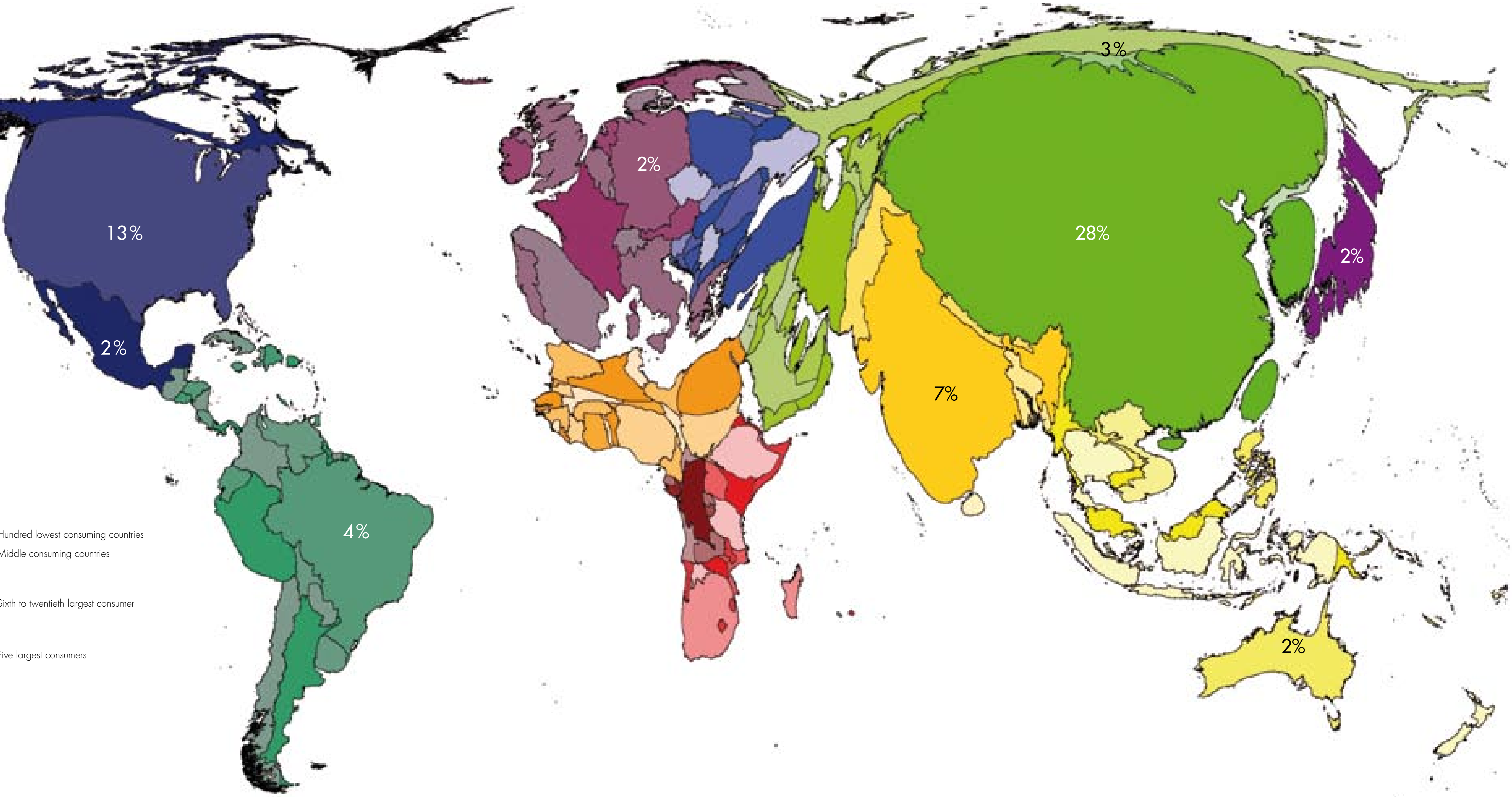


Absolute resource consumption is especially relevant from an environmental perspective because it indicates the overall magnitude of various environmental pressures related to material use as explained in chapter 4. The share of the "big five" in global resource consumption grew from 48% to 54% between 1980 and 2008, while the share of the next 15 high consuming countries of the top 20 (mainly OECD members and populous developing countries) decreased.

The 100 least consuming countries are predominantly small islands and city-states but also include developing countries with several million inhabitants, for example Rwanda and Eritrea. Their material consumption doubled in absolute terms, but their share in global resource consumption remained constant at around 1.5% of globally used materials since 1980.

Absolute material consumption of countries and share in global material consumption in 2008

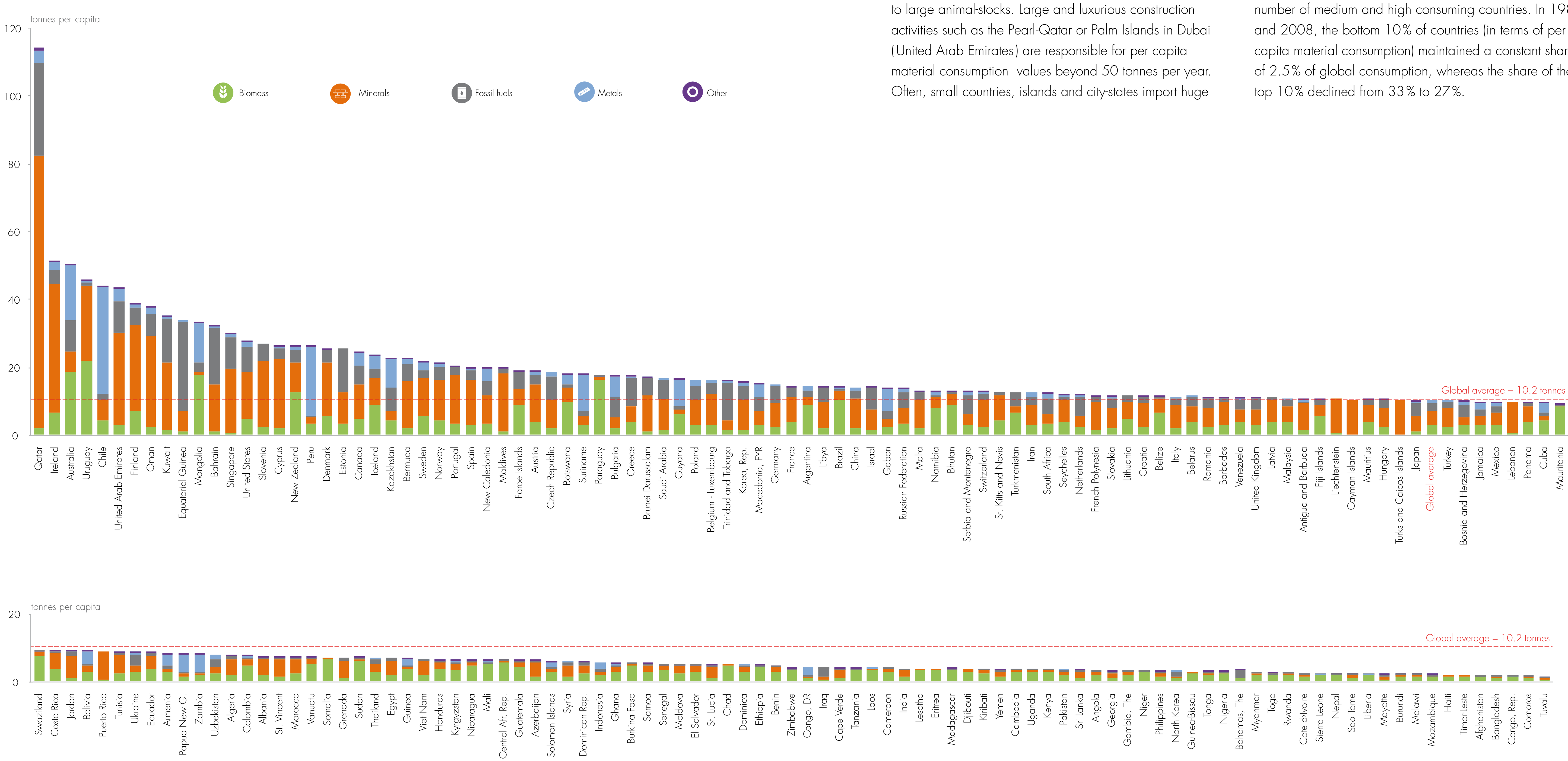
Country size is proportional to its share in global material consumption



Consumption: from survival to affluence

Average material consumption in per capita terms varies greatly across the globe. As observed in countries with the lowest per capita consumption, the minimal consumption for survival is around two tonnes per person per year, which includes materials for the basic needs of food and shelter. The highest average per capita consumption is sixty times the lowest and is dominated by minerals for large construction activities and by the consumption of fossil fuels.

Material consumption per capita
2008



Globally, a person uses at least 1.5 tonnes of biomass and 0.3 tonnes of minerals per year. Biomass is predominantly used for nutrition and as a source of energy; minerals are mainly used for shelter. In general, rising material consumption goes along with an increasing use of fossil fuels, of minerals and metals for public and private infrastructure and of metals for technical equipment. Biomass consumption increases only slightly with higher income. High amounts of biomass use are mainly due to large animal-stocks. Large and luxurious construction activities such as the Pearl-Qatar or Palm Islands in Dubai (United Arab Emirates) are responsible for per capita material consumption values beyond 50 tonnes per year. Often, small countries, islands and city-states import huge amounts of single commodities in one year, e.g. petroleum, minerals or ships, and hardly any of these commodities in the next year; sometimes, they even export them (partly further processed) in the following years. Thus, their material consumption can fluctuate wildly, exceeding 100 tonnes per capita in some years, and falling below zero in some material categories in other years. Inequalities between countries with high and low average per capita consumption declined slightly over the past 30 years due to an increasing number of medium and high consuming countries. In 1980 and 2008, the bottom 10% of countries (in terms of per capita material consumption) maintained a constant share of 2.5% of global consumption, whereas the share of the top 10% declined from 33% to 27%.

Material productivity: sufficient progress?

Between 1980 and 2008, the world economy increased the amount of economic value created per unit of consumed material by about 40%. Yet, despite this growth in material productivity, overall material consumption has been increasing at an unprecedented scale. Only very few countries increased economic output while decreasing absolute material consumption.

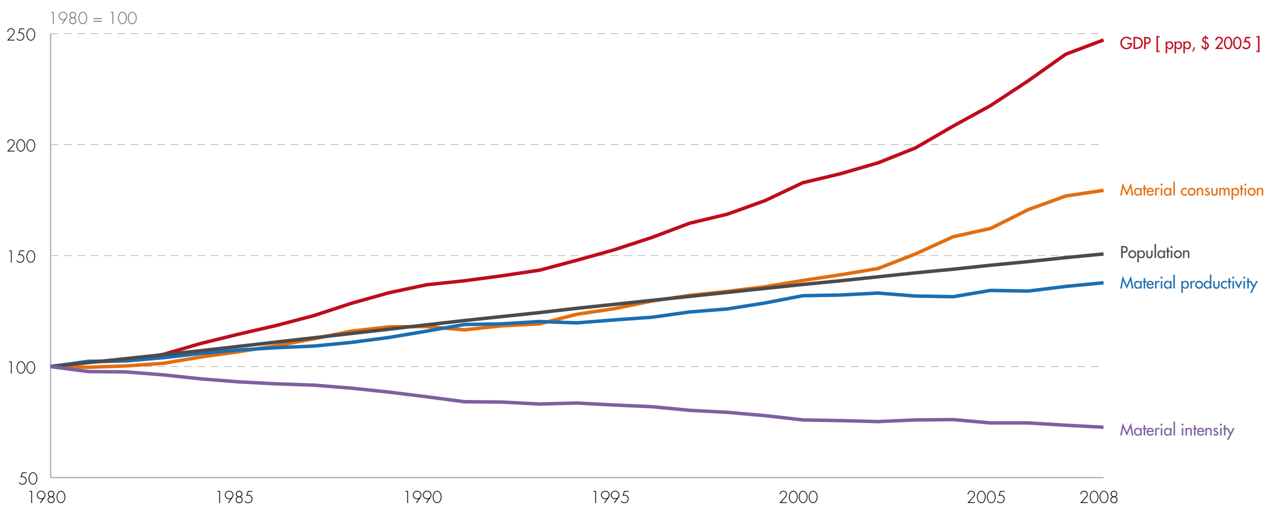
Relative versus absolute decoupling

Assessing the extent to which an economy has achieved green growth requires an understanding of so-called "decoupling". Decoupling generally refers to the amount of materials used in relation to economic output. Relative decoupling means that material consumption is increasing at a pace slower than economic output. This is a good start towards sustainable development but not sufficient in the long term, as environmental pressures continue to increase.

Given that environmental pressures are already above sustainable levels on the global scale, absolute decoupling must be the objective, in particular for the high-consuming rich countries. This can be achieved when GDP grows while material use and associated environmental pressures decrease in absolute terms. On the other hand, growth in material consumption will be necessary for poor countries, in order for them to achieve at least minimum acceptable material standards. However, globally and in the medium term, an absolute decrease of material consumption should become the main benchmark for green growth.

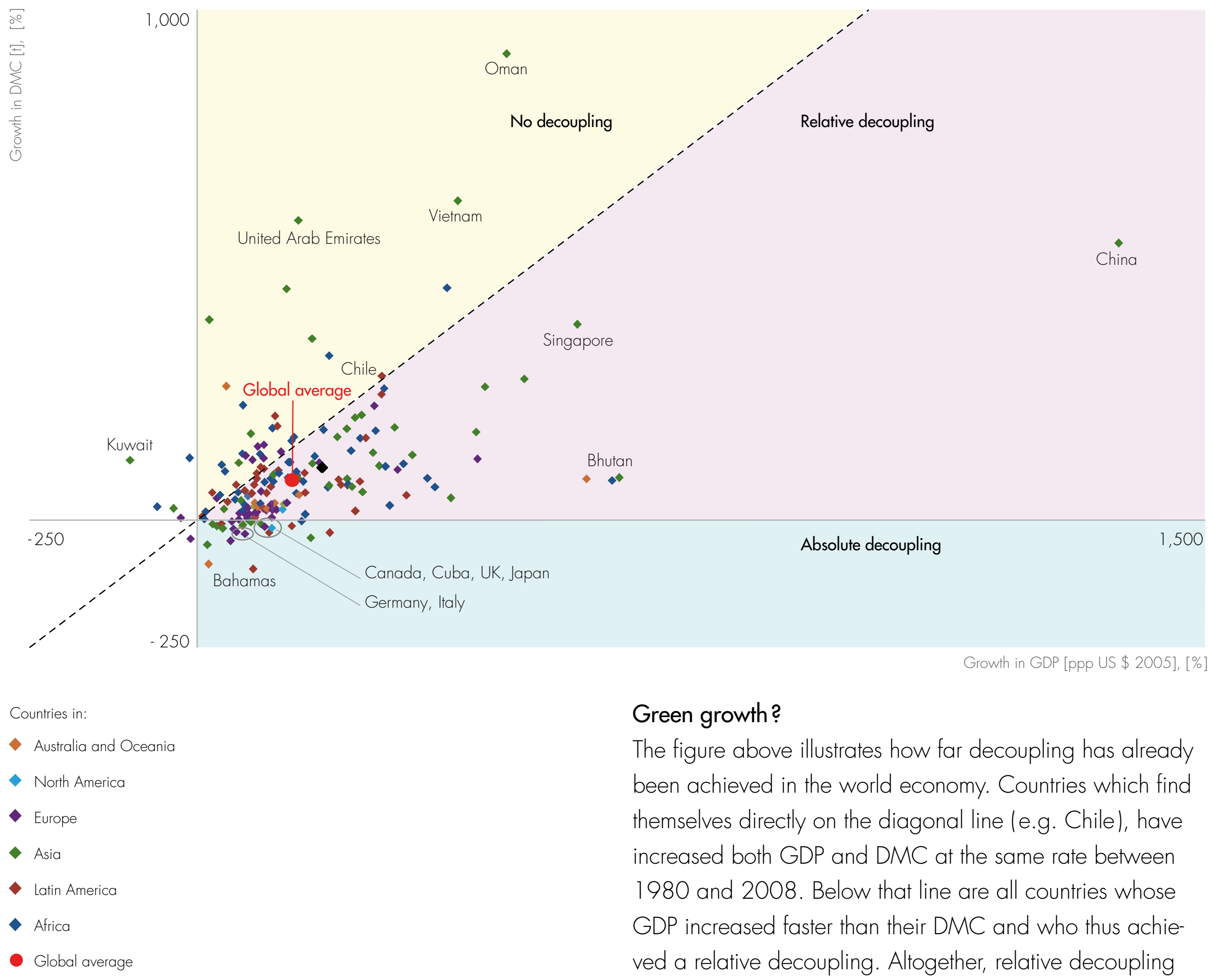
Growth of GDP, material consumption, material productivity and intensity, and population

1980–2008



Worldwide trends in GDP and domestic material consumption (DMC) growth

1980–2008



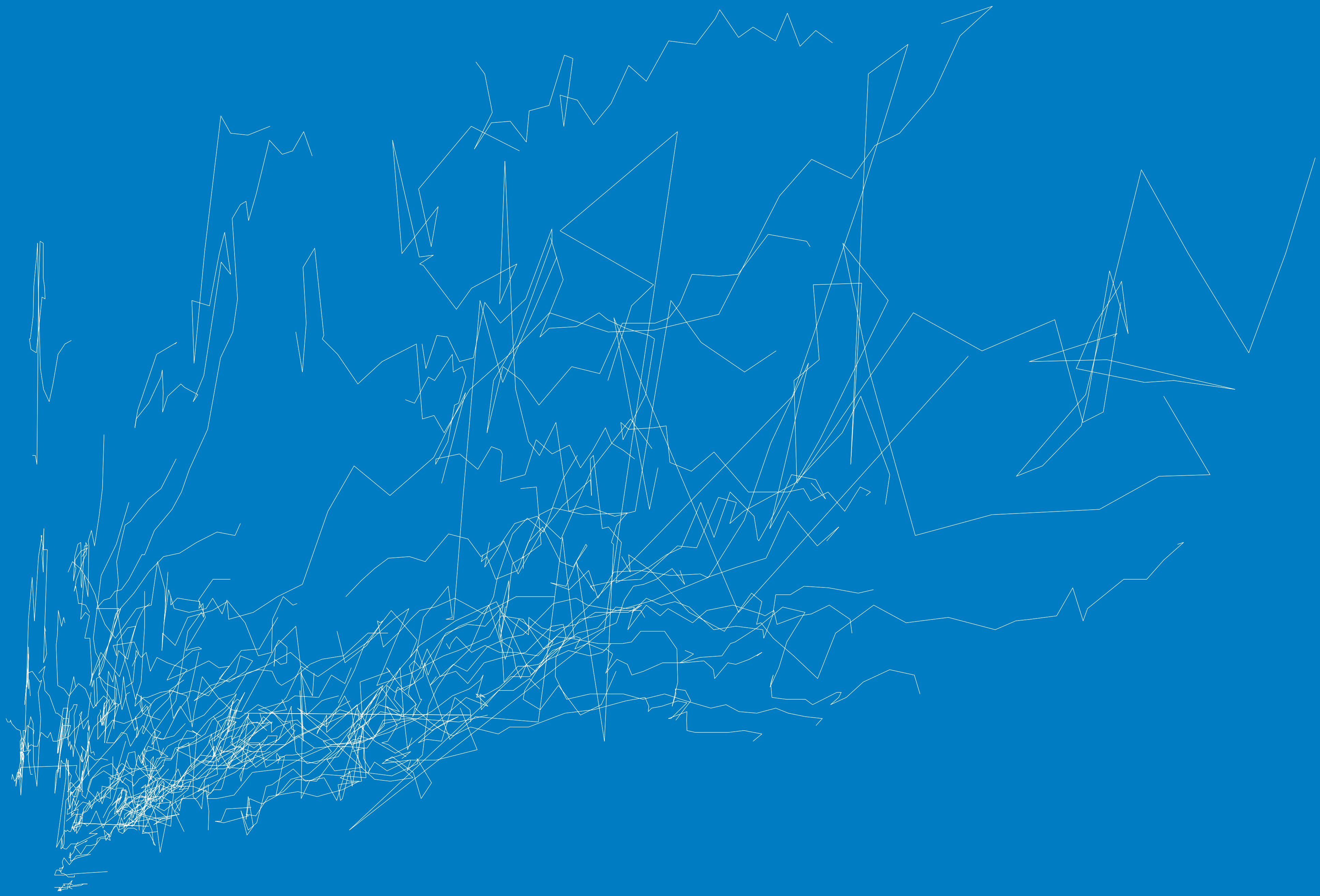
Relative decoupling at the global level

From 1980 to 2008, material intensity of the world economy decreased by about a third. This is reflected by an increase in material productivity of 37%, as GDP grew faster than material consumption (147% vs. 79%). So far, however, there are no signs of dematerialisation (absolute decoupling) at the global level. The achieved efficiency improvements have therefore been over-compensated by economic growth.

Green growth?

