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Resource Use in Austria

Report 2011

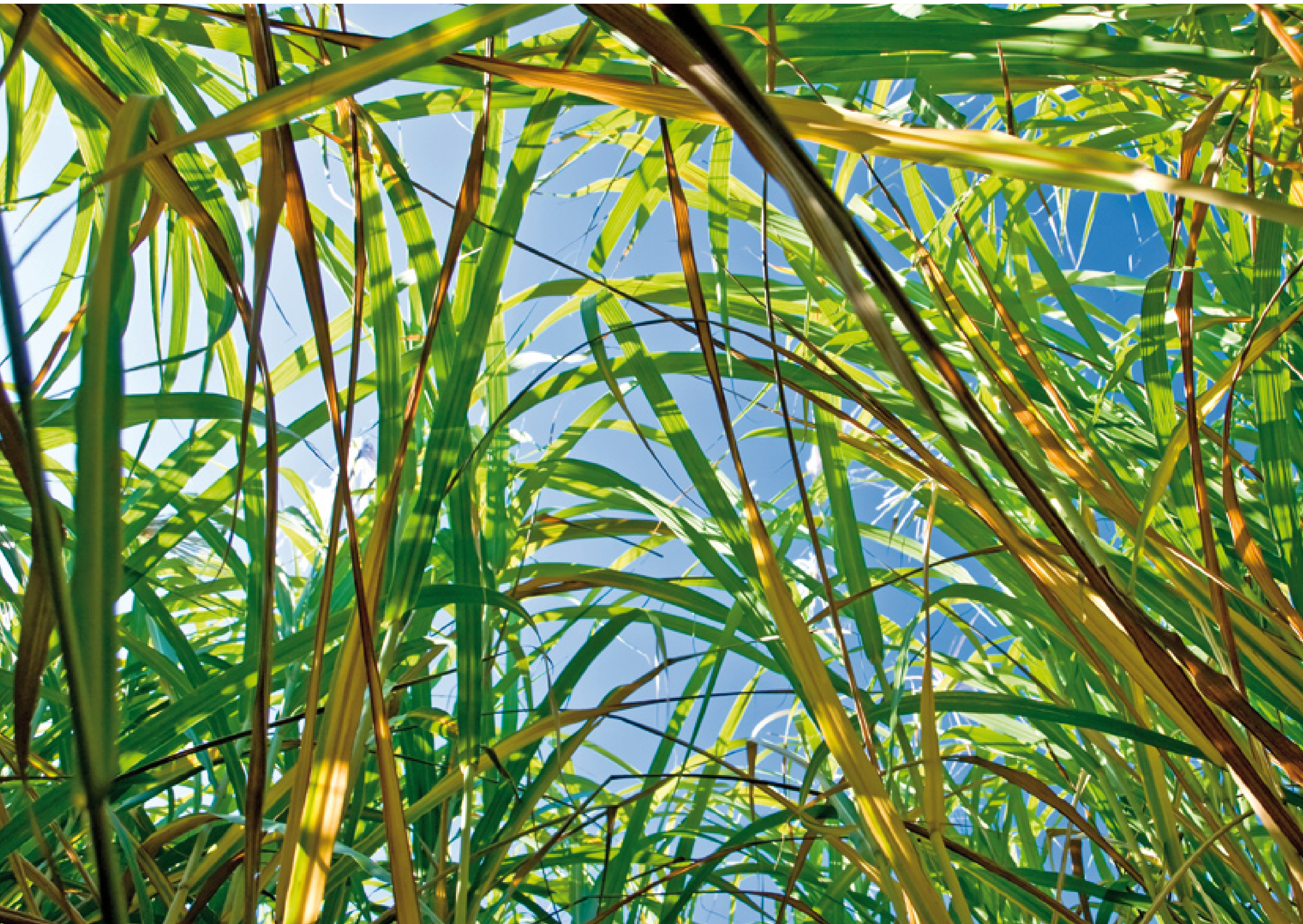

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Table of Contents

Preface

This publication describes Austria's natural resource use using current figures and analyses. A new method developed for data on construction minerals was applied for the first time.

Data on construction minerals cannot be obtained for all relevant enterprises in Austria. Smaller enterprises, for example, are exempt from reporting obligations and reporting is voluntary in some other cases. Statistical offices fill the resulting data gaps using carefully calculated estimates, while ensuring that no double-counting occurs.

In the course of the project work for the publication "Resource use in Austria", the method for estimating such missing data was further developed and substantially improved. This enabled reliable estimates to be produced for most of the non-reported data and thus resulted in a significant improvement of the data basis for minerals, in particular for construction minerals. Using this advanced method, it has been possible to correct the statistical figures on resource use for the years from 1995 to 2008. With this statistical innovation, Austria has taken on a pioneer role within Europe as a whole.

However, the new high quality data also reveals that Austria's overall resource use is considerably higher than was previously assumed.