The figure above illustrates how far decoupling has already been achieved in the world economy. Countries which find themselves directly on the diagonal line (e.g. Chile), have increased both GDP and DMC at the same rate between 1980 and 2008. Below that line are all countries whose GDP increased faster than their DMC and who thus achieved a relative decoupling. Altogether, relative decoupling was the dominant trend across countries worldwide over the period, including the world economy as a whole. Absolute decoupling, i.e. GDP growth and falling DMC, was less common. Among the 34 OECD countries, only Canada, Germany, Italy, Japan, and the UK achieved an absolute decoupling. It is important to emphasise that this does not necessarily signify green growth, but could also be the results of outsourcing material-intensive production to other parts of the world. However, those aspects of dislocated environmental pressures through trade are not covered by the DMC indicator and would require more comprehensive data which reflects materials embodied in trade. This is currently unavailable. It is also obvious that absolute decoupling was only possible in countries with relatively low economic growth. At higher growth rates, huge improvements in material productivity would be required to achieve absolute decoupling. In some countries, growth in material consumption outstripped even GDP growth (e.g. Vietnam, the UAE and Kuwait).

3 Material use and development

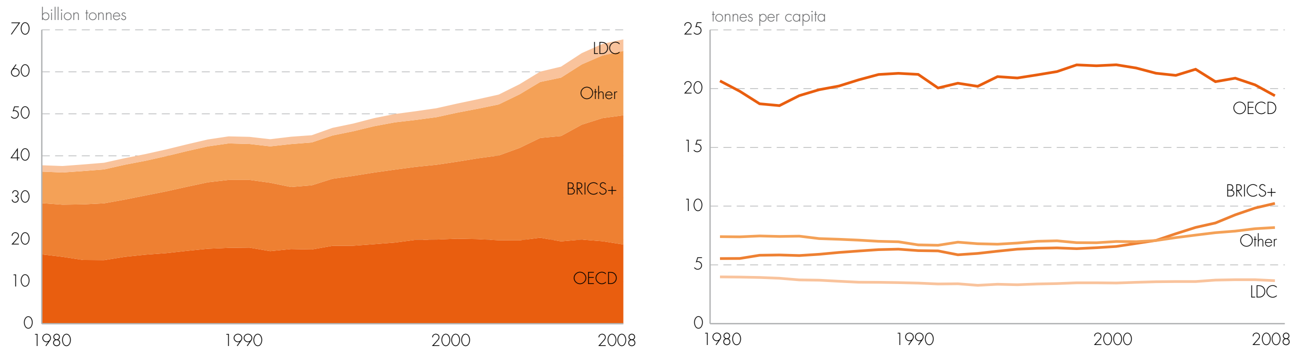


Material use and development at a glance

What looks like modern art in the illustration below is in fact what the real development paths of all countries worldwide look like, in terms of per capita income and material consumption between 1980 and 2008. The spread of income at similar levels of material consumption and vice-versa is remarkable. Furthermore, a number of factors influencing per capita income and material consumption are observed worldwide – these are explored further in the following pages.

Material consumption absolute (left) and per capita (right) of country groups

1980–2008

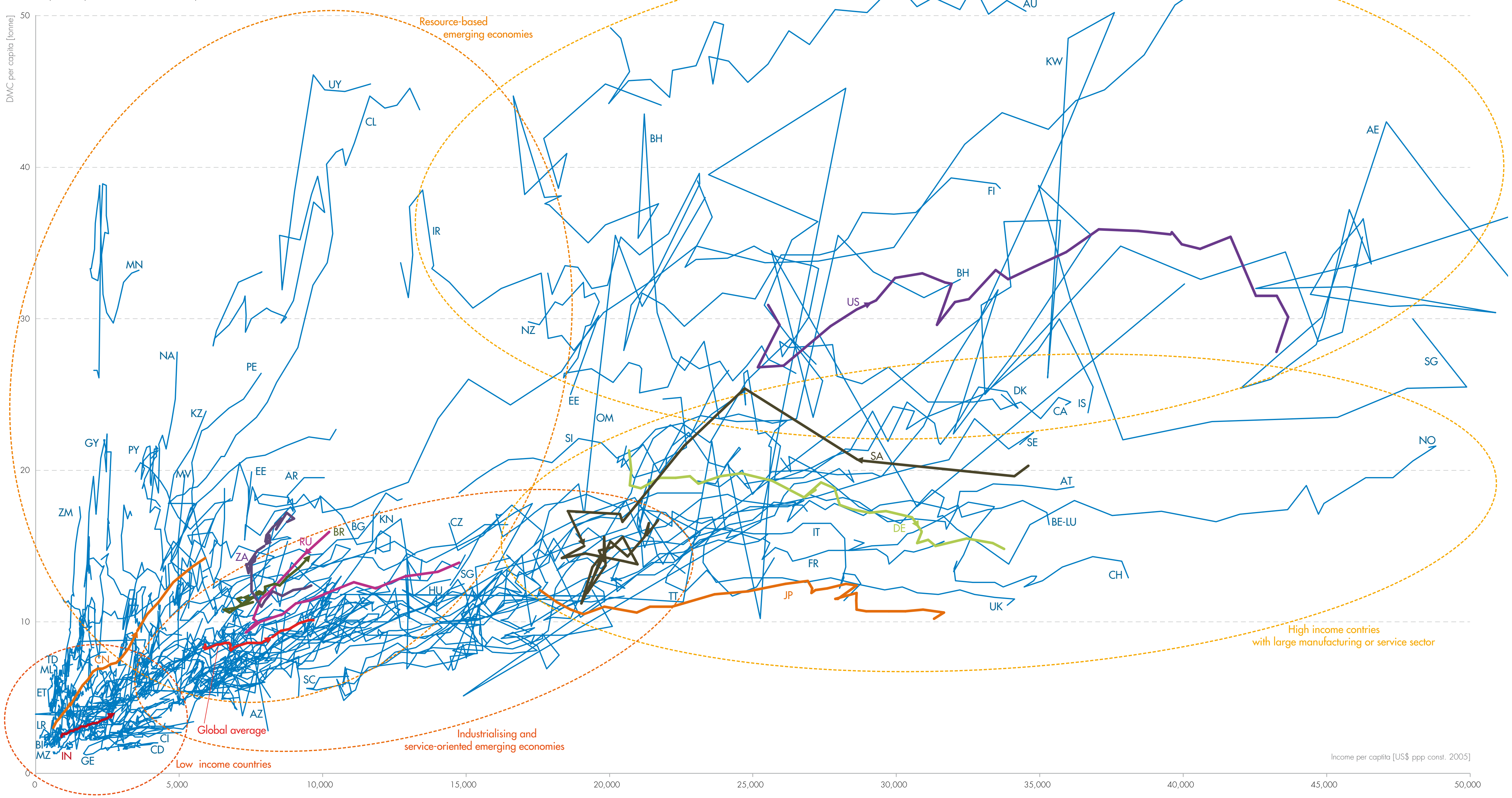


OECD members 1980; BRICS+: BR, RU, IN, CN, ZA, KR, SG, MX; LDC according to UN

Development of per capita material consumption and income of all countries*

1980–2008

*Please note: Brunei Darussalam and Qatar are excluded due to excessively high values in per capita material consumption and income; landcodes are listed at the back side of the cover.



Does material consumption, which is linked to a variety of environmental pressures (see next chapter for details), grow with increasing income? This most basic question about the link between environment and development has to be answered with a clear "yes". However, the differences in direct material consumption levels up to a factor of 9 between countries with similar income are surprising. What is even more astonishing is the differences in income of more than a factor 20 among countries with similar levels of per capita material consumption.

Levels and dynamics of material consumption of all countries globally show some remarkable patterns which lead to the identification of typical groups: low income countries have rather highly fluctuating consumption dynamics which are not linked as much to income. Medium income and emerging economies, understood as those with high growth rates in income, can on the one hand, be grouped into industrializing or service-oriented economies (in both, value is created basically by human labour) and on the other hand, in resource-based economies where wealth is generally gained by extracting resources. The first group has significant lower material consumption per capita and higher material productivity than the latter one. These differences remain even when a high income is reached. Further differences within the groups are driven by a variety of factors, such as the economic structure and the sectoral composition, political, financial or other external circumstances; all those aspects will be further explored on the following pages, which closely examine specific aspects of this main figure.

Low income countries

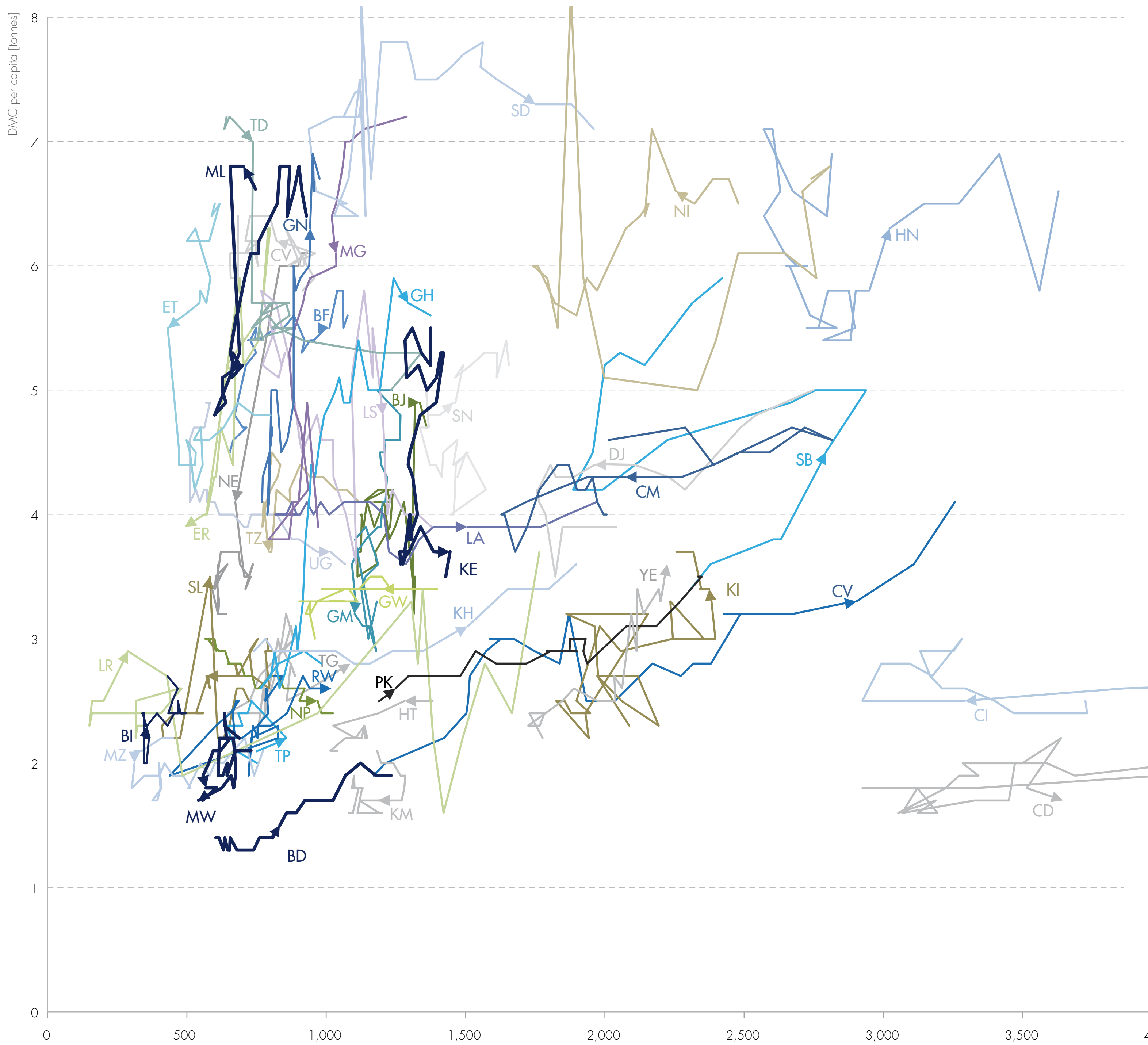
Material consumption per capita and material productivity is generally low in low income countries, around an average of 3.7 tonnes per capita in 2008. Nevertheless, a multitude of factors governing material use can be observed, ranging from growth, stagnation and decrease in material consumption and income. These are driven by factors such as population growth, dominant land-use systems or even natural disasters such as droughts.

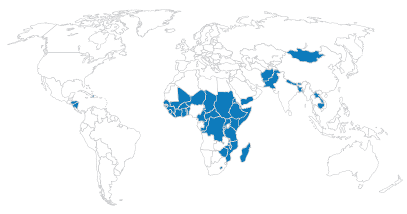
In low-income countries, humans consume predominantly biomass which includes food, feed and to some extent, products from forests such as charcoal. Furthermore, few minerals for housing and infrastructure are used, and consumption of fossil fuels or metals is negligible. Absolute resource consumption in all low income countries increased during the past 30 years. However, in many of these countries, population size increased faster than material consumption, resulting in a decrease of per capita material consumption. Most of the low-income countries are nominally integrated in the world market in material terms, although food is increasingly imported.

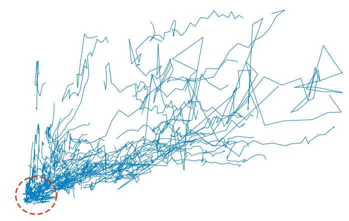
In general, animal-based agriculture is less resource efficient than a crop-based one. Biomass consumption in countries with higher animal stocks is often three times or more higher than in crop-based agricultural systems while income is comparable, e.g. in the cases of Mali and Malawi. While crops are easier to cultivate in fertile regions, animals can transform plants which are not fit for consumption by humans into edible meat, which enables human settlement in regions where crop-based agriculture is barely possible.

During the past thirty years, some low-income countries have developed more efficient agricultural production or diversified into other economic sectors such as manufacturing, mining or tourism, while retaining low income levels and low material consumption.

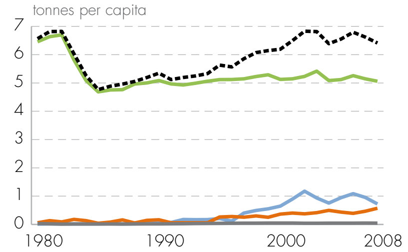
Development of per capita material consumption and income of low-income countries
1980–2008





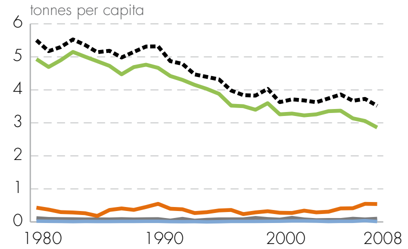


Material consumption per capita in Mali



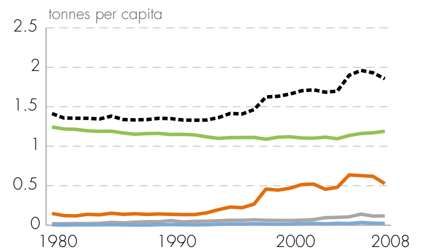
In countries with extensive and animal-dominated agriculture, feed for animals has a share of 75% or more in total resource use. In **Mali**, e.g., before extraction of metals (mainly iron ores) increased in the 1990s, up to 89% of consumed materials have been used for feed. Droughts often result in large-scale perishing of animals, e.g. the Sahel drought in the 1980s which caused the death of almost 25% of the animal stock in Mali, resulting in a significant drop in used feed stuff and biomass consumption.

Material consumption per capita in Kenya



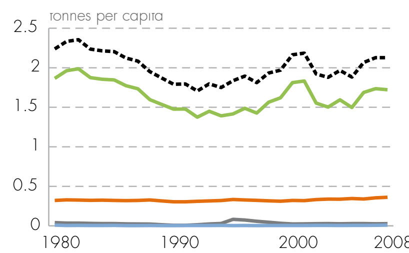
Although absolute resource consumption increased over the past 30 years, population size increased faster than material consumption, resulting in a decrease of 36% in per capita material consumption in **Kenya**. Two structural changes contextualise this immense decline: first, the share of rather inefficient feed-stuff extraction for animals declined in favour of more efficient crop-based food extraction. Second, Kenya increasingly imports finished food and feed which means that upstream flows of production are counted as material consumption in the exporting country and not in Kenya. In sum, biomass consumption per capita in Kenya declined by almost 30%.

Material consumption per capita in Bangladesh



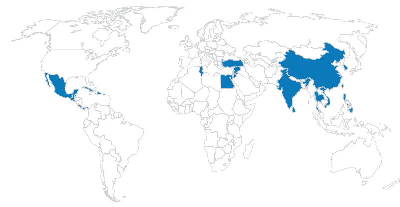
Bangladesh is one of the few examples among low-income countries where a constant rise in material consumption goes along with constantly increasing income. Unlike the other examples, Bangladesh has been rapidly integrating into the world market during the past 30 years. It is a net importer not only of food but also of raw materials such as fibres and fossil fuels for further processing. Beginning in the 1990s, growth in material consumption was driven mainly by increasing construction activities.

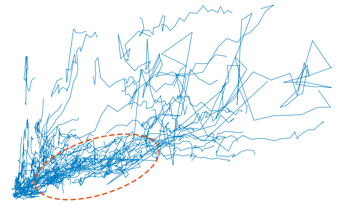
Material consumption per capita in Malawi



With around 2 tonnes per capita, low income countries with an intensive and crop (rather than animal-based) agriculture have the lowest resource consumption per capita. In **Malawi**, e.g., almost half of material consumption is composed of directly harvested and consumed food. Construction minerals are often poorly documented in statistics; low income countries with reliable data show a minimum of around 0.3 tonnes per person.

Industrialising and service-oriented economies



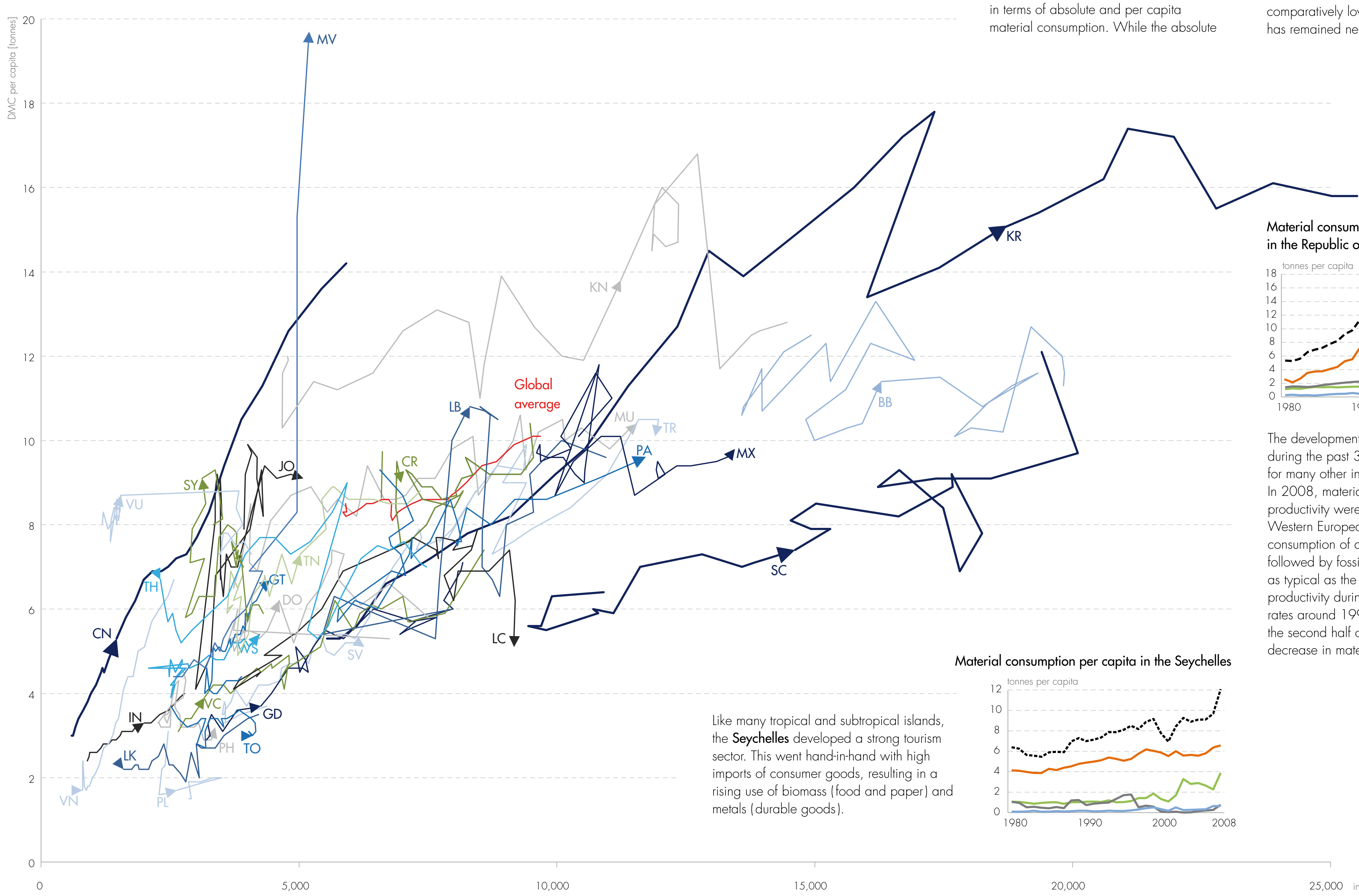


Many developing countries follow a strategy of industrialisation or foster service-oriented sectors such as tourism. These countries are predominantly resource importers in physical terms with an average per capita material consumption below 18 tonnes in 2008. In spite of the many differences among these countries, one similarity is an increase in material consumption during construction of large infrastructure projects and an even higher increase of income thereafter.

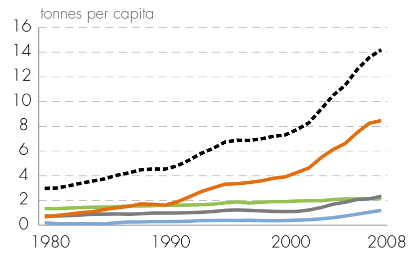
Economic development includes the construction of public and private infrastructure such as roads, ports or power plants, hospitals, schools, private dwellings or industrial plants. Bulk minerals, mainly sand and gravel, along with a variety of metals and fossil fuels for energy are required during the construction process, and later on, for maintenance and expansion. Durable and consumer goods which are usually associated with development such as cars, television sets, or meat-based diets become more common as average income increases and larger parts of society demand these goods.

Developing countries differ in speed, scale and type of construction of infrastructure. While many Latin American countries built large parts of their infrastructure before 1980, during the period of import substitution or even before, many Asian countries started after 1980, resulting in higher growth rates of resource consumption. Demand and characteristics of material use differ depending on the specific composition of economic sectors. Large-scale construction activities and basic manufacturing require more bulk materials while the added economic value is minor, resulting in comparatively low or even stagnating resource efficiency. On the other hand, knowledge-based industries and service-oriented economies gain more economic value with a lower material input.

Development of per capita material consumption and income of industrialising and service-oriented economies
1980–2008

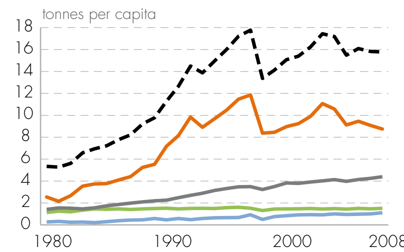


Material consumption per capita in China



China is one of the fastest-growing countries in terms of absolute and per capita material consumption. While the absolute dimension of material use is incredible, the basic processes in China are typical of the initial stages of development: construction of public and private infrastructure and an expansion of basic industries. In China, the magnitude of construction activities resulted in a stagnation of material productivity, despite strong economic growth. Due to its size and extended economic boom, China dominates nearly all global indicators of material use. It is worth noting that the comparatively low consumption of biomass has remained nearly constant since 1980.

Material consumption per capita in the Republic of Korea

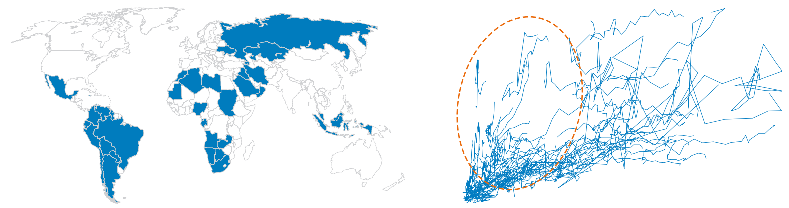


The development of the **Republic of Korea** during the past 30 years is exemplary for many other industrialising countries. In 2008, material consumption and productivity were higher than in many Western European countries. The rising consumption of construction minerals followed by fossil fuels and metals is as typical as the decrease in material productivity during periods with high growth rates around 1990. The financial crisis in the second half of the 1990s led to a sharp decrease in material consumption.

Like many tropical and subtropical islands, the **Seychelles** developed a strong tourism sector. This went hand-in-hand with high imports of consumer goods, resulting in a rising use of biomass (food and paper) and metals (durable goods).

Material consumption per capita in the Seychelles

Resource-based emerging economies



Given that there is much to be gained by following the ongoing trend of rising resource prices, a development strategy based on exporting raw materials is increasingly attractive for resource exporting countries. However, the risk inherent in this are the down cycles in resource prices, as seen in recent decades. However, resource exporting countries have a significantly higher per capita consumption of materials than resource importing countries at similar levels of income, and higher growth rates of material consumption per unit of generated income.

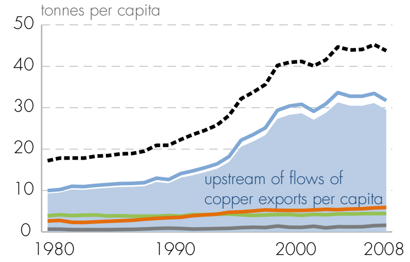
As already noted with regard to industrializing countries, the initial stages of development in resource-based emerging economies are also dominated by the building-up of public and private infrastructure.

In order to analyse the different dynamics of material use of net resource exporters and net importers, it is important to understand some basic rules of material flow accounting. Domestic Material Consumption (DMC) includes only the directly used resources of an economy. Calculating DMC implies that only the physical volume of exports is subtracted while upstream flows to produce these exports, including production leftovers, remain in the exporting country as part of its material consumption.

Thus, the more material flows are necessary to extract the exportable good and the more that good is refined, the more upstream flows remain within the exporting economy, leading to a higher DMC value, even if the leftovers are not "consumed" in the literal sense of that term. In general, metal extracting countries have a higher DMC (due to excavation) than countries with a large share of agrarian goods, whereas oil-exporting countries have a lower DMC because oil production requires comparatively minor upstream flows.

The particular share of upstream flows of the different products are as yet unknown in most countries. Nevertheless, to some extent, an abundance of resources goes along with squandering them (oftentimes linked to subsidies for the consumption of the respective resources), as shown by the relatively high values of per capita consumption of fossil fuels in oil-exporting countries.

Material consumption and selected upstream flows per capita in Chile

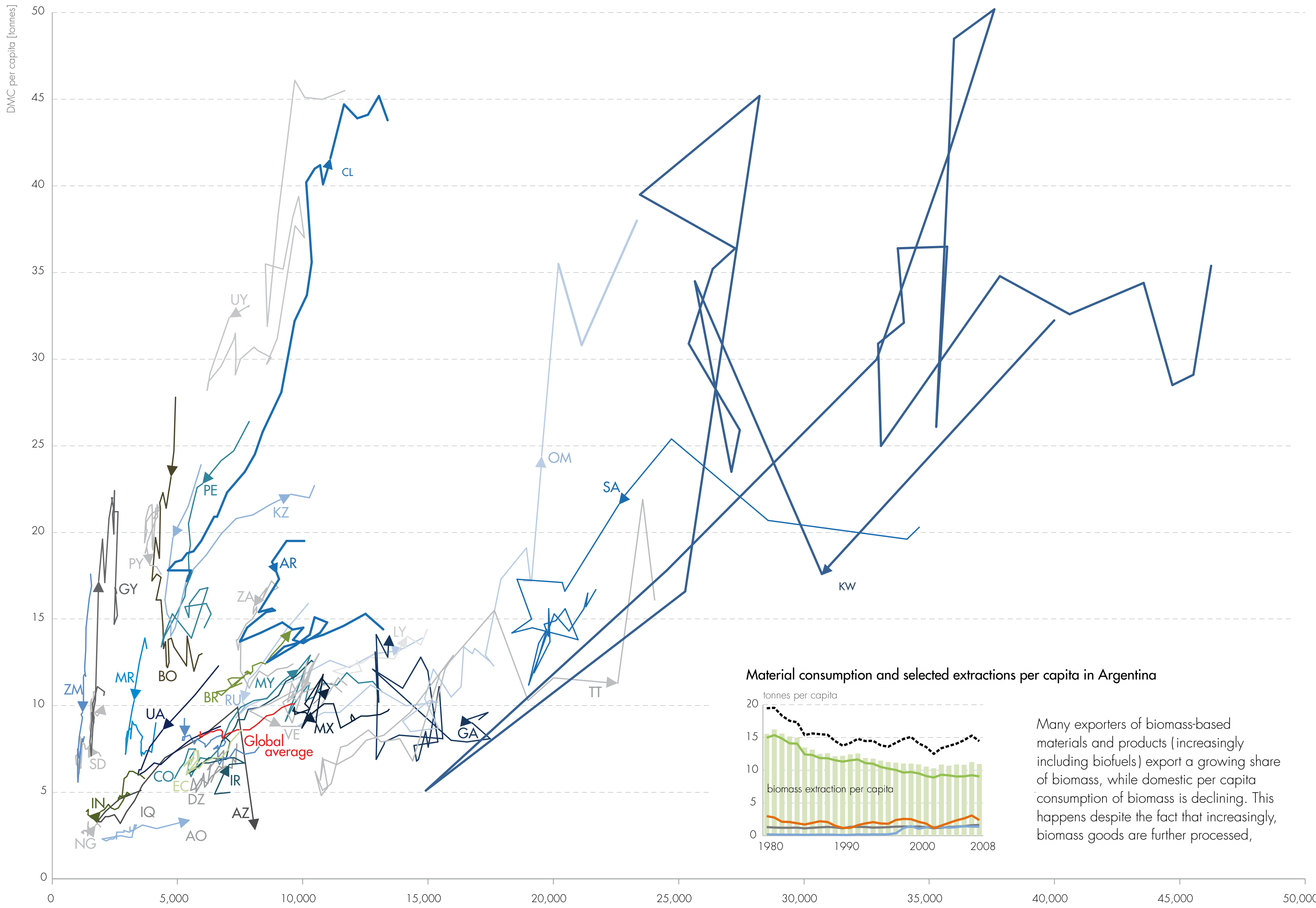


In many cases, the concentration of metals in crude ores is very low. The concentration of copper in curde ores in **Chile**, for example, which is the most important exporter of copper, is less than 1 %. Nevertheless, metals are mainly exported as concentrates or in a refined form.

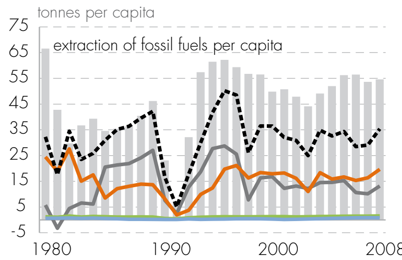
The excavation is counted in the consumption of Chile, resulting in a remarkably high metal consumption, although around 95 % could be considered as upstream flows of copper production.

Development of per capita material consumption and income of resource-based emerging economies

1980–2008



Material consumption and selected extractions per capita in Kuwait

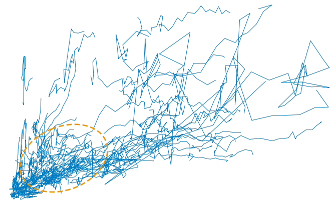


Normally, no data is available during times of war. In the case of **Kuwait**, however, some data is obtainable, showing the sharp breakdown of extraction and consumption during and after the occupation. In Kuwait, as in most other small oil exporting countries, storage of extracted oil has an above-average effect on per capita DMC, resulting in highly fluctuating per capita values.

Material consumption and selected extractions per capita in Argentina

Many exporters of biomass-based materials and products (increasingly including biofuels) export a growing share of biomass, while domestic per capita consumption of biomass is declining. This happens despite the fact that increasingly, biomass goods are further processed, and thus a higher share of upstream flows remains within the country. In **Argentina**, for example, per capita consumption of biomass declined by 40 % while absolute extraction remained constant. Furthermore, material consumption of minerals declined as a consequence of the financial crisis.

Material use during transition processes

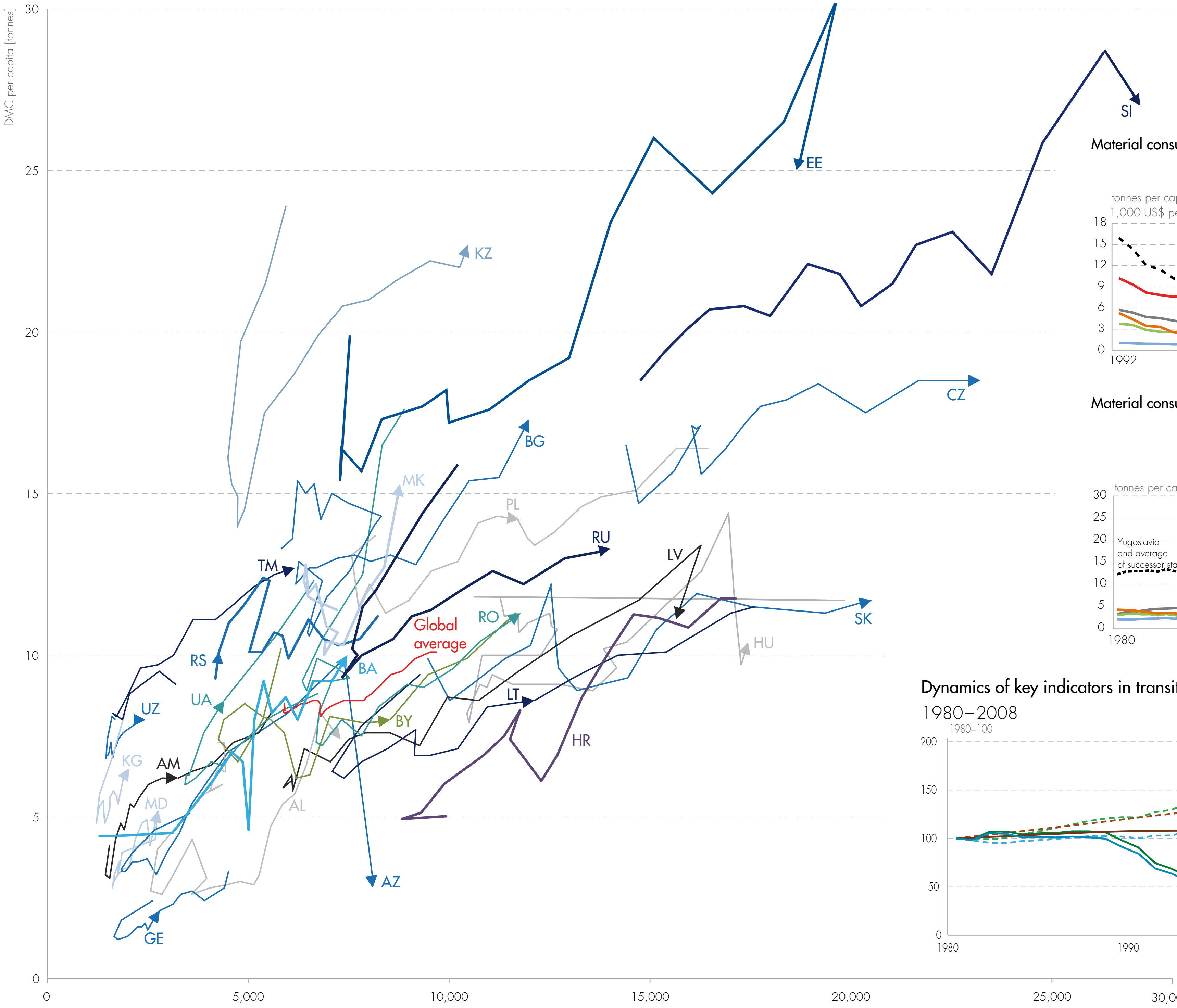


Transitions of economic systems have a significant effect on material use. In Europe and Central Asia, the most important change has been the transformation of economies, from centrally-planned to market economies. The pattern and extent of the collapse and recovery differs across countries, based on their status in 1989, when the transition started.

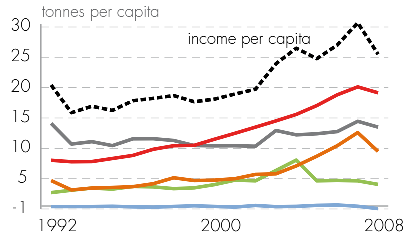
The collapse of Communism resulted in many countries in Eastern Europe and Central Asia in a transition from centrally-planned to market economies. This phenomenon could also be observed in some developing countries, in particular in Africa. The typical transition patterns can best be seen in European and Asian countries, although data availability for the period before 1989 is limited. Central Asia and Eastern Europe show a clear drop of material consumption in absolute and per capita terms during the transformation process, while their population size remained relatively stable. The collapse of Communism and the transition towards market economies was initially (between 1989 and 1995) accompanied by high rates of inflation, a marked decline in output (on average by 40%), a stagnation in material extraction and a decline in all categories of resource consumption, in some countries even until the year 2000.

In those transition countries that later joined the European Union, the decline in income and material consumption was comparatively lower than in their neighbouring countries, and the recovery was faster, kicking off already in the first half of the 1990s. In contrast, the drop in material consumption of eastern European countries, in particular in former Yugoslavia during the civil wars, was stronger, and the recovery started only in the second half of the 1990s. The non-EU former Soviet Union countries exhibit two different dynamics: the large and resource rich ones, such as Russia, Kazakhstan or Ukraine, suffered deep drops in resource consumption during the 1990s. Thereafter, they showed the typical characteristics of resource-based developing economies. The smaller countries, such as Uzbekistan or Kyrgyzstan, displayed basically the characteristics of low-income countries with more fluctuations and unclear trends.

Development of per capita material consumption and income of transition countries
1980–2008

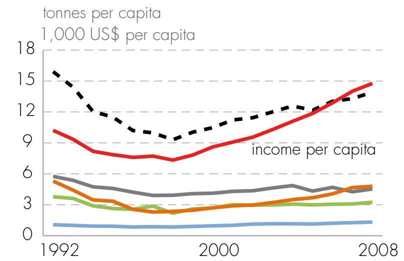


Material consumption and income per capita in Estonia



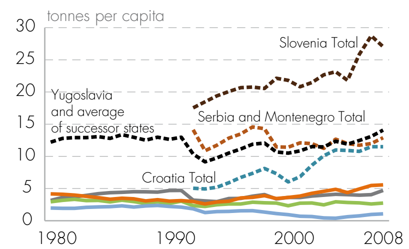
Estonia is a good example to illustrate two typical trends in new EU Member States: a slight drop in income and resource consumption in the early 1990s, followed by a fast recovery during the later 1990s. Estonia, which has no metal extracting industry, has net exports of metals in different years. To some extent, this is due to the dismantling of industries and/or insufficiently classified trade in machines or vehicles. Estonia's high consumption of fossil fuels is due to the use of coal as the major source of energy .

Material consumption and income per capita in Russian Federation



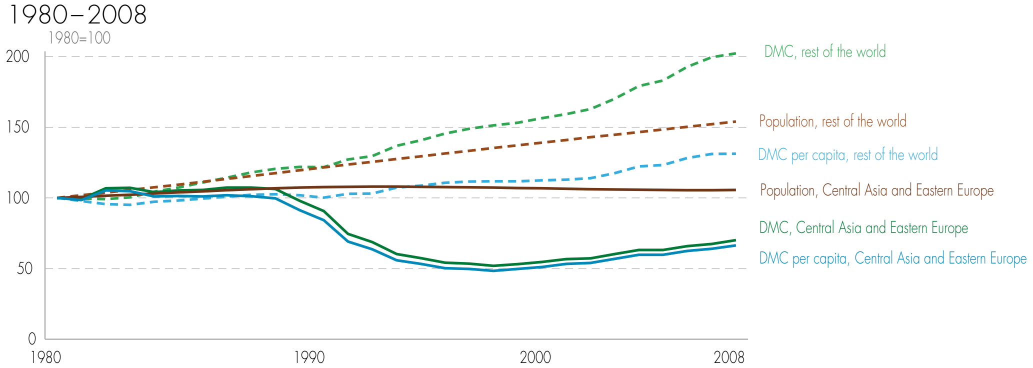
After the collapse of the former Soviet Union, income and resource consumption per capita decreased sharply in the Russian Federation. The decrease was caused by a decline in metal extraction, forestry, agriculture and construction activities. Economic recovery started in the second half of the 1990s, when exports, in particular of metals and fossil fuels (oil, gas and coal), increased.

Material consumption and income per capita in former Yugoslavia



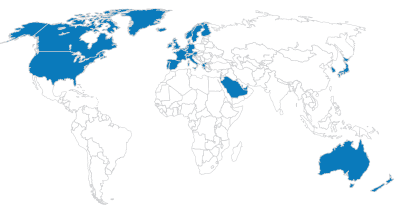
In former Yugoslavia and its successor states (the figure shows the average of all successor states and selected successor states independently after 1992) two breakdowns are visible. The first one is due to the transformations after the break-up of Yugoslavia. The second breakdown reflects the civil wars, visible in particular in Serbia and Montenegro. By contrast, Slovenia's consumption increased rapidly after its integration into the EU in 2004

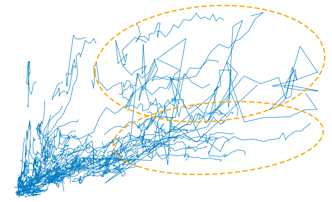
Dynamics of key indicators in transition countries compared to rest of the world
1980–2008



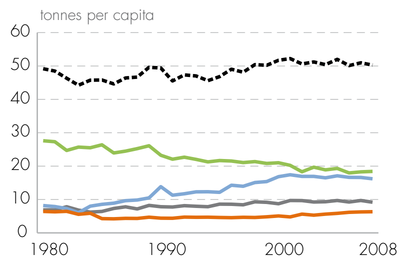
High income countries

In 2008, a per capita income of US $ 35,000 was linked to material consumption levels of between 10 and 50 tonnes per capita in different countries. The material consumption of high income countries depends on various factors. Of particular importance is the share of material intensive agriculture and mining activities, in comparison to the share of less material intensive high-tech and financial service sector activities. The composition of a country›s main primary energy sources is another factor that determines material consumption levels.