The under-reporting of construction minerals is likely to occur in other European countries and at international level as well and it seems that statistical reporting has only been able to provide an incomplete picture of mineral resource use. This fact must be taken into account especially when making comparisons between countries. Austria's resource use appears to be very high by international comparison. Here, factors such as population density, gross domestic product or climate play an important role, but so do the methodological improvements made for construction minerals. A comparison of the data over time (time series) will be useful and informative.

This publication documents the success of efforts to improve resource efficiency in Austria during the past 50 years. Efficiency has been increased by a factor of 2.5. However, in spite of these considerable efficiency gains, resource use in Austria is, as in other European countries, undeniably too high; the objective of achieving an absolute reduction of resource use has not been achieved. Environmental policy thus has to concentrate not only on efficiency gains, but must make efforts to reduce resource use in absolute terms as well. With its Resource Efficiency Action Plan [REAP], scheduled for the second half of 2011, Austria will make another important contribution to meeting this challenge.

Summary

The economical and efficient use of natural resources is considered to be one of the key strategies in the sustainable development of our economy and society. But how has "Resource use in Austria" progressed? The report thus titled addresses this question using the most recent data available from material flow accounts.

Between 1960 and 2008, Austria's total annual resource use rose from 114 to 197 million tonnes, which was equivalent to 24 tonnes per person per year, or 66 kg per person per day, in 2008. Domestic extraction through mining, agriculture and forestry is the most important factor when it comes to meeting our country's demand for resources. Imports, however, are increasingly gaining importance. In 2008, 88 million tonnes of resources were imported; this amount corresponds to half of the total domestic extraction. Austria's dependence on imports is particularly pronounced for fossil energy carriers and commodities made of metallic raw materials. At 60 million tonnes, export flows were smaller in 2008, yet they play a crucial role economically as they are comprised predominantly of highly processed goods at high unit prices.

The (internationally) increasing trade flows are a consequence of growing differentiation within production process, which is usually split into many individual steps carried out in many individual countries. In the international division of labour, highly industrialised countries (like Austria) tend to specialise in tasks towards the end of the production chain and to outsource the material-intensive first steps of production. An assessment for the year 2005 shows that, to cover Austria's annual resource use, an additional 35 million tonnes of resources per year were required in the form of intermediate inputs into imported goods. If we take into account all the resources used in Austria and abroad, the total resource use of 2008 would amount to as much as 30 tonnes per person per year, or to 80 kg per person per day.

Which resources does Austria use in economic production and consumption?

In 2008, biomass accounted for 22 % of Austria's resource use. These resources are, on the one hand, indispensable for human nutrition and, on the other hand, important raw materials in industrial production (especially timber). The close link between biomass production and the type and, above all, the intensity of land use make careful management necessary in order to prevent soil degradation and biodiversity loss. Fossil energy carriers, which are essential for energy supply, account for 12 % of the resource use. Their use significantly contributes to climate change. Scarcities increasingly affect international prices. Metals are important components of infrastructure, machines, and consumer goods. Although at 4 % they have the smallest share in resource use, they play an important role in terms of environmental impacts, which is above all due to the high quantities of material and energy required to extract and refine them. With regard to fossil energy carriers and metals, Austria depends heavily on imports. In this context, the question of supply security is becoming increasingly urgent. At 62 %, non-metallic minerals account for the largest share in resource use. They are mainly comprised of construction minerals, the area-intensive use of which is closely linked to economic growth. For a long time, the availability of these "bulk raw materials" was thought to be unproblematic, but land-use conflicts are increasingly causing supply bottlenecks.

Overall, resource use in Austria has risen by a factor of 1.7 during the past 50 years. Over the same period of time, however, resource efficiency has improved by a factor of 2.5: One tonne of resources can thus be used to generate 2.5 times more economic wealth. This is due to the fact that the increased resource use (+73 %) was by far overcompensated by the economic growth rate (+325 %). This development, which Austria shares with most other industrialised countries, evokes the question of what an economy might look like that does not depend on rising resource use. Achieving wealth and high quality of life whilst carefully safeguarding nature and its resources must form the focus of this vision. The challenges involved are simultaneously important opportunities for Austria's environment, economy, and society.

Introduction

Natural resources, i. e. fossil energy carriers, metals, non-metallic minerals, biomass, water, and air, are crucial to our life on this planet. Commodities which are required in everyday life and indispensable for our society are based on raw materials provided through mining and agriculture. As opposed to agricultural raw materials, the renewal of mineral raw materials takes millions of years. Even though shortages are unlikely to occur in the short or medium term, artificially induced scarcities can already be felt (limited market availability, higher prices, etc.). Each interruption in raw material supply can have serious consequences (production losses, impacts on financial markets etc.). Growing resource use is associated with environmental burdens the negative impacts of which we are confronted with in many respects. Resources must not be wasted at the expense of future generations. The economical and efficient use of natural resources is considered to be one of the key strategies in the sustainable development of our environment, economy, and society.