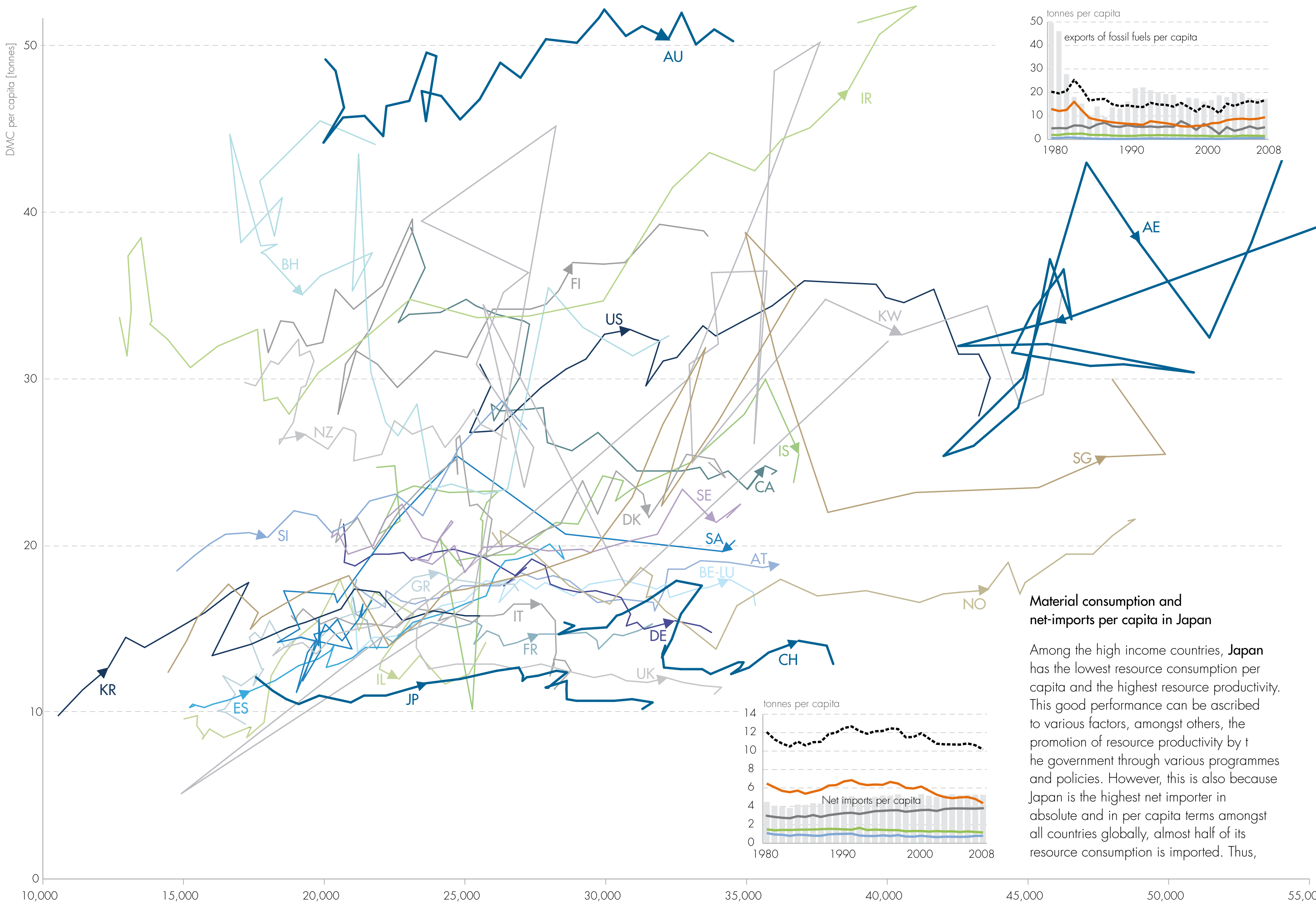
Material consumption per capita in Australia



Australia is one of the most important resource suppliers among the high income countries. It has a variety of different industrial resources. In material terms, the extensive production e.g. of wool and meat and the extraction of metals and black coal are most dominant. A large part of Australia's material consumption is due to the production of exported goods.

Development of per capita material consumption and income of high income countries

1980–2008



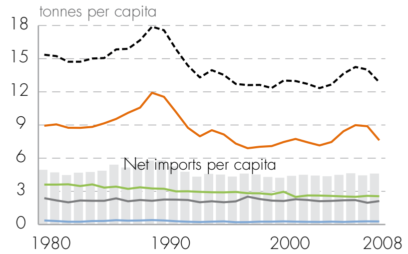
Material consumption in economies with large agricultural and mining sectors is generally higher than in countries with large, less material-intensive sectors such as financial services, knowledge-based and research intensive manufacturing, where mostly semi-processed commodities and final goods are imported.
Per capita resource consumption has stagnated over the past few years in various high income countries (roughly defined here as countries with a per capita income of US $ 20,000 or more in 2008). Net imports have risen in some of these countries, which indicates that domestic extraction was reduced. Very few high income countries, such as Japan, show a stagnation in both consumption and net imports, which could be interpreted as a sign of material saturation.

Another major difference among high income countries is their mix of energy sources. Coal (the dominant source of energy e.g. in Australia and Germany), for example, is generally more resource-intensive than hydro power, which basically requires mineral resources during the construction phase. Subsidies on fossil fuels are one reason for their high consumption.

Material consumption and selected exports in Saudi Arabia

During the second oil crisis, **Saudi Arabia** sharply reduced extraction and exports of oil. In 1985, for example, Saudi Arabia, extracted less than half the oil it extracted in 1980 and its exports fell by 72%.
Per capita consumption of fossil fuels is generally higher in oil-extracting countries than elsewhere, up to 5 tonnes per capita per annum or more.

Material consumption and net-imports per capita in Switzerland



Countries with large shares of business-related and financial services, which are generally less material intensive, are amongst the most resource efficient economies worldwide and also those with the highest material imports per capita. **Switzerland**, for example, net imports more than one-third of all its consumed materials. Many of the environmental pressures associated with Swiss consumption thus remain in the extracting and producing countries. Furthermore, since Switzerland's main energy sources are nuclear and hydropower, its fossil consumption is comparably low but mineral consumption is high, partly attributable to construction activities in the mountainous area.

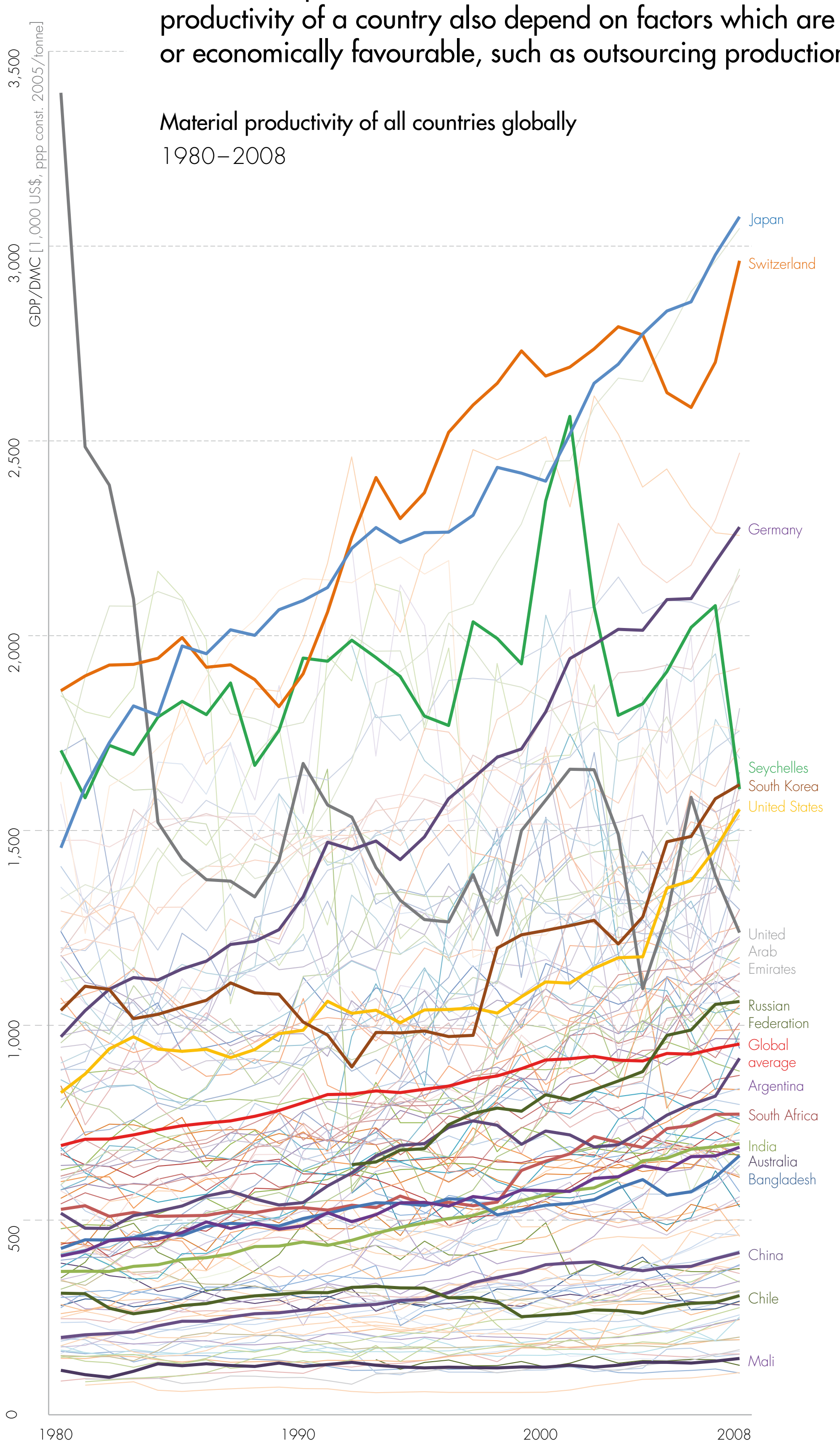
Material consumption and net-imports per capita in Japan

Among the high income countries, **Japan** has the lowest resource consumption per capita and the highest resource productivity. This good performance can be ascribed to various factors, amongst others, the promotion of resource productivity by t he government through various programmes and policies. However, this is also because Japan is the highest net importer in absolute and in per capita terms amongst all countries globally, almost half of its resource consumption is imported. Thus, the upstream flows of resources required to produce Japan's imports are not counted as Japanese consumption but as that of the exporting countries.

Development and material productivity

Increasing material productivity which means gaining more income per unit of material is one major strategy to reduce environmental pressure, but it is also a common strategy to stimulate economic growth and increase income. Thus, material productivity and increasing income are closely linked to each other. Levels and the dynamic of material productivity vary largely according to the dynamics of economic development and the sectoral composition of national economies. Furthermore, improvements in material productivity of a country also depend on factors which are not necessarily environmentally or economically favourable, such as outsourcing production to other world regions.

Material productivity of all countries globally
1980–2008



The material productivity of the majority of countries has improved over the past 30 years. Nevertheless, there is a variety of levels and dynamics of change, depending on a number of factors, amongst others, on the composition and characteristics of the countries' main economic activities, a country's position in the global division of labour and also its specific resource endowment.

High income countries with strong service and/or knowledge-based technology sectors are amongst those with the highest material-productivity. Their rates of increase in productivity were also higher during the observed time period. Examples include Japan, Switzerland and South Korea.

Countries specialising in resource exports, such as Chile, Australia or South Africa, have generally lower resource productivities, which also depends on the resource prices of the dominant raw material exports.

Low income countries , e.g. Mali, usually have a huge primary sector (agriculture and/or mining) which is generally less productive and almost stagnant in terms of material productivity, whereas cattle-based agrarian systems are less productive than crop-based ones.

Thus, benchmarking the resource productivity performance of different countries has to factor in the sectoral composition of the national economies.

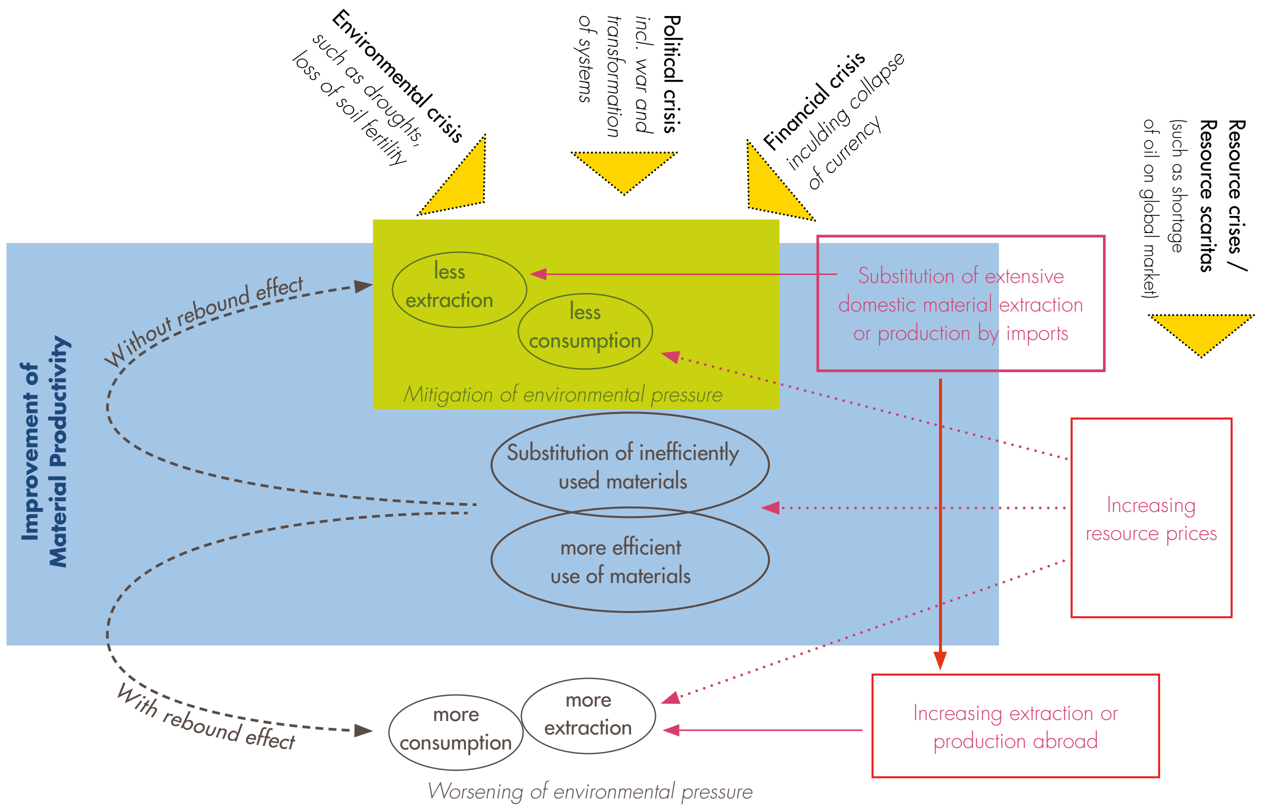
There are various reasons why material productivity is increasing in different countries. It is important to distinguish between the underlying trends determining material productivity improvements.

Some material productivity improvements are based on an absolute decrease of material extraction or consumption, e.g. the decrease in construction activities in the USA after 2005 or the decline in metal extracting activities in Zambia during the 1980s. As income and material extraction and production are linked to each other, those decreases often go along with stagnating or even decreasing income.

Other improvements in material productivity are a result of stagnation or only minor changes in use of materials combined with increasing incom. This results in higher material productivity, as long as there is no strong rebound effect. This effect means that improvements due to increasing material productivity are overcompensated by increases of the overall consumption of the respective materials.

Other important factors contributing to improved material productivity are, for example, resource policies encouraging more efficient use of materials by recycling and/or reuse (e.g. in Japan), the application of more efficient technologies, the substitution of materials (e.g. the substitution of brown coal for electricity generation in Germany by other energy sources) or the shift in agricultural production systems from extensive cattle-based towards more efficient crop-based food production systems (e.g. in Kenya).

Influencing factors and mechanisms to improve material productivity



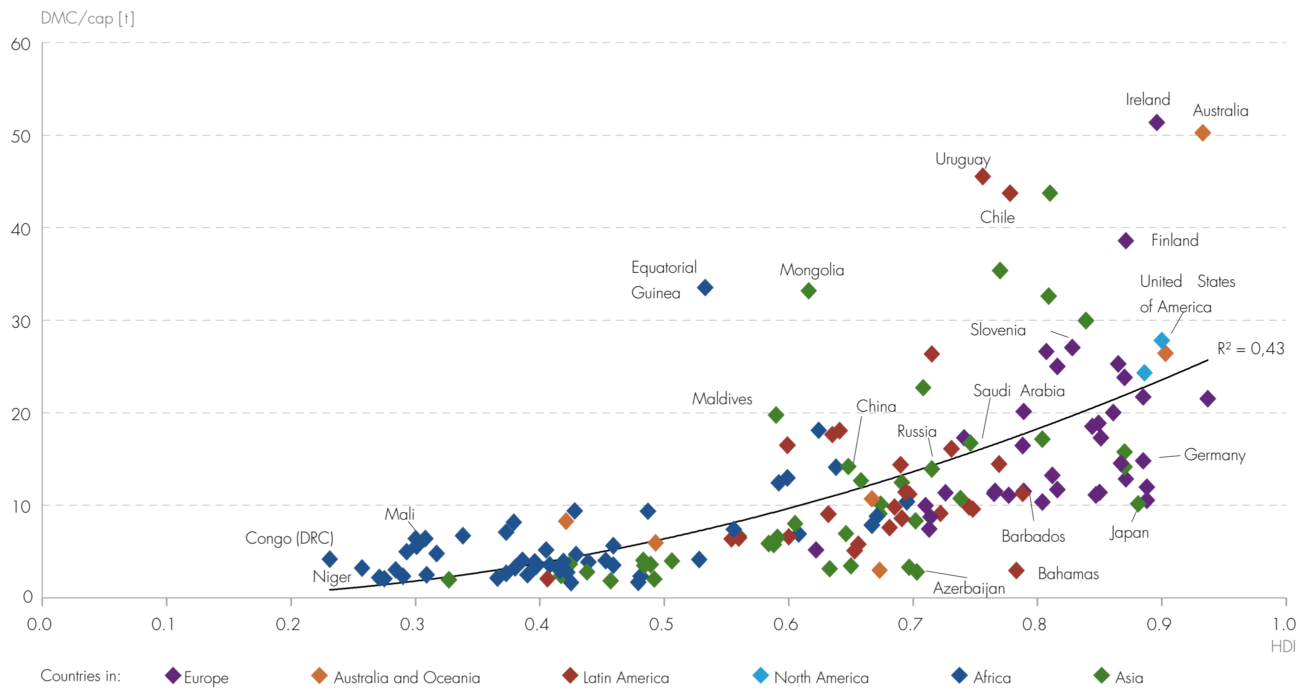
In contrast to the examples above, some improvements in material productivity also result from outsourcing. If, for example, a country decreases its domestic resource-intensive production and increasingly imports the respective semi-finished or finished goods, material productivity measured in terms of direct material flows, as done in this study, would increase – at the expense of the exporting country. Increasing resource prices result in increasing income of resource exporting countries; thus, material productivity may increase without any changes in resource management. Vice versa, it may lower resource productivity of resource importing countries without any real changes in the efficiency of resource use.
It is also worth noting that the main global or regional crises such as environmental, political, financial or resource crises, often have an impact on material extraction, consumption and production systems. In the short term, they predominantly result in lowering amounts of extracted or consumed materials, while in the medium term, the effects vary from increases in resource efficiency due to improvements of technologies during the crisis (e.g. after the oil crisis), no changes due to postponing consumption (e.g. after a regional financial crisis) or even increases in extraction and consumption as a consequence of destruction during a civil war.
Generally, material productivity can also increase if GDP grows faster than material consumption, without having a positive impact on the environment.

Material use and well-being

In general, material consumption is positively correlated with well-being, as measured by indicators of human development and quality of life. The bottom 30% of countries with the lowest score on the Human Development Index (HDI) all consume less than 10 tonnes of materials per capita. The 5% of countries with the lowest life expectancy also consume less than 10 tonnes per capita. However, increased material consumption does not necessarily lead to higher levels of well-being. Some countries achieve high levels of well-being at relatively low levels of material consumption.

Human Development Index[19] and material consumption per capita

2008



A high HDI can be achieved at low levels of consumption

Like the positive correlation between Domestic Material Consumption (DMC) and income, DMC and the HDI are positively related at first glance. Australia, for example, with the highest score on the HDI in 2008 has the second highest DMC. Countries with a low score on the HDI (typically low income countries such as the DR Congo or Niger), by contrast, generally also have a low DMC. Closer examination, however, reveals two groups of countries: those with a HDI below 0.53 and low material consumption (below 10 tonnes/capita) and those with a HDI above 0.53 and diverse levels of material consumption. Those in the first group are typically low income countries, while those in the second are medium or high income countries, emerging and transition economies. While some countries with a high level of HDI (e.g. Ireland or Australia), also have a high DMC, others (e.g. Japan or Barbados) reach similar levels of human development with a comparably low level of consumption.

Measuring human development and happiness

The value of goods and services produced within a country (GDP) is a widely used indicator of economic development. To measure human development, or well-being, and happiness, however, other indicators are more useful. Well-being comprises both objective and subjective components and its main factors are good relations and health, which are not expressed by GDP.