The European Commission presented the conservation of resources as one of seven flagship initiatives under the **Europe 2020 Strategy** (European Commission 2010). The "Europe 2020 Strategy" is the centrepiece of Europe's policy for promoting growth and revitalising the labour market and is supported by the European Parliament and the Council of Europe. Smart, sustainable and inclusive growth is the key target of the Strategy. In January 2011, the Commission launched the so-called flagship initiative for a **Resource-Efficient Europe** in a Communication to the Council (European Commission 2011 b). The initiative sets out the strategic framework for a more sustainable use of natural resources and a shift towards resource-efficient growth in Europe. The "Roadmap to a Resource-Efficient Europe" provides recommendations relating to the implementation of the initiative at the national level. Resource efficiency is thus at the centre of the EU policy.

The Austrian Federal Government is equally committed to the efficient and economical use of natural resources. Within the framework of a national action plan, the current government programme provides for discussion on the topic of the environment and resource conservation with representatives of the economy. Under the guidance of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (Lebensministerium), the **Austrian Resource Efficiency Action Plan (REAP)** is thus being prepared and is to be completed in the second half of 2011. In dialogue with the administrative sector, the economy, academia, and civil society, objectives to promote resource efficiency in Austria are being identified and suitable flagship policies and key instruments to achieve them are developed.

Resource efficiency is also one of the three pillars of the **Austrian Raw Materials Plan**[1] of the Federal Ministry of Economy, Family and Youth (Ministry of Economic Affairs). The Communication of the European Commission, **Tackling the Challenges in Commodity Markets and on Raw Materials** (European Commission 2011 a) provides the European framework for the Austrian Raw Materials Plan. An important issue in the Raw Materials Plan is a well – thought out procedure for recycling raw materials from "urban" stocks. The Ministry of Economic Affairs attaches great importance to these raw materials, as being comparable to raw materials from primary deposits.

The present publication **Resource Use in Austria – Report 2011** is closely linked to the Europe 2020 Strategy. It presents the most recent data and findings from the fields of resource use and resource efficiency in Austria and thus provides an important basis both for the Austrian Resource Efficiency Action Plan (REAP) and for the Austrian Raw Materials Plan. The Lebensministerium and the Ministry of Economic Affairs jointly initiated the present publication and commissioned the Institute of Social Ecology (Alpen-Adria University, Klagenfurt, Vienna, Graz) and Statistics Austria with its preparation (project period July 2010 – April 2011).

1 The other two pillars are the securing of domestic deposits by means of land-use planning and the support bydomestic companies for foreign participation(s) in securing the supply of raw materials (internationalisation campaign).

In the context of a **project to improve statistical data on natural resources** (see page 16), the nationwide statistical collection of resource data on material flows was further optimised, to bring it up to the highest possible quality. For many years, Austria has made efforts to implement and further develop methods of accounting for environmentally relevant material flows. The tool applied in this context is called **Material Flow Accounting (MFA)**. As a module of Austrian environmental accounts (Lebensministerium et al. 2011 a), material flow accounts are published annually as a part of official statistics. This method of calculation which has been harmonized at the EU level, allows for comparable presentation of resource use and resource efficiency and has strongly gained in significance over the past few years. Improvements in the data sources for resource use as outlined in the present publication contribute significantly to further enhancing the high quality of data in Austria and allow for holistic analyses of the resource efficiency of the Austrian economy and its development over time.[2]

The objective of the publication, "Resource Use in Austria – Report 2011" is on the one hand to give concrete insights into the use and supply of natural resources in Austria, and on the other hand to outline the improved methods and data available in material flow analysis, in particular with regard to construction minerals. This publication addresses enterprises as well as stakeholders from the fields of politics, administration, and academia.

Structure and contents

The chapter **Natural Resources – the Foundation of our Society** describes which amounts of which resources we need, or have needed in the past, and which implications this usage has for the environment. Resources are defined and organisation of resource use as an exchange between society and nature is discussed. The chapter ends with a brief description of material flow analysis methodology. In the chapter **Resource Use in Austria**, patterns and trends are presented using results of material flow analysis. This encompasses resource extraction and resource use across the four material groups. Furthermore, imports and exports are discussed in particular and Austria's dependence on imports and the role of resource inputs into the production of traded goods are described. The chapter closes with a comparison of European countries in terms of their resource use. The following chapter, **The Four Groups of Materials – an Overview** (the four groups being biomass, fossil energy carriers, metals, and non-metallic minerals), provides detailed information about material flow data. The individual chapters deal with the specific role that the respective resource plays in economic production and social life as well as with socio-political questions associated with this. The chapter **Resource Use and Economic Development** addresses the question of whether a decoupling of resource use from economic growth can be observed in Austria. In conclusion, the final chapter, **Scenarios for the Future**, presents seven strategies for assessing resource use and resource efficiency until 2020 and partly, until 2050. The main section is followed by **three annexes:** Annex 1 provides detailed information on the concept, method and data sources of the material flow analysis. Annex 2 contains a glossary and Annex 3 provides comprehensive data tables on the results of the Austrian material flow analysis.

The Austrian Lebensministerium and the Austrian Ministry of Economic Affairs intend to continue their joint publication of further updated versions of "Resource Use in Austria – Report 2011" into the future and to supplement this with new priority themes in the fields of resource efficiency and security of raw materials supply.

2 The analyses in this present publication are, among others, based on scientific findings from the project "GLOMETRA – global metabolic transition" P21012-G11, subsidised by the Austrian Science Fund (FWF).

Key Terms

Provided below are explanations of a number of key terms that are useful for readers to understand this publication. For more detailed information, please see the relevant parts of the text or the glossary (Annex 2).

The term **natural resources** as used in this publication denotes raw materials for material or energetic use (referred to also as "materials" and "energy carriers") as well as water, air and land. These resources are either used directly by society or are processed for subsequent use. In the empirical analysis, this publication focuses on material resources, that is, on materials such as biomass, fossil energy carriers, metallic and non-metallic minerals as well as products derived from them that are traded.

The term **raw materials** is used in this publication for all resources obtained from nature. Accordingly, raw materials are unprocessed natural resources. The term 'raw material' can thus relate to materials, energy carriers, water or air, but not to land which, as such, is not extracted.

The term **materials** is used in this publication to refer to the material perspective of resources where the relevant statement cannot be applicable to all resources.

Materials are presented as material flows, expressed in tonnes per year, and are divided into four main groups:

Biomass encompasses the entire range of organic matter, that is: live plants, animals, micro-organisms, and also dead organic matter (dead wood, leaves, straw, etc.). Biomass is often referred to as a renewable raw material. It does not include the fossil energy carriers which have their origin in biomass.

Fossil energy carriers are minerals which have generated from the decomposition of plants or animals in the Earth's crust over millions of years and are primarily used for the production of energy.

Metals include mineral materials ranging from ores to processed metals. Raw material science defines ores as mineral materials from which metals can be extracted with economic benefit.

Non-metallic minerals comprise construction minerals and industrial minerals.**Construction minerals** are mineral raw materials, like sand and gravel, great amounts of which are required for construction. **Industrial minerals** are mineral raw materials which, due to their chemical or physical properties, can be directly employed in production processes. Industrial minerals do not include ores, construction minerals or raw materials for energy.

1 Natural Resources – Foundation of our Society

One Austrian uses ...[3]
66 kg material per day
470 MJ energy per day
240 l water per day
0.95 ha land per year

Table 1: Resource use of an Austrian
Source: Statistics Austria 2011 d, Statistics Austria 2011 c, Lebensministerium 2011, Erb et al. 2001

Natural resources are essential for our social existence. We eat and drink, use different means of transportation, sit at office desks and work on computers or practise agriculture. We live in heated rooms and ride our bicycles through the forests; we use sports halls for our fitness training, and pursue many other activities. For each of these, we use materials or water in one way or another, we consume energy and use land. In 2008, each Austrian used an average of 66 kg of materials per day (Statistics Austria 2011 d) and 470 megajoules of energy (Statistics Austria 2011 c) (this equates to the energy content of approximately 11 litres of oil). In addition, each Austrian used 240 litres of water per day (Lebensministerium 2011) and, for the provision of all resources and services consumed, made use of almost one hectare of land per year (Erb et al. 2001) (this equates to the area of a soccer field). In general, only a small portion of the natural resources (5 – 8 kg per day) is used by consumers directly. The greater part of the resources (nearly 90 %) is used in production processes or for infrastructure (roads, buildings, communication). In the case of products and commodities, this indirect resource use is called the "ecological rucksack" (Schmidt-Bleek 1994).

Resource use was not always at the high level it is today, but it has increased continually through the history of mankind's development. In about 1800 the average per capita daily resource use in Europe was still roughly 8 – 15 kg of materials and 150 megajoules of energy (Krausmann et al. 2008). In modern industrial societies, these figures are four to eight times higher.

Since the beginning of the 20th century in particular, the use of natural resources has increased rapidly. At present, about 60 billion tonnes of material are used annually (Krausmann et al. 2009), almost nine times as much as in 1900. After the two World Wars, industrialisation in large areas of the world and the use of fossil energy carriers drove the far-reaching establishment of a society characterised by mass production and consumption. Globalisation a has accelerated these processes in recent decades. Figure 1 illustrates the growth of domestic resource use in Austria, in relation to economic growth for the years from 1970 to 2008 (indexed presentation, 1970 = 100 %).

The development shows clearly that both economic value added and resource use continue to grow in Austria. Only the speed of growth is different. Energy use (measured as primary energy demand) and, even more markedly, material use, are growing more slowly than economic output.