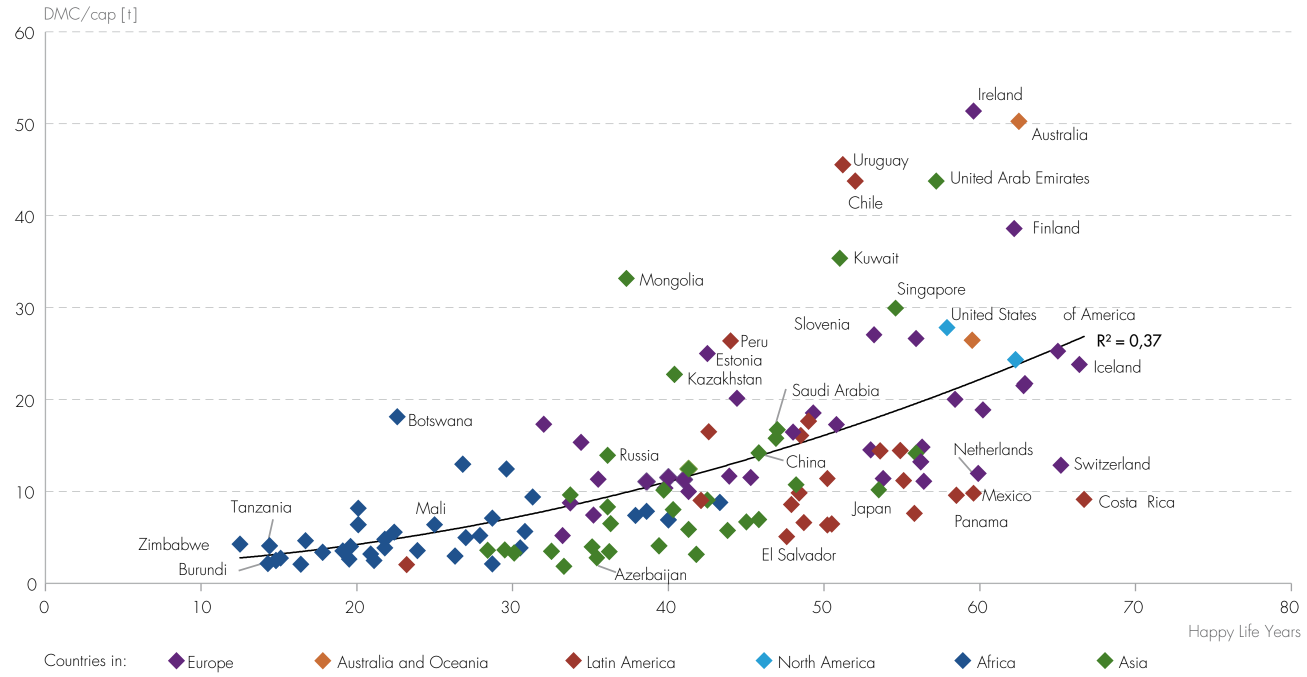
The **HDI** (Human Development Index), is a standard means of measuring human development objectively. It ranks countries in terms of life expectancy, education and income. Thus, the HDI focuses largely on the objective components of development. The index ranges from 0 to 1.

The **HLY** (Happy Life Years) Index aims at measuring the quality of life in a country with the help of subjective measures of happiness. A country's average score on the happiness scale, that ranges from 0 to 1, is multiplied by the average life-expectancy in that country.

Of course, even these established indicators are only an attempt to objectively shed light on an issue as complex as development and well-being. Results should therefore be interpreted with caution.

Happy Life Expectancy[20] and material consumption per capita

2008



High subjective well-being at low levels of DMC

Similar to the HDI-DMC relation, the spread of possible levels of DMC gets bigger with increasing happy life years. Ireland reaches 60 happy life years at a level of DMC of more than 50 tonnes/capita. Costa Rica, by contrast, reaches even more happy life years (67) with a DMC of only 9 tonnes/capita. Hence, there is no automatic relationship between HLY and DMC at high levels of happiness. High happy life years numbers can be achieved with high or low levels of material consumption.

There is also no automatic relation between HLY and HDI. Latin American countries with medium levels of HDI and DMC reach higher levels of HLY than their Asian counterparts with similar HDI and DMC scores.

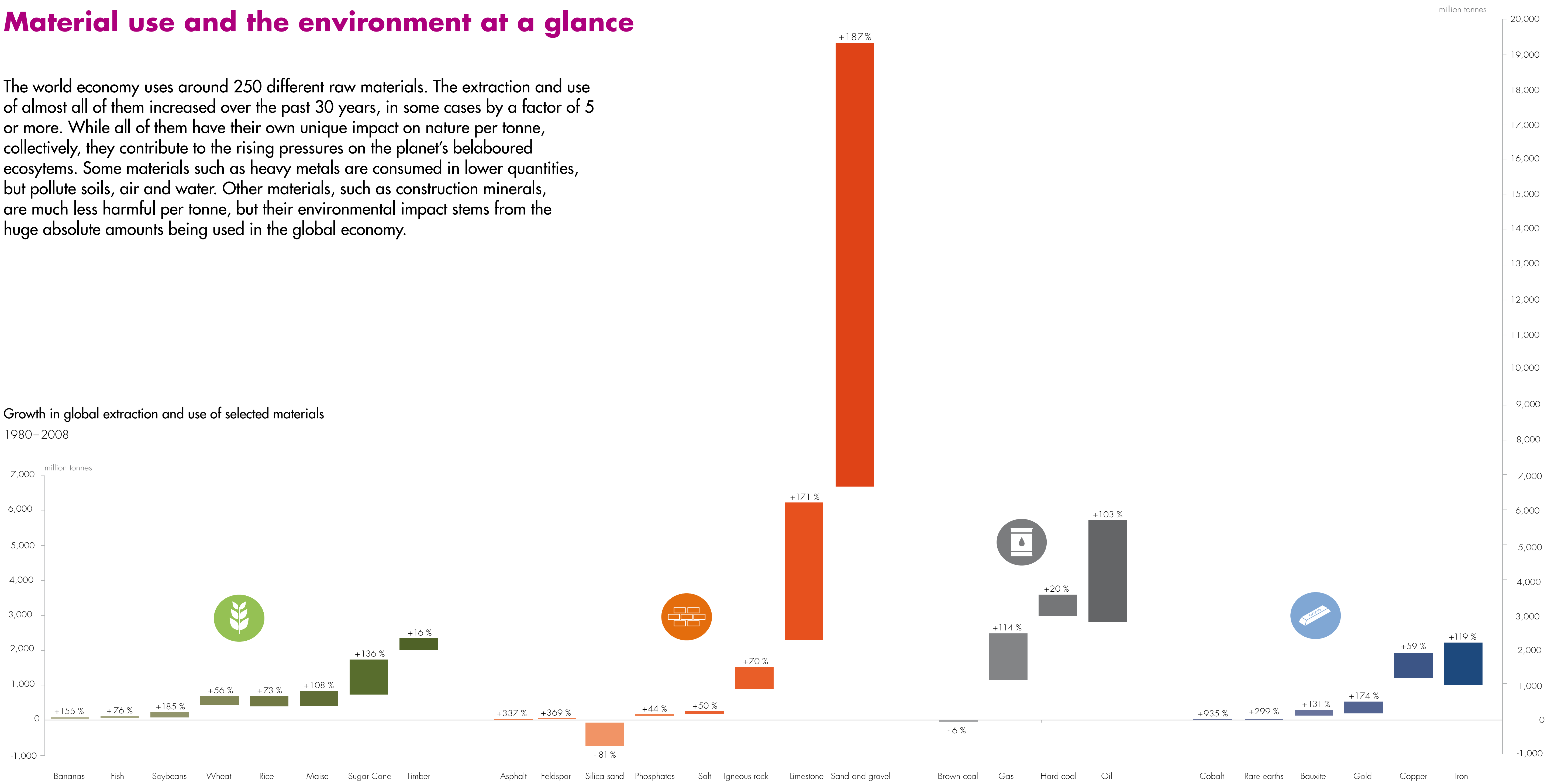
4 Material use and the environment

Material use and the environment at a glance

The world economy uses around 250 different raw materials. The extraction and use of almost all of them increased over the past 30 years, in some cases by a factor of 5 or more. While all of them have their own unique impact on nature per tonne, collectively, they contribute to the rising pressures on the planet's belaboured ecosytems. Some materials such as heavy metals are consumed in lower quantities, but pollute soils, air and water. Other materials, such as construction minerals, are much less harmful per tonne, but their environmental impact stems from the huge absolute amounts being used in the global economy.

Growth in global extraction and use of selected materials

1980–2008



Biomass-based materials comprise products from agriculture, forestry and fishery. Conventional monoculture production puts pressure on the environment in the form of soil degradation and ground and surface water pollution (e.g. eutrophication) due to the use of pesticides and fertilizers. Furthermore, water scarcity due to high water exploitation for irrigation is a problem in an increasing number of countries. Clearing primary forests to expand agricultural areas or transforming them into forestry monocultures are another major pressure, with negative effects on ecosystems, leading to biodiversity loss and displacements of endangered species.

Industrial and construction minerals such as salt, sands, gravel and limestone are typical examples of bulk flows with low environmental impacts per tonne. However, global use of these minerals increased significantly over the past three decades to meet the demand for creating and maintaining infrastructure such as buildings and roads.
On the one hand, the environmental impact stems from the highly energy and CO_2-intensive production of construction materials such as cement. On the other hand, construction can lead to a disruption of the landscape due to land sealing, urban sprawl and negative impacts on ecosystems and biodiversity.

Significant impacts on the environment by using **fossil fuels** are not only a consequence of a high impact per tonne (e.g. oil spills), but also stem from the rapidly increasing absolute levels of use. Bulky flows from coal and oil producing countries to industrialised countries and emerging economies lead to growing environmental problems during extraction. The environmental consequences of oil and gas extraction in river deltas, rain forests or the open sea are well known. The main consequence of fossil fuel combustion is the emission of greenhouse gases, the main driver for global climate change.

Mining and processing of **metal ores** as well as the use and disposal of refined metals have considerable impacts on the environment. In metal mining, large amounts of materials need to be removed in order to get access to the metal deposits. This so-called "unused extraction" contributes to land use changes and ecosystem disruption. Large amounts of metal particles are discharged into soils and water bodies during the mining and refining processes. In addition, gases emitted during the various stages of refining metal have a severe impact. In particular, metal waste from discarded manufactured products are a main source of global metal soil pollution.

Agriculture and water scarcity

The world's population reached 7 billion in 2011 and is projected to hit the 9 billion mark by 2050. As a consequence, the demand for food is increasing rapidly. In the period 1980–2008, harvest of biomass increased by 40%. Enormous amounts of water are required to grow the crops needed for nourishment. Agriculture and other sectors like the energy sector are competing for and putting pressure on water resources. Additionally, the use of fertilizers, pesticides and herbicides has a significant impact on the environment. Due to increasing worldwide trade in agricultural products, the link between material consumption and water scarcity has gained a global dimension.

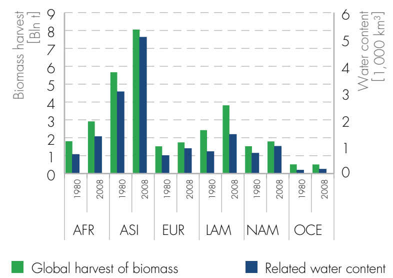
Water scarcity can be illustrated by the indicator "Water Exploitation Index" (WEI)[21] which compares total water abstraction in a country or region with the long term annual average availability of fresh water. Values higher than 20% indicate water scarcity, with severe scarcity indicated by the WEI exceeding 40%. Countries with values higher than 100% also exploit their non-renewable water resources, such as groundwater bodies.
While countries like Brazil have a very low WEI due to the enormous reserves of renewable water, many Western countries like the US, France or Poland have already reached the scarcity threshold. In particular, countries of the Middle East are already above the 100% threshold, indicating non-sustainable practices.
However, when applied to the national level, this index does not take into account regional differences in water availability; neither does it consider water return flows or indirect water flows incorporated in traded products (water which was needed for their production; so-called virtual water). To examine water consumption related to human activities more comprehensively, these aspects have to be taken into consideration.
Some regions of the world do not grow all their food and feed within their own territories. The water needed for the production of traded goods is hence imported "virtually". This creates pressures on local water resources and dependencies on other regions.

Water resources are unevenly distributed around the globe. Quantities of biomass production often do not go hand in hand with available quantities of water. Some countries, such as Israel, even specialise in agricultural exports despite water shortages within their own boundaries.

Global harvest of biomass and related virtual water

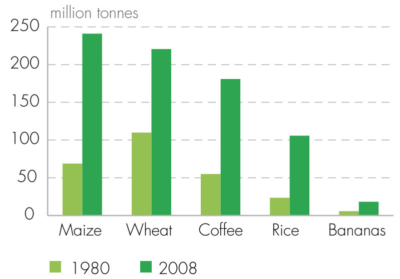
1980 and 2008

In the period 1980–2008, biomass harvest increased by 40%. Related water requirements increased by as much as 60%. Numbers were calculated using production volumes and world average water requirements per plant.



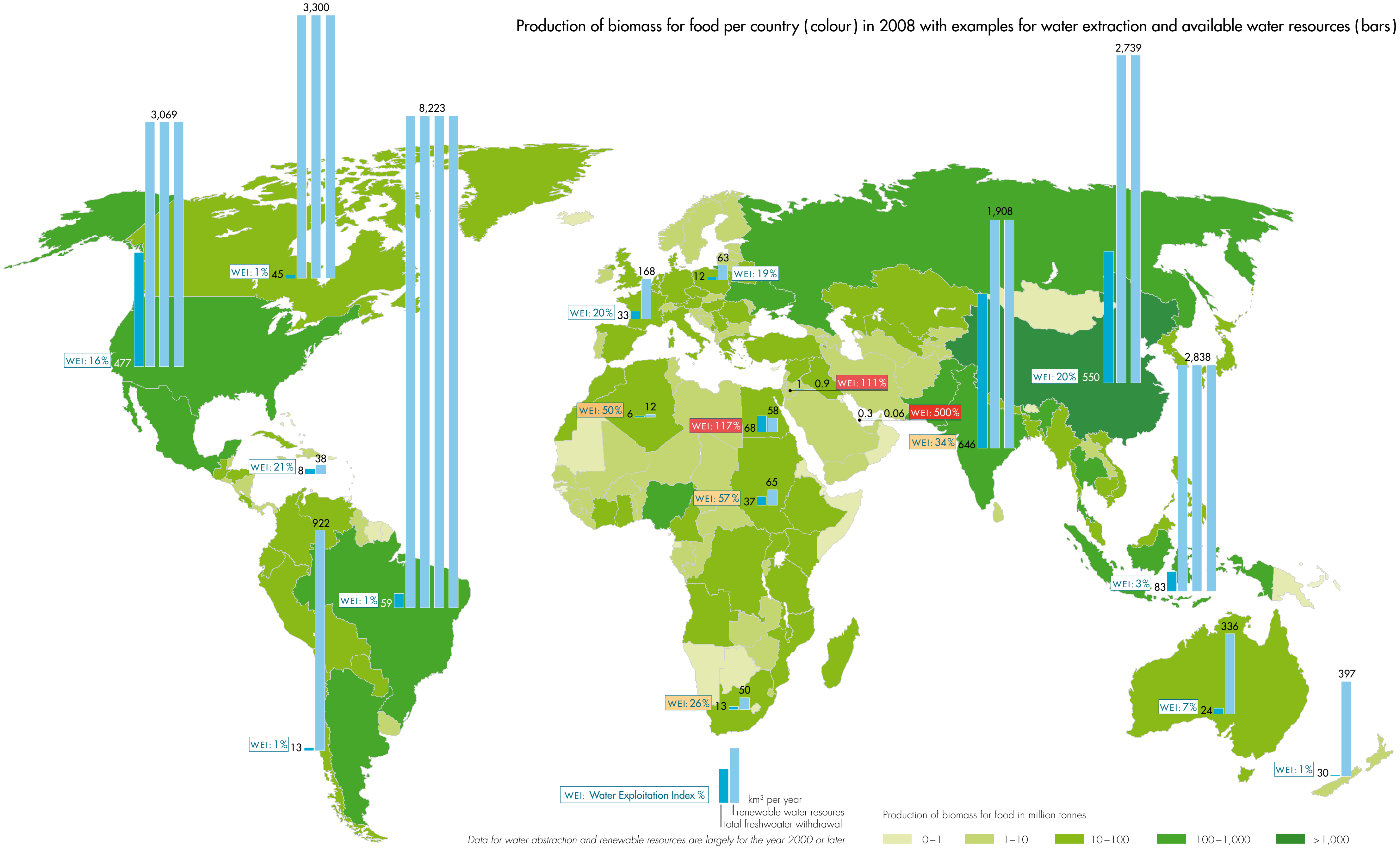
Physical trade volume of five selected agricultural products

1980 and 2008



Trade in agricultural products is rapidly growing, along with trade of so-called "virtual water" embodied in traded goods. Consequently, with increasing globalisation, issues related to local water scarcity have become global in scale.

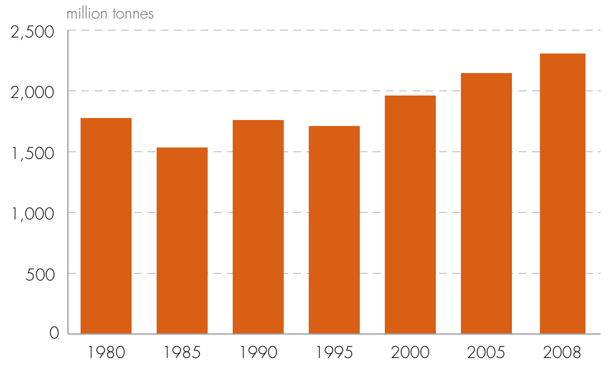
Production of biomass for food per country (colour) in 2008 with examples for water extraction and available water resources (bars)



Minerals, sealed land and CO_2 emissions

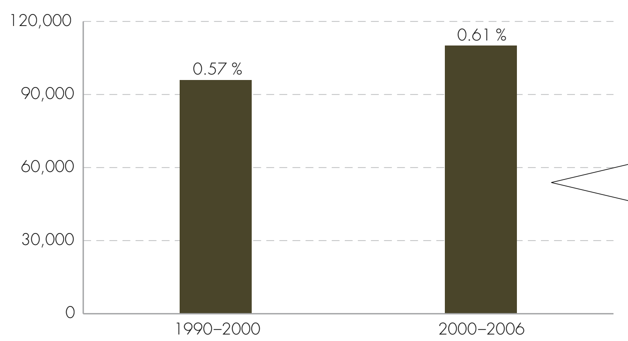
At almost 30 billion tonnes, minerals made up more than 40% of the global material consumption in 2008. The largest fraction in this group are materials for construction purposes, such as limestone, gravel and sand. The specific environmental impacts of each tonne of construction mineral extracted are low, but the rapidly growing amounts being used around the globe lead to significant environmental problems. The most important of them are the high CO_2 emissions related to the production of cement and the increased loss of fertile land areas due to land sealing and the expansion of built-up areas.

Consumption of sand and gravel in Europe
1980–2008

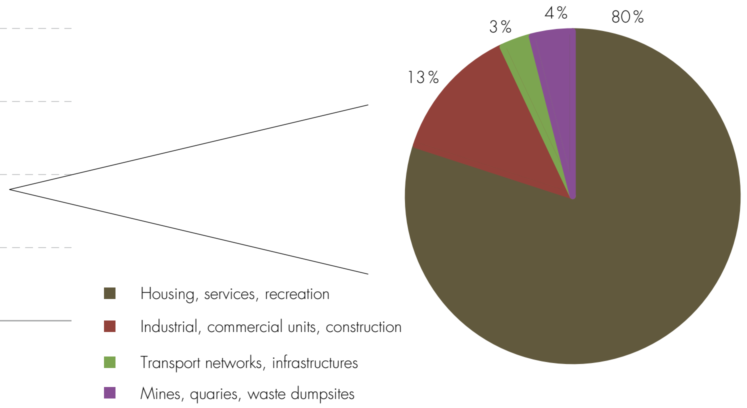


The basic raw materials which are being used for producing construction materials, such as cement and concret and for creating infrastructure such as buildings, roads or airports are limestone, sand and gravel. A multiple amount of aggregates such as sand and gravel are required to produce one tonne of construction materials, such as concrete. Built-up areas, especially in the emerging economies, are rapidly expanding. This led to a 133% increase in the global use of construction minerals between 1980 and 2008. However, growing consumption can also be observed in industrialised countries, such as Europe, where the consumption of sand and gravel grew by more than 20% between 1980 and 2008. This increased consumption is linked to the growing land take of artificial areas, which expand at the expense of agricultural areas[25].

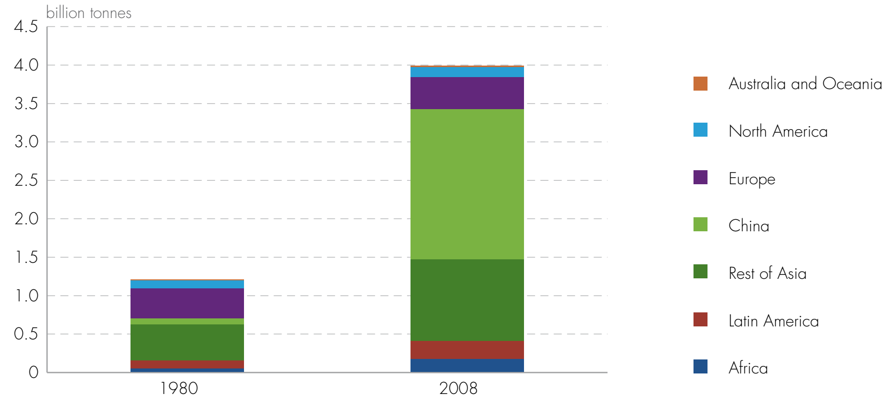
Artificial land take in Europe[25]
(ha/year and % change to initial year)



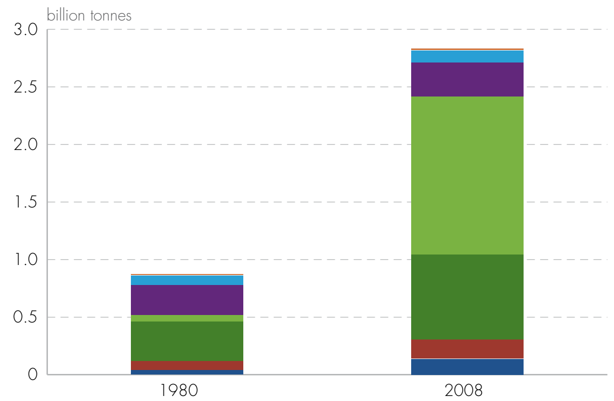
Artificial surfaces 2006[25]
(% of total area)



Limestone extraction by continent
1980 and 2008



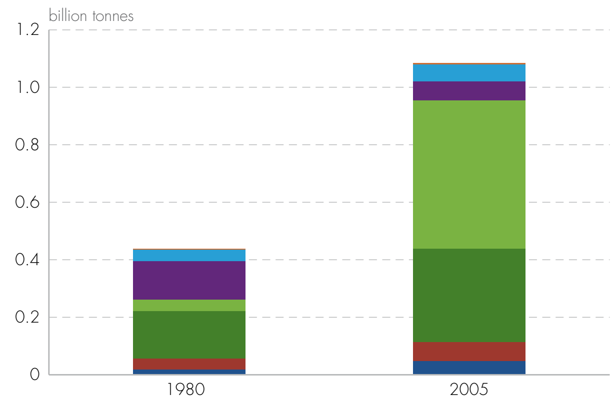
Cement production by continent
1980 and 2008



Limestone is the major ingredient used to produce cement. Around 1.4 tonnes of limestone are required to produce 1 tonne of cement.[26] The process of cement production is very energy intensive and thus produces huge amounts of CO_2 emissions. Depending on the type, around 400 kilograms of CO_2 are emitted for each tonne of cement.

Countries in Asia observed a huge increase in cement production in the past decades. In 2008, almost 75% of global cement production was located in Asia, with China alone accounting for almost 50% of world production. Cement production grew by a factor of 22 since 1980, reflecting the huge demand for construction minerals for building up infrastructure, such as roads and buildings.

CO_2 emissions from cement production by continent
1980 and 2005

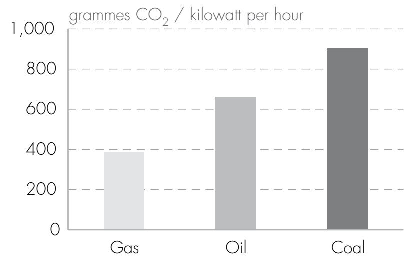


In 2005, more than 1 billion tonnes of CO_2 emissions were related to cement production. This is around 4% of total global CO_2 emissions. If the emissions related to fossil fuel use for energy generation in the cement production process were also included, the cement industry globally accounts for about 8% of global CO_2 emissions, a figure that has doubled since 1990[27]. As CO_2 emissions are closely correlated with cement production volumes, China also witnessed an exceptionally high growth rate. Significant growth was also observed for other emerging economies, such as India, making Asia by far the biggest producer of cement-related CO_2 emissions.

Fossil fuels use and climate change

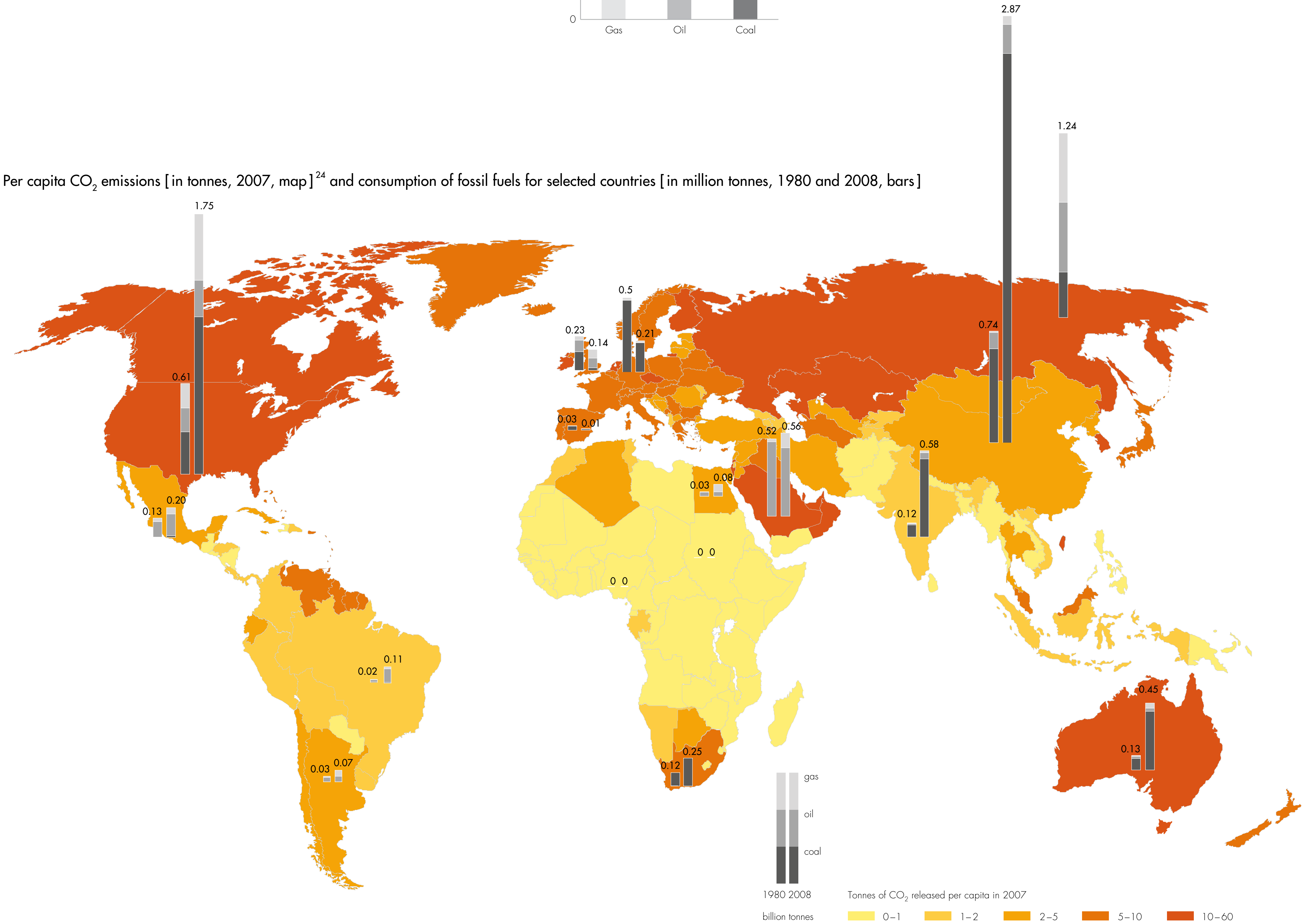
Fossil fuel consumption is a major driver of global warming. More than two-thirds of all human greenhouse gas emissions stem from the combustion of coal, petroleum, and natural gas. Globally, fossil fuel consumption increased by 60% between 1980 and 2008, mostly driven by growth in Asian countries. High-income countries have generally higher per capita emissions of CO_2 than low-income countries. A high share of coal in the energy-mix leads to exceptionally high CO_2 emissions.

CO_2 emissions/kWh for fossil fuels, 2007[24]



The structure of fossil fuel consumption has a significant impact on the CO_2 emissions produced by combustion. Reaching the same heating value, oil emits 71% more CO_2 than gas, which is relatively the cleanest of the fossil fuels. Coal emits 36% more CO_2 than oil and 133% more than natural gas[24].

Per capita CO_2 emissions [in tonnes, 2007, map][24] and consumption of fossil fuels for selected countries [in million tonnes, 1980 and 2008, bars]



Global consumption of fossil fuels increased by 60% between 1980 and 2008, mostly driven by Asia, which almost doubled its consumption mainly because of its rapid industrialization accompanied by a high population growth (+150%). Some countries such as China and India even increased their consumption by more than a factor of 4. Asia and Oceania have by far the highest share of coal in their consumption of fossil fuels with 88% for Australia and 91% for China in 2008 compared to global average of 52% coal, 20% gas and 28% oil. The share of coal in overall consumption of fossil fuels for Germany is 94%, mainly due to the large amount of coal used for electricity production. Argentina, on the other hand, has a completely different structure, with a share of 52% for gas and 47% for oil. Fossil fuel consumption of Brazil and Saudi Arabia is dominated by oil, at 83% and 82% respectively.

With regard to CO_2 emissions per capita due to fossil fuel consumption, Qatar tops the table with 58 tonnes of CO_2 emissions per capita, followed by the United Arab Emirates with 30 tonnes per capita in 2007. The United States have CO_2 emissions per capita of around 19 tonnes and Germany of around 10 tonnes. Emissions in the US are almost 500 times higher than the per capita emissions for the poorest countries. An average inhabitant of the Republic of Congo, for instance, emits only 0.04 tonnes[24].

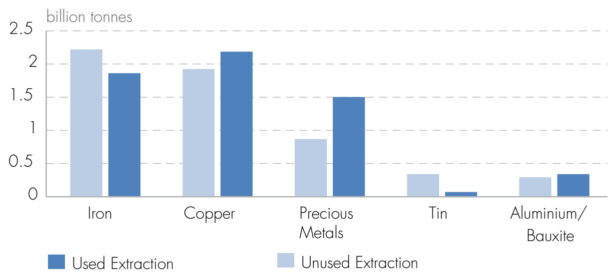
Metal ores and unused material extraction

In the period 1980–2008, global consumption of metals increased by 87%. Some metals, such as aluminium or copper, are used in large quantities and for a large number of applications. Others, such as indium, are used in small quantities but in everyday high-tech products. With ever increasing demand, ever more metals are exploited, with the related environmental implications such the degradation of ecosystems through metal mining and pollution of water and soil.

Mining and processing of metal ores as well as the use and the disposal of refined metals have considerable impacts on the environment. During the mining and refining processes large amounts of metal particles get emitted into the adjacent soil and ground or surface water. Gaseous emissions stemming from the different steps of metal refinery also have a severe impact. Finally, discarded manufactured products are a major source of global metal input into soils. Additionally, in many cases the content of metals in crude ores is very low and the usable ores are not readily accessible. A certain amount of so-called "overburden" has to be removed in order to reach the metal-containing ore. This overburden is part of the so-called "unused extraction"[15,22]. The quantity of overburden depends on the type of extraction process chosen and the local properties of the metal deposit. The higher the ratio of used to unused extraction the more serious the impact on the surrounding environment.

Global extraction of main metal ores

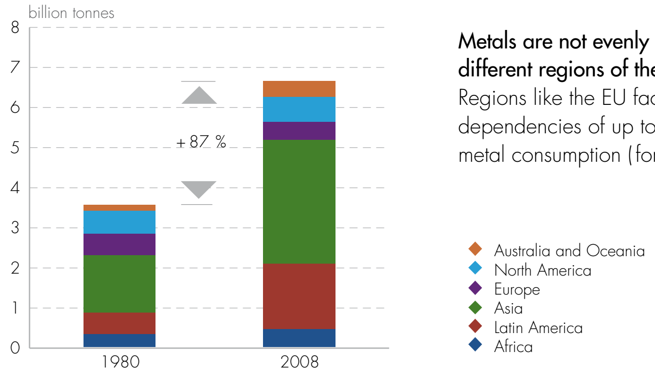
2008



Iron and copper are by far the leaders in global extraction of crude ore. The related unused extraction is in the same order of magnitude as the economically-used metal containing ore. Precious metals on the other hand have a high ratio of unused extraction due to difficult accessibility to the metal-containing ores.

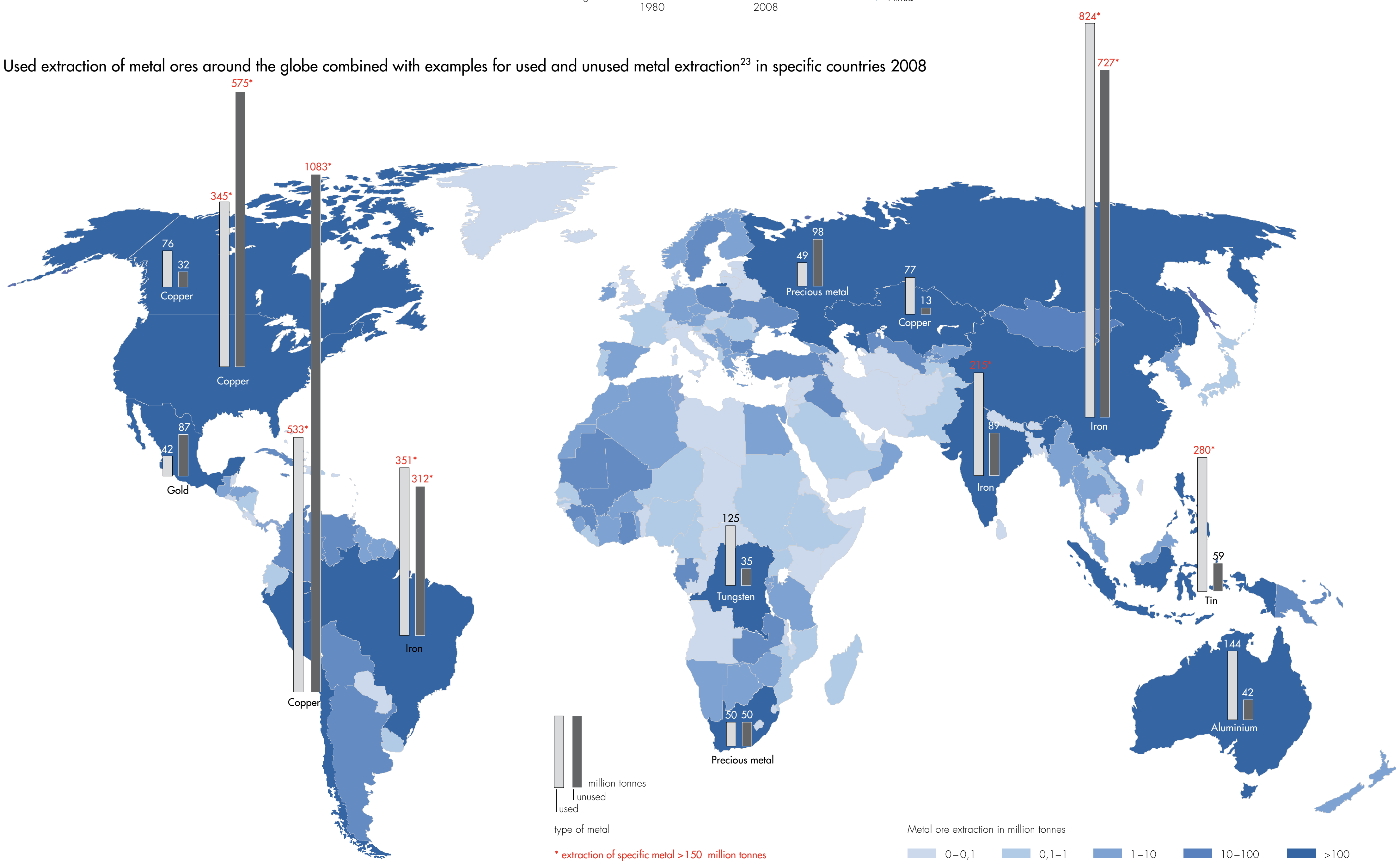
Global consumption of metals

1980 and 2008



Metals are not evenly distributed among the different regions of the world (see map). Regions like the EU face high import dependencies of up to 100% for domestic metal consumption (for example in Cobalt, Platinum or Rare Earths). In particular in periods of rising metal prices, import dependencies are closely linked to issues of supply security. In contrast, to satisfy worldwide demand for metals resource-rich countries increased their metal extraction considerably – often combined with even higher amounts of unused extraction, as in the case of copper extraction in Chile or precious metal extraction in Russia.

Used extraction of metal ores around the globe combined with examples for used and unused metal extraction[23] in specific countries 2008



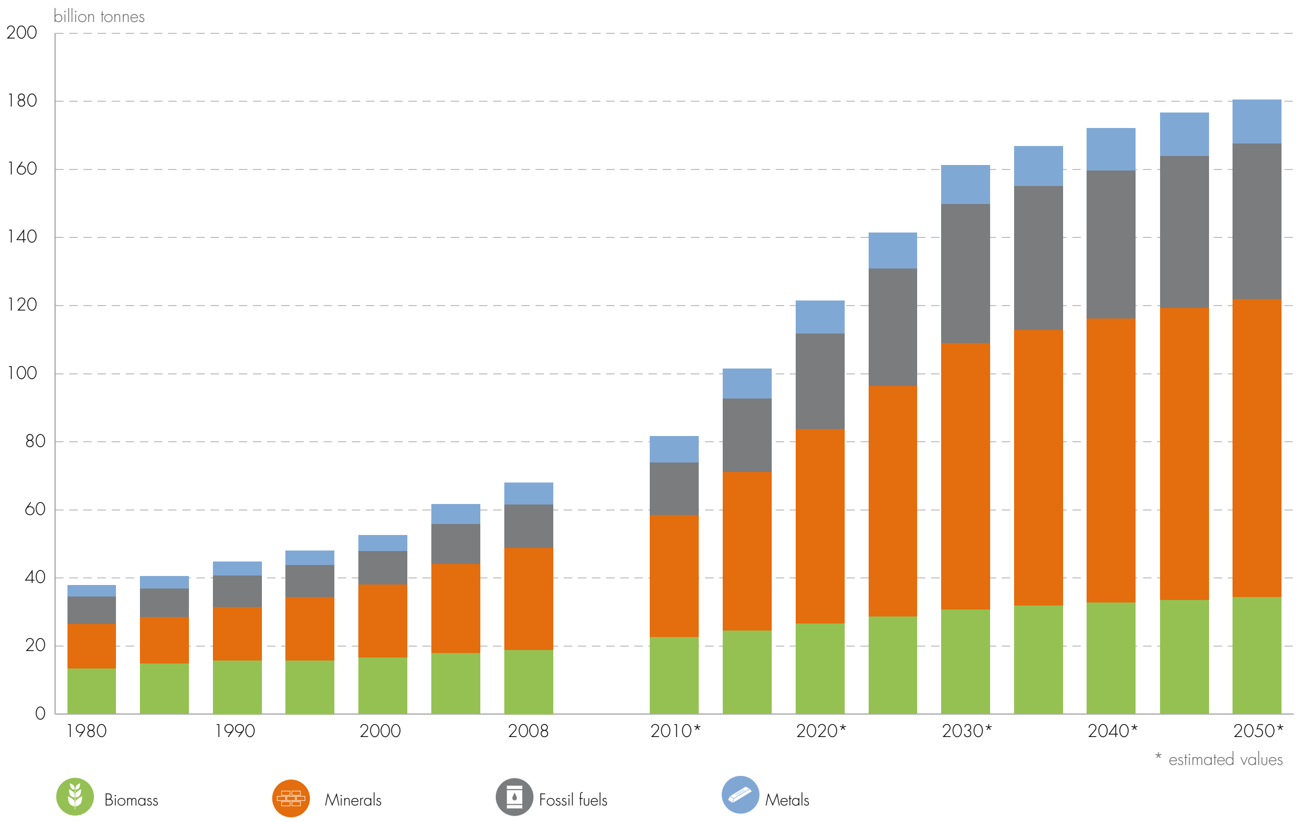
5 Conclusions and outlook

Business as usual: not an option for the future

The last few decades saw rapidly rising levels of global material use. Industrialised countries maintained high consumption per capita, even as some emerging economies caught up. People still need to increase their material welfare to overcome poverty in many parts of the world. However, if by 2030, all countries around the world had the same levels of material consumption as rich countries have today, it would imply an increased environmental threat and aggravate material scarcities.

Global material consumption

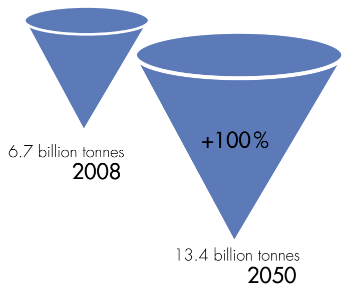
assuming catching up of all developing countries and OECD per capita levels from 2030 onwards



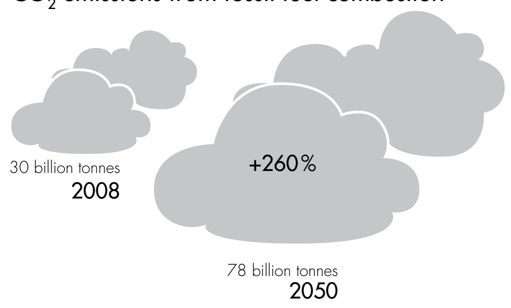
Dramatic changes have taken place in the last 30 years in the way humanity is using the planet's material resources. Global material consumption increased by 80% in absolute terms. Per capita consumption remained high in the rich, industrialised countries, and increased particulary in some of the fast-growing emerging economies such as China and Brazil. Yet, billions of people still live in material poverty and lack enough means to satisfy even their basic material needs.