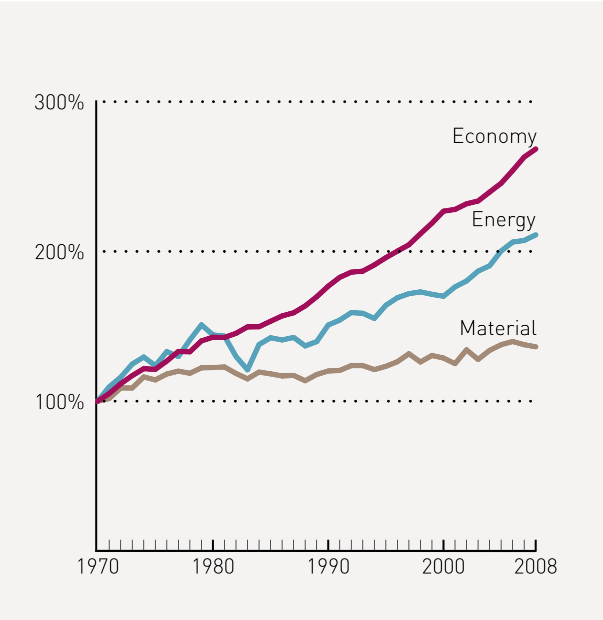


Figure 1: Development of resource use and gross domestic product in Austria from 1970 to 2008 (indexed presentation, 1970 = 100 %)
Source: "Economy" = gross domestic product (Havel et al. 2010), "Material" = domestic material consumption (DMC)[4] (Statistics Austria 2011 d), "Energy" = total primary energy supply (Statistics Austria 2011 c)

3 The figures in kilogrammes and megajoules refer to the entire social metabolism, which means that all inputs are counted either in terms of their mass or in energy units. The two figures are therefore based upon overlapping quantities: Fossil energy carriers or biomass used for energy are counted in the data in tonnes as well as in megajoules; other resources are counted only as materials or only as energy.

4 DMC is calculated from domestic extraction plus imports and minus exports.

In 2004, each of the world's ca. 6 billion inhabitants used 9 tonnes of material per year on global average (Krausmann et al. 2009). However, there are marked differences in the per capita resource use of individual countries: For example, the material use of India, a country with a low level of economic performance which is in the early phase of its industrial development, amounts to slightly less than 4 tonnes per capita and year. Compared to this, a Japanese person uses three times, a European four times, and an American almost seven times as much (see Fig. 2).

In most of the so-called 'developing countries', use is significantly below the global average, whereas in all industrialised countries it is far above. This divergence alone represents a significant source of tension for the near future. It is expected that, with continuing industrialisation, the resource use of those countries that are presently just beginning their industrial development will significantly rise and will aggravate the pressure on natural stocks.

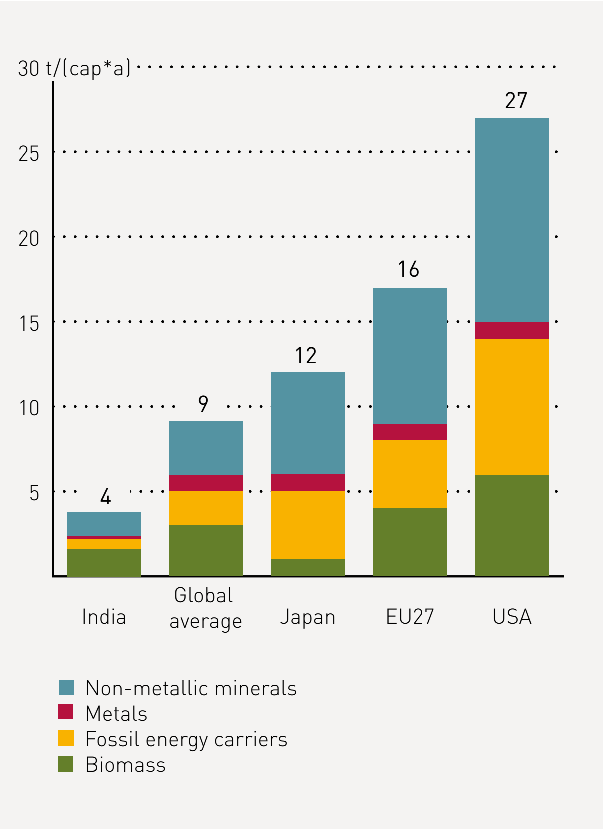


Figure 2: Resource consumption per capita, presented as domestic material consumption (DMC) in tonnes per year for 2004
Sources: India: Singh et al. 2011; global average: Krausmann et al. 2009; Japan: Ministry of the Environment 2007; EU-27: Eurostat 2009 b; Austria: Statistics Austria 2011 d; U.S.: Gierlinger and Krausmann 2011

A country's resource use thus depends to a great extent on its economic development. However, there are also great differences between individual industrialised countries: Japan's resource use, for example, is relatively low compared to the EU average, whereas that of the USA significantly exceeds it.