To illustrate the magnitude of changes humanity would face in a "business as usual" scenario, it is assumed that the current dominant model of economic development will be adopted across the developing and emerging world. As a consequence, it is further assumed that global average per capita consumption levels would equal the current level observed in the OECD countries from 2030 onwards. The rough estimation illustrates that humans would require around 180 billion tonnes of different materials in 2050, which is a growth by a factor of 2.7 compared to today's levels. Restrictions in material supply and scarcities are not considered in this scenario.

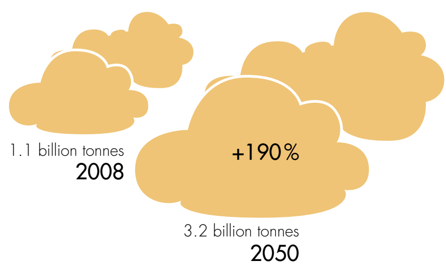
Unused material extraction related to metal mining



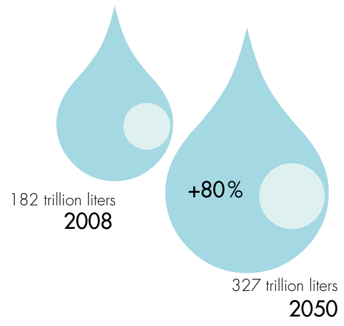
CO_2 emissions from fossil fuel combustion



CO_2 emissions from cement production



Water requirements for agricultural production

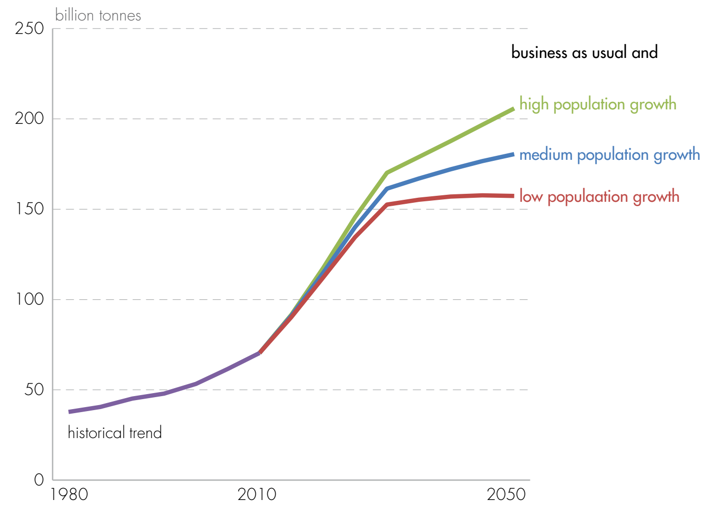


Environmental pressures from material consumption would increase significantly in all major categories under this scenario. This would exacerbate problems such as growing greenhouse gas emissions both from the increased use of fossil fuels and from energy use for producing products such as cement, as mineral use would almost triple compared to today's levels.

A doubling of global metal demand would entail increasing amounts of excavated earth and related landscape disruptions, even without taking into account the fact that metals will likely face continuously declining ore grades in the future. If demand for biomass would grow by 80%, the requirement for water, fertile land areas, fertilizer minerals and other inputs would rise. The situation would be made worse by the fact that agriculture would need to expand to less productive and fertile areas.

Global material use and population growth

Population growth plays an important role in determining the overall levels of material use in 2050 and beyond. Following the medium growth assumption by the United Nations (nine billion people by 2050), consumption levels in the scenario would reach around 180 billion tonnes in 2050. In the high population growth scenario (ten billion people), consumption would surpass 200 billion tonnes, whereas in the low population growth scenario (eight billion people), material consumption would level off at around 160 billion tonnes by 2050.



Setting a target

If business as usual is not an option, what are the possible alternatives? This section is an attempt to elaborate different scenarios for future material requirements, if humans agree to work together towards a common goal. Existing good practices in material use set the tone for the future. Setting international targets for resource use and resource efficiency could push efforts in the right direction.

Good practices
To achieve a more sustainable resource use, one strategy could be to base development, as much as possible, on existing good practices in the use of different materials.

Good examples in terms of biomass consumption
Biomass consumption varies between one and 22 tonnes per capita. Globally, food-related activities make up the highest share of biomass use. Less than two tonnes of biomass consumption per capita can be found in biomass-importing countries (with insufficient domestic agricultural production such as Kuwait) and in countries with insufficient diets, while values above 5 tonnes are usually linked to a material intensive rather cattle-based and/or export oriented agriculture. Between these – often ecologically limited extremes – are many countries with internationally renowned cuisines, low consumption values and a predominantly domestic production of around 2.2 tonnes of biomass per capita, such as China or Italy, which may be considered as good examples in terms of biomass use.

Good examples in terms of fossil fuels consumption
Fossil fuel consumption varies between almost zero and more than 30 tonnes per person. Good examples are rare among countries with a secure supply of energy, as the amount of renewable energy is still low and most of the countries use oil, gas or coal as main energy sources. Switzerland, Sweden and Iceland have high shares of renewable energy and could be cited as positive examples. All these countries consume between 2 and 2.5 tonnes of fossil fuels per capita.

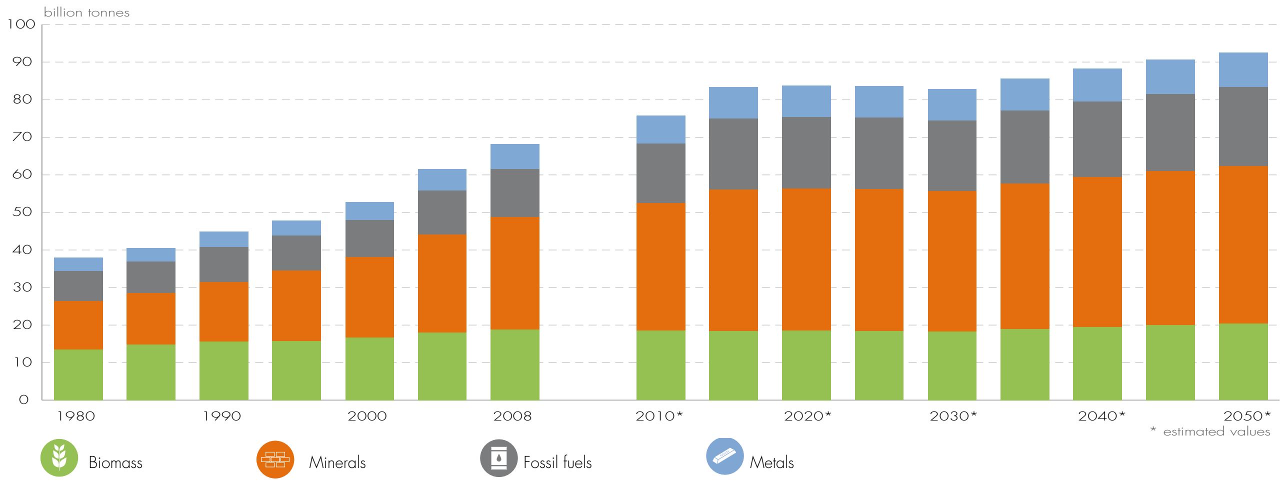
Good examples in terms of metal use
Metal consumption varies between almost zero and more than 30 tonnes per capita. Low values are found in the least developed and metal importing countries, whereas high values can be observed in metal extracting and exporting countries. Both groups depend on each other. Nevertheless, ignoring the upstream flows of trade, Japan with its 3R-initiative (reduce-reuse-recycle) and its average of 0.8 tonnes per capita emerges as the best example that currently exists.

Good examples in terms of mineral use
Mineral consumption varies between 0.3 and 80 tonnes per capita. Minerals are used for public and private infrastructure. Consumption is high in countries currently investing in infrastructure, and in large countries with a greater infrastructural requirement. Countries with hardly any public infrastructure have low mineral consumption. In between these extremes, comparatively low values can be found in countries where maintenance dominates new construction such as United Kingdom or the Netherlands, where average consumption is around 4 to 5 tonnes per capita.

Assuming (1) medium population growth, (2) that all countries could follow these best examples of high development standards and comparatively low resource use without any constraints until 2030 (including some exceptions in countries that are catching up) and (3) that the reduction in the consumption of one material category does not require higher consumption of other materials, humans would need around 10 tonnes per capita per year or 93 billion tonnes of resources in 2050. Resource consumption would stabilize at a consumption level of around 100 billion tonnes annually by the end of the century. Of the total amount, 22 billion tonnes would be biomass, 23 billion tonnes of fossil fuels, 8 billion tonnes metals and 45 billion tonnes minerals.

Global material consumption assuming best practice level from 2030 onwards for all countries

including catching-up of developing countries until 2030 and continuous change of all countries toward best practice level until 2030



Targets

In principle, the following need to be considered when setting targets for sustainable material use

- with regard to the environment, it could be argued that nature has limited resources, and therefore, global resource extraction should be frozen at the level of one base year, for example 1992, the year of the first Rio Summit at around 50 billion tonnes.
- with regard to equality considerations, it could be argued that a limit per capita has to be acknowledged, e.g. based on the current best practices, assuming the complete substitution of fossil fuels without increases of other materials (substituting are gained by further efficiency improvements) resulting in a level of 8 tonnes per capita by 2030.
- with regard to improvements in resource productivity, e.g.by a factor of 2 or a factor of 5 until 2050 or a factor of about 4 or 10 until 2100. Due to lack of forward projections of income, one could promote the reduction of *per capita consumption* by a factor of 2 and 5 respectively, compared to the current level of the OECD countries and assuming that developed countries would catch up by 2030.

These could result in different scales of absolute and per capita resource use.

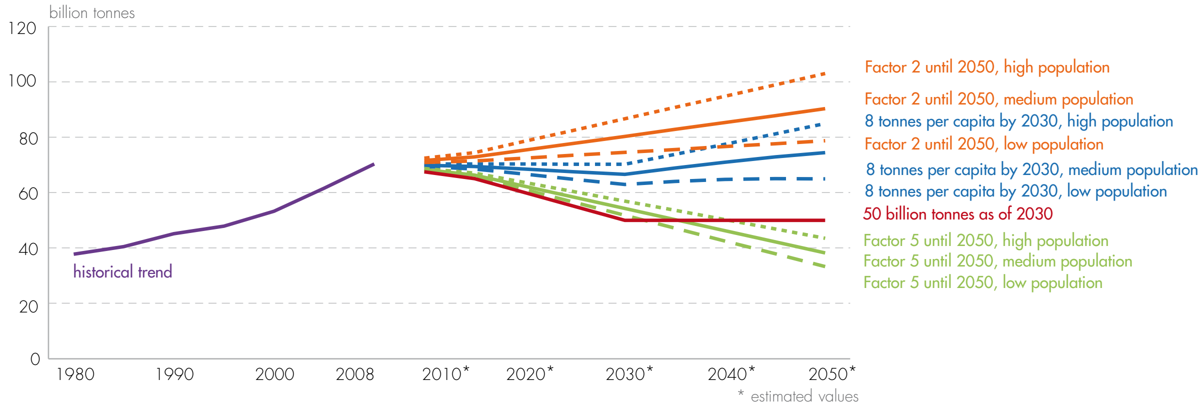
However, to achieve any or all of these would require massive improvements in resource productivity, possibly combined with a reduction in material consumption in high and medium material consuming countries (currently classified as high-income countries and some emerging economies).

In the meanwhile, low consuming countries (currently predominantly low income countries) could still increase their levels of resource consumption.

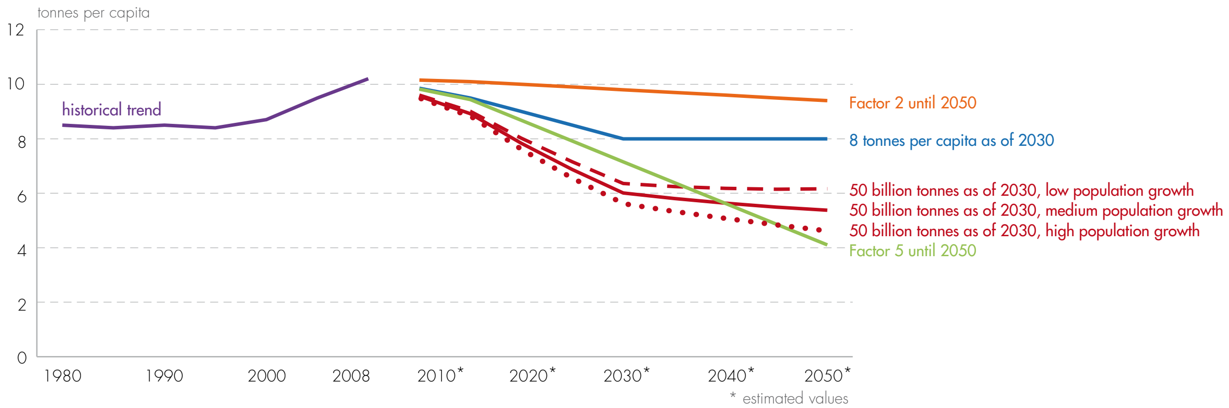
Under the overarching goal, differentiated targets for resource exporting and importing countries would need to be set till the point where resources embodied in traded goods are charged against each other.

In any case, given the current situation and the rate of unequal growth versus environmental damage, it is imperative to set a target and start moving towards it.

Scenarios of global material consumption
absolute values, based on different assumptions



Scenarios of global material consumption
per capita, based on different assumptions



Green economies for sustainable resource use

Key findings from this study

In general global dynamics during the past thirty years have shown that economic growth entailed increased material extraction and consumption. Although most countries made improvements in material productivity, the current amount of used materials and the continued unequal distribution of consumption between different world regions is far from being sustainable.

Some current trends are extremely alarming. The development process itself and the perpetuation of highly material-intensive life-styles in rich countries and in an increasing number of emerging economies require large amounts of resources. The quantities are so huge that this model of development cannot realistically be provided for all humans.

Many countries with a relatively higher performance of material use and resource productivity achieved this by outsourcing their material-intensive economic activities. Those countries which increased their activities in material-intensive economic sectors had a worse performance. Nevertheless, both developments are two sides of the same coin in the interlinked system of international specialisation. From those findings arises the question "What are the options that the green economy concept can provide?"

The potential of green economies

A key component of green economic strategies is improved resource management. Green economies thus have to improve resource productivity and reduce absolute levels of resource use. Such a transition could be achieved through concerted action by policy makers, setting the framework for increased resource efficiency, by companies exploiting the economic and environmental potentials of increased resource efficiency and by consumers making informed and active choices for resource efficient products and services. A few examples for such effective measures include:

- a transition towards more sustainable **energy** production by substantially increasing investments in renewable energy sources for power generation, while considering limits e.g. related to increased biomass use and environmental impacts;
- a transition in **manufacturing** industries towards closed material cycles and improvements in resource efficiency and productivity;
- a transition towards eco-friendly housing by constructing new green buildings and retrofitting the existing energy and material intensive buildings stock, and
- a transformation of the **transport** sector by promoting access instead of mobility, shifting to less harmful modes of transportation, and lowering carbon emissions by improving vehicles.

Some fundamental questions

Based on the information presented in this study on green economies and its potential to increase resource efficiency and decrease the amounts of materials required for production for production and consumption processes around the world, the fundamental questions humanity will face in the future are:

- Is the current model of material intensive lifestyles desirable as a future vision? And if not, what is an attractive and sustainable alternative?

- Are we willing to implement a limited and equal distribution of material consumption globally? If yes, at what level? The current OECD-level, which would mean accepting a doubling of environmental pressures? The current global average, accepting global distribution and current levels of ecological pressure? A level oriented on current best practices or maybe less? If one of these options seems to be favourable, what kind of incentives and sanctions would humanity accept to enforce them?

- If an equal distribution is not worthwhile, what would be an alternative approach to reach a globally sustainable level of resource use? Should inequalities of more than a factor of 50, as we observe currently, be maintained or would a minimum or maximum level of material consumption for each person be more attractive? What level of inequality could be acceptable in terms of global social justice?

Reducing our resource use, improving our quality of life

Independently of how those important questions are being addressed, two basic facts need to be taken into account when global strategies towards sustainable resource use are being discussed.

First, the current level of global resource use is not sustainable. The significant growth of resource extraction, trade and consumption is the main driver for most global environmental problems. At least with regard to some environmental impacts, humanity already exceeds the ecological capacity of the Earth's ecosystems. Climate change is the most prominent example, but biodiversity loss, desertification and soil erosion are also clearly linked to our use of natural resources. A sustainable system of global resource use must therefore operate on a level significantly below the current one; we need to reduce our resource consumption in absolute terms.

At the same time, billions of people on the planet are still living in material poverty and rightly demand a substantial increase of their consumption and material welfare. A strategy of reducing global resource use therefore needs to fully address distributional aspects, both between different countries and regions and – to a growing extent – also within countries. Ultimately, the objective is to ensure a high quality of life for all people while keeping resource use within the ecological limits of our planet.

Annex

Methodology and main data sources

This study is based on the methodological framework of material flow accounting and analysis (MFA). MFA builds on earlier concepts of material and energy balancing, as introduced in the 1970s. The MFA concept was developed as a reaction to the fact that many environmental problems result from a high material and energy consumption and related negative environmental consequences are determined by the overall scale of industrial metabolism rather than toxicities of specific substances.
Today, the MFA methodology is internationally standardised, and methodological handbooks are available, for example from the European Statistical Office (EUROSTAT, 2011) and the OECD (2007).
For MFA on the national level, two main boundaries for resource flows can be defined. The first is the boundary between the economy and the domestic natural environment from which raw materials are extracted. The second is the frontier with other economies with imports and exports as accounted flows.

The data and indicators presented in this study build on the integration of two existing data bases: (1) the global database on resource extraction developed and maintained by SERI, and (2) the global database on resource trade developed and maintained by M. Dittrich.

EUROSTAT. 2001. *Economy-wide material flow accounts and derived indicators. A methodological guide.* Luxembourg: Statistical Office of the European Union.

EUROSTAT. 2011. *Economy-wide Material Flow Accounts (EW-MFA) – Compilation Guidelines for EUROSTAT's 2011 EW-MFA questionnaire.* ENV/MFA/06 (2007). Luxembourg: EUROSTAT.

OECD. 2007. *Measuring material flows and resource productivity. The OECD guide ENV/EPOC/SE(2006)1/REV3.* Paris: (OECD) Organisation for Economic Cooperation and Development.

The global database on material extraction is based on international statistics including the International Energy Agency (for fossil fuels), the UN FAO (for biomass) and the US and British Geological Surveys (for metals and industrial minerals). This database is accessible in an aggregated form on the webpage www.materialflows.net, where a detailed technical report can be downloaded (see below).
Data quality varies for the different types of materials.
It is generally good for the extraction of fossil fuels and metal ores. However, in the case of a number of metals, estimations have to be applied regarding the concentration of metals in crude ore extraction.
It can be assumed that parts of the biomass extraction for subsistence purposes are not covered in official statistics, so biomass values might be underestimated, particularly for poor countries.
It is important to note that statistics about mineral use are poor in nearly all investigated countries. Thus, for the estimation of the extraction of construction minerals an estimation method was used, where the physical production of cement and bitumen was used to estimate overall levels of extracted construction minerals, in particular limestone, sand and gravel. Where no reliable data on cement and bitumen production was available the estimations were carried out using per capita income as proxy, assuming that demand for construction minerals per capita increases when countries become richer. The exact amounts of mineral extraction may therefore be over- or underestimated in some of the countries.

SERI. 2011. *Technical Report on the compilation of the material flow database for www.materialflows.net.* Vienna: (SERI) Sustainable Europe Research Institute

The global database on resource trade was developed by Monika Dittrich at the University of Cologne and the Wuppertal Institute in Germany. It is based on UN Comtrade data and includes global accounts of imports and exports in physical (mass) units. All missing mass values in UN Comtrade were filled using the global annual price for each commodity group, starting at the most differentiated level, then summed up according to the classification structure and repeated at the next higher differentiation level up to the total sum.
Values of direct trade flows of major outliers were corrected by adjusting the concerned values with regard to global prices, amount of global imports and exports and – as far as available – bilateral trade data as well as with regard to national and international sector statistics such as FAO or IEA. A detailed methodological description is given by Dittrich (2010) and Dittrich and Bringezu (2010).
In order to calculate aggregates on regional and global level, lacking original trade data reports of countries were estimated using as far as possible and available extrapolation, bilateral data of trade partners and/or further sectoral, national and international trade statistics.
In general, UN Comtrade trade statistics for the majority of OECD and Latin American countries are good with respect to differentiation and reliability while the others are of mixed quality. In general, trade statistics after 1995 are more differentiated and complete than before.

Dittrich, M. 2010. *Physische Handelsbilanzen. Verlagert der Norden Umweltbelastungen in den Süden?* Kölner Geographische Arbeiten, 91. Köln.
Dittrich, M. and S. Bringezu. 2010. *The physical dimension of international trade. Part I: Direct global flows between 1962 and 2005.* Ecological Economics 69: 1838–1847.

For this study, both databases have been combined.
In the first step the combination has been used to detect further outliers and unreliable data for all countries and years on different levels of aggregation. Main criteria applied were net exports of materials being higher than extraction for several years and consumption per capita being extraordinary higher or lower than the average range during that years or compared to other years. In a second step both databases were fully integrated in order to calculate the various material flow indicators.