In addition to economic structure and consumption patterns, resource availability and foreign trade influence per capita use. Countries rich in raw materials typically exhibit higher levels of material use. An example is provided by Chile, the world's biggest copper producer. During copper extraction and the initial stages in processing the crude ore , great quantities of waste products, in particular large amounts of waste rock, remain in Chile and are counted as "material use" there, while only the concentrated ore is exported (Giljum 2004). In contrast, Japan, being a major importer of copper, has a relatively low per capita material use, as the upstream material flows in Chile are not taken into account for Japanese use. For this reason countries which import on a large scale usually present a lower domestic use level because the material-intensive stages of production are carried out elsewhere. This interrelation will be dealt with in greater detail in Chapter 2 (p. 18).

Increased resource use can lead to shortages and negative consequences for the environment

There are limits to the Earth upon which we live and to the natural resources it provides to us. We only have the natural resources that exist on and in the Earth, only the quantities of water flowing in natural and socioeconomic cycles, and the land area which spans the globe. Only in respect of solar energy is the Earth an open system: Energy derived from the sun, the basis of so-called 'renewable resources', is continuously supplied to the Earth, but the influx is limited and cannot be influenced. The use of renewable resources also always involves the use of non-renewable resources, for example in connection with the construction of relevant infrastructures (photovoltaic power stations, wind turbines, etc.). But also soils, which provide the foundation for biomass production, are not renewable on human temporal scales. Therefore renewable resources must also be used as carefully and efficiently as possible.

The increasing demand for raw materials and the growing extent of their extraction thus contrast with the Earth's limited resources. Society's growing metabolism[5] places the environment under stress through the exploitation or exhaustion of the available resources and through the excessive strain placed on nature and its capacity to absorb our waste. Exactly this dependency of society on natural resources and the stress exerted on ecosystems due to resource use are becoming increasingly noticeable: Water shortages and conflicts concerning access to water resources; soil degradation and the loss of productive agricultural land; climate change and global warming of the Earth's atmosphere; the destruction of rain forests for agricultural production; price explosions relating to food, petroleum, special metals etc. caused by real or artificially induced shortages; problems in the storage of toxic residues, etc. The list is long and a mounting number of reports on problems related to society's resource use is being produced. As the recent political developments in North African countries show, political crises in countries rich in raw materials also have impacts on access to and the prices of resources. The rising demand for resources of a continuously growing economy, higher consumer use and increasing population sizes lead us ever nearer to natural limits.

In Austria too, environmental and sustainability problems related to growing resource use are tangible. For example, we are observing a rising number of extreme weather events (for example floods) as well as the melting of domestic glaciers as consequences of global climate change and the intensive use of fossil energy carriers. Another example is the extraordinarily price of oil and gas or also wheat in 2008 and again during recent months. The increasing use of limited resources also creates more and more problems in global distribution and facilitates speculation. With its limited raw material deposits, Austria depends in many fields upon imports. This dependence is already causing trouble for many industries, in particular in conjunction with rising prices. The situation is similar throughout the entire European Union and has already led to political reactions (see for example European Commission 2008, 2011).

Resource use – what does it entail?

Societies extract raw materials from nature, transform and process them in order to benefit from their useable qualities (Krausmann et al. 2011). Once their use by society has ended, (waste) materials are released to nature again. The exchange process in its entirety is referred to as "social metabolism" (Fischer-Kowalski et al. 1997). Extractions from nature are mainly organised by agriculture and forestry as well as by mining; these sectors provide the basis for the subsequent production of material goods and services (Fettweis et al. 1987). Natural resources thus encompass raw materials for energetic or material use (ranging from crude oil, wheat and timber to copper or salt; often also referred to as materials and energy carriers or differentiated in terms of renewable and non-renewable resources), and water.

However, societies interact with their natural environment not only through exchange processes, but also rearrange natural systems in specific ways for their own purposes and maintain them in these changed states (Fischer-Kowalski and Haberl 1997). An example is agricultural land use. Land is therefore also considered to be a natural resource. Land use comprises cultivated areas for food production (agriculture), for forestry, or areas for infrastructure (roads or buildings). However, we also need areas beyond these types of use (e.g. protection zones) which maintain the functioning of ecosystems.

Resource use is reported in different physical units, for example as masses (tonnes), corresponding to their energy content (joules), or in units of volume or area. Depending on the unit applied, specific resources play a major or minor role. If we look at mass flows, construction minerals, such as sand and gravel, or biomass, such as timber, cereals or pastured grass prevail. However, measured by their energy content, these materials are of little account when compared to petroleum, natural gas or coal. Certain raw materials are suited both for material and for energetic purposes (for example timber or petroleum), whereas others have no usable energy content and are used exclusively as materials (construction minerals or almost all metals).

5 In the concept of society's metabolism (see also page 14 or Fischer-Kowalski et al. 1997) societies are understood as analogous to biological organisms: Societies have a "metabolism" (or exchange) with their natural environment, which means they take up natural resources and release waste and emissions into nature.

What are natural resources?

In this publication, the term 'resources' is used to denote all physical raw materials and stocks that are deliberately extracted or modified in nature by society for the purpose of generating economic value. The physical resources themselves are not lost through being utilised, but are changed in such a way that their specific useable quality is consumed and is thus no longer available.

The term "natural resources" refers to raw materials for material or energetic use (also designated as "materials" and "energy carriers"), water and air as well as land. These resources are utilised by society or enter the process of use in society where they are processed into derived products and then used. In the empirical analysis, this publication focuses on material resources, that is, on biomass, fossil energy carriers, metallic and non-metallic minerals.

The use of specific resources always entails the use of other resources. No material can be processed without the use of energy[6], water plays a major role in most processes (for refrigeration, in manufacturing processes or for irrigation in agriculture), and there is always a need for land from which raw materials can be extracted or for use as a site for infrastructures. The interrelation in terms of use between different types of resources is also evident in the statistical analysis (Steinberger et al. 2010).

Resources are extracted by society and, after having been used, become waste or emissions

A systemic approach to society's use of resources is based on the fact that all resources entering the system will at a later point in time have to leave the system again, either converted into waste or emissions or as export products (Kneese et al. 1970). In a closed system, resources can neither be created nor destroyed[7]. Parts of the inputs leave the socioeconomic system as outputs within one year, but a considerable portion of them (estimates range between 30 % and 80 %, cf. Kovanda et al. 2007) remains in the system as society's stocks. These include above all infrastructure and buildings, but also users durables like industrial machinery, household appliances or cars.

The direct physical relation between inputs and outputs plays a major role in the study and management of resource flows. For – as has been mentioned above – each input will at a later point in time become an output (waste or emission). In environmental policy, this approach has among other things caused a shift in the focus from waste and pollution towards resource inputs. This is because a change in inputs (quantity or composition) has a direct impact on society's outputs and, consequently, on the environmental pressure caused by waste and emissions.

Figure 3, below, is a schematic representation of flows between the natural system and society. With its

6 It should not be forgotten that the input of human or animal work is also a form of energy use!

7 In physics, this concept is referred to as the principle of mass conservation, which states that inputs equal outputs +/- change of stocks.

stocks, but also with its mode of functioning, the natural system serves as the basis of all socioeconomic activities. There are limits to our planet Earth, hence also to our natural resources, and there are limits to the strain ecosystems can cope with. Sustainable use should therefore not overstrain the natural system. To achieve the best possible quality of life for ourselves and for future generations, it is necessary to satisfy our needs in the most efficient, material- and energy-saving and environmentally compatible way possible.

If we look at the resource flows in society, the natural environment fulfils two fundamental functions: On the one hand it serves as a source of raw materials, like petroleum or cereals, which are extracted from nature and processed in society. On the other hand, the natural environment acts as a sink which must reduce the emissions and wastes generated by society (physical outputs) and return them to natural cycles or deposits. On the input side, problems in the relationship between society and nature (that is, problems of social metabolism) can arise due to resource shortages, ecosystem degradation, land shortages, etc. On the output side, waste and emissions as well as the partly high concentration of individual substances and the resulting toxic effect are an additional burden to the limited absorption capacity and exploitability of the natural system (Fischer-Kowalski et al. 1997, Ayres 1994). Environmental problems are thus a consequence of the quantity and quality of the exchange processes taking place between society and the natural system or result from the impact on and the changing of natural cycles. In other words: Social