Global data on material extraction, trade, consumption and productivity used in this study can be downloaded at an aggregated level from www.materialflows.net.
Material productivity was calculated using GDP in purchasing power parities and constant terms derived from the World Bank (2011). Population data are also used as provided by the World Bank (2011).

Sustainable Europe Research Institute (SERI) in cooperation with Wuppertal Institute and Monika Dittrich: *Global Material Flows Database, 1980–2008.* Available at http://www.materialflows.net/

Worldbank. http://databank.worldbank.org/

Key indicators

	DMC [Mio. t]			DMC/cap [tonnes per capita]			Material Productivity [US$$_{ppp, const. 2005}$/tonne]		
	1980	2008	% change	1980	2008	% change	1980	2008	% change
World	37,966	68,119	79	8.5	10.2	19	691	952	38
Africa	2,573	4,876	89	5.7	5.3	-7	339	517	53
Asia**	14,146	36,029	155	5.1	8.7	69	577**	698	21
Australia & Oceania	871	1,269	46	38.1	36.0	-6	409	686	67
Europe	8,000	8,685	9	14.5	14.7	1	936	1,771	89
Latin America	4,173	7,587	82	11.6	13.3	15	635	730	15
North America	7,975	9,282	16	31.7	27.5	-13	799	1,547	94
Afghanistan	59	57	-4	3.9	1.9	-50	n.a.	506	
Albania	20	23	19	7.3	7.4	1	577	982	70
Algeria	96	270	180	5.1	7.8	53	1,241	940	-24
American Samoa	0	0	117	n.a.	0,6		n.a.	n.a.	
Angola	23	61	160	3.0	3.4	13	n.a.	1,625	
Antigua and Barbuda	0	1	246	3.7	10.7	189	1,625	1,756	8
Argentina	548	576	5	19.5	14.4	-26	517	915	77
Armenia	..	26		..	8.3		..	674	
Australia	722	1,077	49	49.2	50.3	2	408	687	68
Austria	136	157	16	18.0	18.9	5	1,176	1,917	63
Azerbaijan	..	24		..	2.8		..	2,893	
Bahamas, the	25	1	-96	121.2	3.0	-98	176	8,199	4,571
Bahrain	15	25	65	44.1	32.6	-26	495	989	100
Bangladesh	128	297	132	1.4	1.9	31	427	665	56
Barbados	3	3	-7	12.5	11.3	-9	1,199	1,756	46
Belarus	..	110		..	11.3		..	1,027	
Belgium-Luxembourg	181	183	1	17.8	16.4	-8	1,185	2,156	82
Belize	2	4	49	17.0	11.4	-33	197	546	177
Benin	15	40	177	4.1	4.7	14	280	292	4
Bermuda	1	1	69	15.9	22.7	42	n.a.	n.a.	
Bhutan	5	9	83	11.5	13.0	13	86*	340	298
Bolivia	71	88	23	13.3	9.0	-32	284	458	62
Bosnia and Herzegovina	..	38		..	10,0		..	749	
Botswana	20	35	77	19.9	18.1	-9	174	705	304
Brazil	1,374	2,759	101	11.3	14.4	28	670	665	-1
Brunei Darussalam	1	7	392	7.1	17.1	142	11,170	2,678	-76
Bulgaria	118	132	12	13.3	17.3	30	438	693	58
Burkina Faso	31	85	175	4.5	5.6	24	145	193	33
Burundi	11	18	55	2.7	2.2	-21	157	163	4
Cambodia	19	50	163	2.9	3.6	24	n.a.	527	
Cameroon	42	76	81	4.6	4.0	-14	434	501	16
Canada	961	811	-16	39.1	24.3	-38	590	1,475	150
Cape Verde	0	2	455	1.3	4.1	222	928*	790	-15
Cayman Islands	0	1	192	10.7*	10.4	-2	n.a.	n.a.	
Central African Republic	13	28	108	5.9	6.4	9	163	107	-34
Chad	33	55	65	7.2	5,0	-30	90	247	175
Chile	192	735	282	17.2	43,8	154	312	306	-2
China	2,943	18,914	543	3.0	14,2	376	199	417	110
Colombia	223	342	54	8.3	7.6	-8	640	1,084	69
Comoros	1	1	47	2.1	1.6	-23	555	663	19
Congo, Dem. Rep.	121	268	122	4.4	4.2	-6	174	70	-60
Congo, Rep.	3	6	88	1.8	1.7	-6	1,644	2,172	32
Costa Rica	24	41	69	10.4	9.1	-12	612	1,135	85
Cote d'Ivoire	26	52	96	3.1	2.5	-20	845	610	-28
Croatia	..	51		..	11.5		..	1,504	

	DMC [Mio. t]			DMC/cap [tonnes per capita]			Material Productivity [US$$_{ppp, const. 2005}$/tonne]		
	1980	2008	% change	1980	2008	% change	1980	2008	% change
Cuba	142	107	-25	14.5	9.6	-34	n.a.	n.a.	
Cyprus	7	23	224	11.6	26.6	129	808	907	12
Czech Republic	..	193		..	18.5		..	1253	
Czechoslovakia	405	..		26.6	..		n.a.		
Denmark	112	139	24	21.8	25.3	16	955	1,345	41
Djibouti	2	3	73	5.6	3.9	-31	n.a.	529	
Dominica	0	0	-12	5,6	5.0	-11	606	1,650	172
Dominican Republic	33	58	76	5.5	5.8	5	665	1,297	95
Ecuador	59	116	97	7,4	8,6	17	788	882	12
Egypt	157	564	258	3,5	6,9	95	686	724	6
El Salvador	17	31	81	3,7	5,1	38	1180	1228	4
Equatorial Guinea	1	22	2616	3,7	33,5	808	n.a.	928	
Eritrea	n.a.	19		..	3,9		..	127	
Estonia	..	34		..	25,0		..	746	
Ethiopia	235	386	64	6,7	4,8	-28	n.a.	167	
Faroe Islands	0	1	85	n.a.	18,9		n.a.	n.a.	
Fiji Islands	7	9	38	10,3	10,7	4	333	398	19
Finland	158	205	30	33,0	38,6	17	541	871	61
France	901	933	4	16,3	14,5	-11	1241	2089	68
French Polynesia	2	3	86	11,2	11,8	6	n.a.	n.a.	
Gabon	6	20	225	9,2	14,1	53	1846	954	-48
Gambia, the	3	5	75	5,0	3,3	-35	247	363	47
Georgia	..	14		..	3,3		..	1369	
Germany	1670	1217	-27	21,3	14,8	-31	970	2278	135
Ghana	31	132	322	2,8	5,6	99	348	244	-30
Gibraltar	0	0	59	6,9	9,8	41	n.a.	n.a.	
Greece	89	194	118	9,3	17,3	87	1859	1556	-16
Grenada	0	1	191	2,9	7,1	150	1123	1147	2
Guadeloupe	4	3	-25	38,6	17,6	-54	n.a.	n.a.	
Guatemala	31	87	184	4,4	6,4	45	887	685	-23
Guinea	25	66	168	5,3	6,7	26	n.a.	146	
Guinea-Bissau	3	5	74	3,3	3,0	-8	275	316	15
Guyana	8	13	54	10,6	16,5	56	195	155	-20
Haiti	19	20	8	3,3	2,1	-38	n.a.	502	
Honduras	25	48	92	6,9	6,6	-4	407	549	35
Hungary	126	104	-18	11,8	10,4	-12	903	1685	87
Iceland	6	8	34	24,7	23,8	-4	884	1540	74
India	1671	4555	173	2,4	4,0	64	368	696	89
Indonesia	576	1309	127	3,9	5,8	47	346	641	85
Iran	197	897	355	5,0	12,5	148	1408	838	-40
Iraq	105	128	22	7,5	4,2	-44	n.a.	762	
Ireland	115	227	99	33,7	51,4	53	378	758	101
Israel	37	103	179	9,6	14,2	48	1571	1819	16
Italy	890	682	-23	15,8	11,4	-28	1194	2469	107
Jamaica	17	26	52	8,1	9,8	21	628	747	19
Japan	1410	1300	-8	12,1	10,2	-16	1455	3075	111
Jordan	17	53	206	7,9	9,1	15	497	560	13
Kazakhstan	..	356		..	22,7		..	461	
Kenya	89	136	52	5,5	3,5	-36	250	406	63
Kiribati	0	0	169	2,3	3,7	62	920	614	-33
Korea, Rep.	204	767	276	5,3	15,8	195	1038	1618	56
Kuwait	44	96	117	32,3	35,4	10	1240	n.a.	
Kyrgyzstan	..	34		..	6,5		..	314	
Laos	13	25	98	3,9	4,1	3	n.a.	483	

Key indicators

	DMC [Mio. t]			DMC/cap [tonnes per capita]			Material Productivity [US$$_{ppp, const. 2005}$/tonne]		
	1980	2008	% change	1980	2008	% change	1980	2008	% change
Latvia	..	25		..	11,1		..	1411	
Lebanon	19	40	111	6,9	9,6	40	n.a.	1137	
Lesotho	7	8	11	5,5	3,9	-30	151	354	135
Liberia	7	9	26	3,7	2,3	-37	479	153	-68
Libya	59	91	55	19,2	14,4	-25	n.a.	1038	
Liechtenstein	0	0	50	9,9	10,5	6	n.a.	n.a.	
Lithuania	..	39		..	11.5		..	1530	
Macedonia, FYR	..	31		..	15.3		..	572	
Madagascar	62	74	19	7.2	3.9	-47	178	252	41
Malawi	14	30	113	2.2	2.1	-5	308	343	12
Malaysia	80	291	261	5.8	10.8	84	836	1,224	46
Maldives	0	6	3,222	1.1	19.7	1,622	n.a.	263	
Mali	48	93	95	6.6	6.4	-2	114	145	27
Malta	3	5	113	7.0	13.2	88	1,293	1,711	32
Mauritania	16	30	92	10.3	9.4	-9	166	192	16
Mauritius	6	13	110	6.5	10.4	60	575	1,112	93
Mexico	684	1045	53	10.1	9.8	-3	1030	1,369	33
Micronesia	0	0	8,858	0.0	1.4	5,822	n.a.	2,062	
Moldova	..	19		..	5.2		..	534	
Mongolia	46	88	89	27.9	33.2	19	n.a.	108	
Morocco	104	234	125	5.3	7.4	39	442	540	22
Mozambique	27	46	70	2.2	2.1	-8	196	373	91
Myanmar	70	140	98	2.1	2.8	34	n.a.	n.a.	
Namibia	28	28	-2	27.8	13.0	-53	177	462	161
Nepal	45	70	55	3.0	2.4	-19	189	422	123
Netherlands	195	197	1	13.8	12.0	-13	1,615	3,183	97
New Caledonia	4	5	26	27.3	19.9	-27	n.a.	n.a.	
New Zealand	93	113	22	29.8	26.4	-11	577	965	67
Nicaragua	22	37	69	6.7	6.5	-3	410	383	-7
Niger	36	47	30	6.1	3.2	-48	152	200	31
Nigeria	210	450	114	2.8	3.0	5	591	652	10
North Korea	78	75	-4	4.5	3.1	-31	n.a.	n.a.	
Norway	85	103	20	20.8	21.5	3	1,248	2,257	81
Oman	10	106	914	8.8	38.0	332	1,112	614	-45
Pakistan	206	580	181	2.5	3.5	40	478	668	40
Panama	18	33	79	9.3	9.6	3	704	1,220	73
Papua New Guinea	41	54	33	12.8	8.3	-35	152	245	61
Paraguay	67	110	65	20.8	17.6	-15	194	246	27
Peru	250	760	204	14.5	26.4	82	420	298	-29
Philippines	217	285	31	4.5	3.2	-30	613	1,072	75
Poland	596	627	5	16.8	16.4	-2	n.a.	1,000	
Portugal	86	214	148	8.9	20.1	128	1355	1090	-20
Puerto Rico	24	35	45	7.6	8.9	18	n.a.	n.a.	
Qatar	8	146	1,770	34.0	114.0	235	n.a.	737	
Romania	411	243	-41	18.5	11.3	-39	413	1,043	153
Russian Federation		1,976			13.9		..	1,061	
Rwanda	14	26	83	2.7	2.6	-2	301	385	28
Samoa	1	1	34	4.6	5.4	16	n.a.	789	
San Marino	0	0	165		9,9		n.a.	n.a.	
Sao Tome and Principe	0	0	125	1.8	2.4	33	n.a.	686	
Saudi Arabia	195	415	112	20.3	16.7	-18	1,700	1,296	-24
Senegal	24	63	163	4.3	5.2	21	344	319	-7
Serbia and Montenegro	..	103		..	12.9		..	732	
Seychelles	0	1	155	6.4	12.1	89	1706	1,606	-6

Key indicators

	DMC [Mio. t]			DMC/cap [tonnes per capita]			Material Productivity [US$$_{ppp, const. 2005}$/tonne]		
	1980	2008	% change	1980	2008	% change	1980	2008	% change
Sierra Leone	10	14	40	3.0	2.5	-18	260	290	12
Singapore	30	145	383	12.4	30.0	141	1163	1,602	38
Slovakia	..	63		..	11.7		..	1,756	
Slovenia	..	55		..	27.0		..	1,006	
Solomon Islands	1	3	262	3.6	5.9	62	n.a.	409	
Somalia	57	65	15	8.8	7.3	-17	n.a.	n.a.	
South Africa	458	607	32	16.6	12.4	-25	527	772	46
Spain	390	912	134	10.4	20.0	92	1,475	1,416	-4
Sri Lanka	34	70	106	2.3	3.5	53	677	1,219	80
St. Kitts and Nevis	1	1	18	12.0	12.8	6	397	1,131	185
St. Lucia	1	1	68	4.4	5.1	14	943	1,814	92
St. Vincent and the Grenadines	0	1	161	3.1	7.4	140	860	1,158	35
Sudan	144	295	105	7.2	7.1	-1	148	276	86
Suriname	7	9	35	18.8	18.1	-4	351	376	7
Swaziland	9	11	29	14.1	9.4	-34	161	485	201
Sweden	174	200	15	20.9	21.7	4	973	1,579	62
Switzerland	97	98	1	15.4	12.9	-16	1,858	2,962	59
Syria	72	121	68	8.0	5.9	-27	416	734	77
Tajikistan	..	7		..	1.1		..	1,618	
Tanzania	99	173	75	5.3	4.1	-23	n.a.	286	
Thailand	327	468	43	6.9	7.0	0	322	1,075	234
Timor-Leste	1	2	162	1.4	2.0	41	n.a.	370	
Togo	8	18	130	2.8	2.8	-1	389	282	-27
Tonga	0	0	-11	3.6	3.0	-17	692*	1,367	98
Trinidad and Tobago	11	21	104	9.7	16.1	65	1,568	1,493	-5
Tunisia	39	91	136	6.0	8.8	46	599	835	39
Turkey	249	749	201	5.4	10.1	88	1,055	1,174	11
Turkmenistan	..	64		..	12.7		..	487	
Turks and Caicos Islands	0	0	456	8.1	10.3	28	n.a.	n.a.	
Tuvalu	0	0	26	1.5	1.5	3	n.a.	n.a.	
Uganda	62	113	82	4.9	3.6	-27	n.a.	300	
Ukraine	..	405		..	8,8		..	767	
United Arab Emirates	29	196	587	28.1	43.7	56	3,394	1,238	-64
United Kingdom	784	683	-13	13.9	11.1	-20	1,323	3,045	130
United States	7,014	8,470	21	30.9	27.8	-10	827	1554	88
Uruguay	96	152	58	33.0	45.5	38	237	256	8
US Virgin Islands	0	0	1	0.8	0.7	-11	n.a.	n.a.	
USSR	4,840	..		18.5	..		n.a.	..	
Uzbekistan	..	219		..	8.0		..	306	
Vanuatu	1	2	81	8.0	7.3	-8	148	557	276
Venezuela	163	312	92	10.8	11.2	4	1,070	1,051	-2
Viet Nam	79	576	625	1.5	6.7	352	n.a.	386	
West Bank and Gaza	1	10	652		2.5		n.a.	n.a.	
Yemen	15	84	453	1.8	3.6	102	n.a.	610	
Yugoslavia SFR	246	8	-97	15.8		-100	n.a.	..	
Zambia	102	101	-1	17.6	8.2	-54	87	156	80
Zimbabwe	52	53	2	7.2	4.3	-40	n.a.	n.a.	

* 1981
** excluding Sovjet Union
n.a. not available
.. country not existing

Population data and GDP data are taken from Worldbank, 2011

References

1. United Nations Environment Management Group. 2012. *Working towards a balances and Inclusive Green Economy: A United Nations System-wide Perspective.* Geneva. http://www.unemg.org/Portals/27/Documents/IMG/GreenEconomy/report/GreenEconomy-Full.pdf
2. OECD (Organisation for Economic Cooperation and Development). 2011. *Towards Green Growth.* Paris. http://www.oecd.org/dataoecd/37/34/48224539.pdf
3. UNIDO (United Nations Industrial Develoment Organization). 2011. *UNIDO Green Industry. Policies for Supporting Green Industry.* http://www.unido.org/fileadmin/user_media/Services/Green_Industry/web_policies_green_industry.pdf
4. UNEP. 2011. *Towards a green economy. Pathways to sustainable development and poverty eradication.* Nairobi. http://www.unep.org/greeneconomy/Portals/88/documents/ger/ger_final_dec_2011/Green%20EconomyReport_Final_Dec2011.pdf
5. Giljum, S., M. Dittrich, S. Bringezu, C. Polzin and S. Lutter. 2010. *Resource use and resource productivity in Asia: Trends over the past 25 years.* Study for the UN Industrial Development Organisation (UNIDO). Vienna. http://seri.at/wp-content/uploads/2010/05/SERI-Working-Paper-11.pdf
6. Dittrich, M., S. Giljum, S. Bringezu, C. Polzin and S. Lutter. 2011. *Resource use and resource productivity in emerging economies: Trends over the past 20 years.* Study for the UN Industrial Development Organisation (UNIDO). Vienna. http://www.unido.org/fileadmin/user_media/Services/Green_Industry/1256_11_Onscreen_Green%20Industry.pdf
7. Polzin, C., S. Giljum, M. Dittrich, B. Lugschitz and S. Lutter. 2011. *Resource use and resource efficiency in Central and Eastern Europe and the Newly Independent States. A pilot study on trends over 13 years.* Study for the UN Industrial Development Organisation (UNIDO). Vienna.
8. Dittrich, M., S. Giljum, C. Polzin and S. Lobo. 2012: *Resource use and resource efficiency in Africa. Trends over the past 30 years.* Study for UNCTAD. Heidelberg/Vienna.
9. UNEP (United Nations Environment Programme). 2011. *Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel.* Edited by M. Fischer-Kowalski and M. Swilling. http://www.unep.org/resourcepanel/decoupling/files/pdf/Decoupling_Report_English.pdf
10. UNEP (United Nations Environment Programme). 2011. *Resource Efficiency: Economics and Outlook for Asia and the Pacific.* Bangkok.
11. von Weizsäcker, E. U.; Hargroves, K. C., Smith, M. H., Desha, C. and P. Stasinopoulos. 2009: *Factor five: transforming the global economy through 80% improvements in resource productivity.* London.
12. Journal of Industrial Ecology. http://eu.wiley.com/WileyCDA/WileyTitle/productCd-JIEC.html
13. Ecological Economics. http://www.journals.elsevier.com/ecological-economics/
14. Schmidt-Bleek, F. 2009. *The Earth: Natural Resources and Human Intervention.* London.
15. OECD (Organisation for Economic Cooperation and Development). 2007. *Measuring material flows and resource productivity.* The accounting framework ENV/EPOC/SE(2006)4/REV1. Paris.
16. Worldbank. http://databank.worldbank.org/
17. Regions according UN, except Russian Federation which is assigned to Asia: United Nations Statistics Division. 2011. *Composition of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings.* http://unstats.un.org/unsd/methods/m49/m49regin.htm
18. Monetary values: UN Comtrade. 2011. http://comtrade.un.org/db/
19. Human Development Index (HDI): UNDP. 2011. http://hdr.undp.org/
20. Happy Life Years (HLY): new economics foundation. 2011. http://www.happyplanetindex.org/
21. Water Exploitation Index (WEI): European Environment Agency. http://www.eea.europa.eu/data-and-maps/indicators/water-exploitation-index
22. EUROSTAT. 2001. *Economy-wide material flow accounts and derived indicators. A methodological guide.* Luxembourg: Statistical Office of the European Union.
23. Data for unused extraction taken from SERI (Sustainable Europe Research Institute) 2011.http://www.materialflows.net/
24. IEA (International Energy Agency). 2009. *CO_2 Emissions from Fuel Combustion* (2009 Edition). Paris.
25. EEA. 2010. *The European Environment. State and outlook 2010. Land use.* Copenhagen.
26. Krausmann, F., S. Gingrich, N. Eisenmenger, K.-H. Erb, H. Haberl, and M. Fischer-Kowalski. 2009. *Growth in global materials use, GDP and population during the 20th century.* Ecological Economics 68(10): 2696–2705.
27. PBL and JRC. 2011. *Long-term trend in global CO_2 emissions.* The Hague. http://edgar.jrc.ec.europa.eu/news_docs/C02%20Mondiaal_%20webdef_19sept.pdf

Key

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AL	Albania
AM	Armenia
AN	Netherland Antilles and Aruba
AO	Angola
AR	Argentina
AS	American Samoa
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