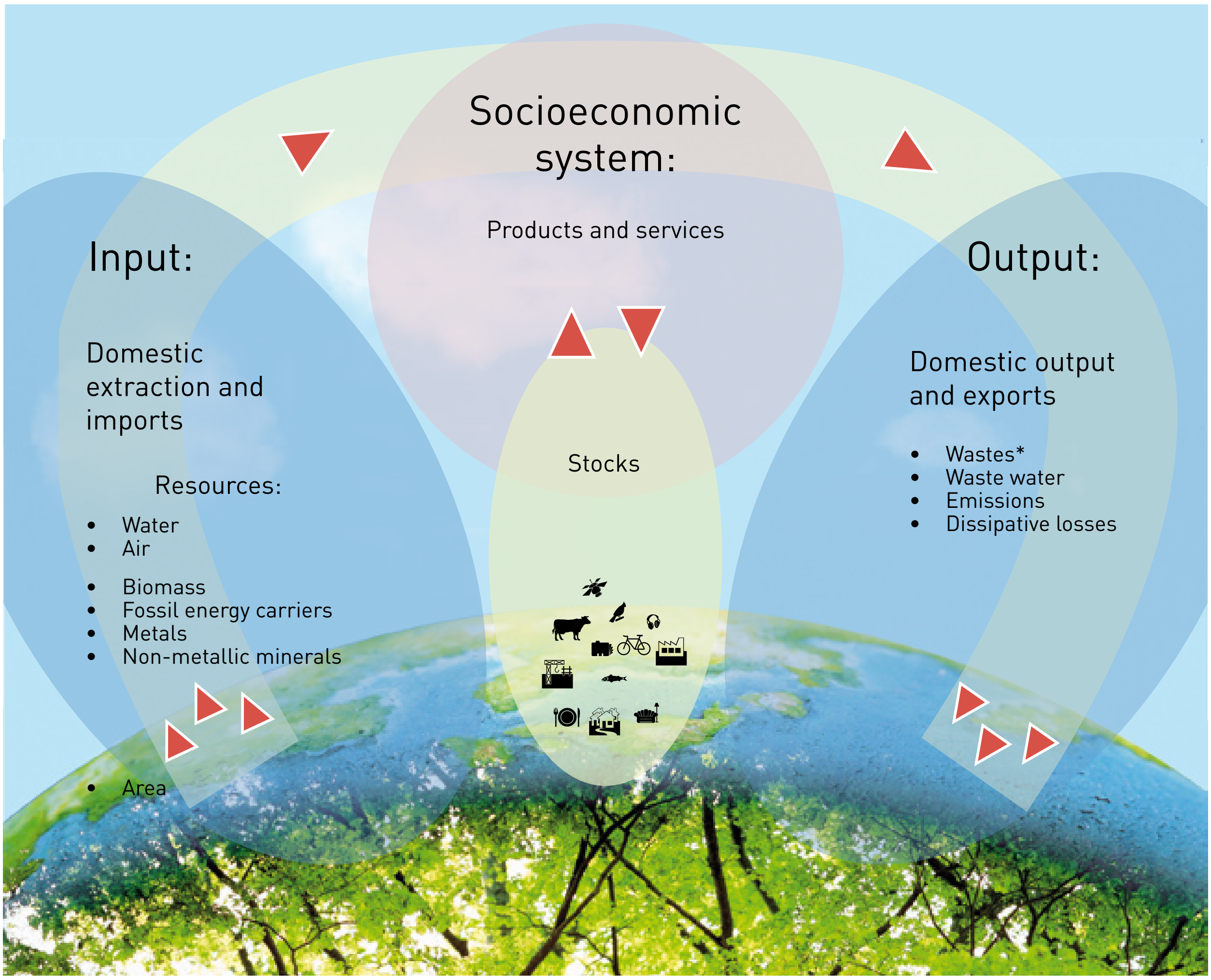


Figure 3: Resource use as an exchange between society and the environment

* Dissipative losses are also taken into account as output. Dissipative losses are unintentional outputs to nature which occur while a specific product is used. They include for example material losses from abrasion, corrosion, erosion or leakage. (Eurostat 2009 a: p. 105).

metabolism – that is, the amount of resources we extract from nature and the waste and emissions we leave to nature – changes our natural environment. Likewise also our direct interventions in nature, such as arable farming, desiccation or the sealing of land and many more, have impacts on ecosystems and change them fundamentally. But societies differ from each other in terms of culture, lifestyles and the technologies they apply. Equally, they differ in the form and extent of their exchange with nature, that is: in their social metabolism.

How are figures on the use of natural resources calculated? Environmental accounting and material flow analysis

To promote sustainable development, we need tools which allow us to observe and analyse society's resource use and its environmental impacts. For this purpose, **physical accounts** (European Commission and Eurostat 2011) have been developed which on an annual basis record all resource extractions and physical trade flows, the use of resources as well as the waste and emissions generated.

The concept of **social metabolism** (Fischer-Kowalski et at. 1997). provides the theoretical basis for the presentation of resource use by means of flow analyses. This is based upon the idea that, in analogy to a biological organism, society maintains a "metabolism" (or exchange) with its natural environment. Inputs (e.g. material, energy, water, air) from nature are used, converted, and partly integrated into society's stocks. Sooner or later all these inputs become outputs again, which society discharges to its environment in the form of waste or emissions. This metabolic process can be recorded in physical accounts.

The conceptual framework is provided by **environmental accounts** (Lebensministerium et al. 2011 a, European Commission and Eurostat 2011, U.N. et al. 2003). These illustrate the interactions between the economy and the environment and contribute environmental indicators to the **national accounts.**

One part of environmental accounting is the so-called **"Material Flow Accounting"** (MFA) (Eurostat 2001, Eurostat 2009 a). It reports all extractions of material in a country, the imports and exports as well as changes in stocks and, ultimately, the outputs to nature.

Figure 4, below, illustrates which flows are recorded by MFA. The socioeconomic system studied, the economy, is defined in analogy to the System of National Accounts (SNA); the boundaries to the natural environment and to other economies are set accordingly[8]. From the natural environment, resources extracted from domestic territory (domestic extraction, DE) enter the system as inputs; emissions and waste (domestic processed output, DPO) flow back to nature as outputs. Imports from other economies enter the system, and exports flow from the system into other economies. There are cases where the inputs are rather quickly converted into outputs again: Examples are the combustion of fossil energy carriers or the processing of imported material for subsequent export. However, there are also cases where materials remain in the socioeconomic system for a longer time (more than one year); they are – at least temporarily – incorporated into the stocks of the system.

All solid, gaseous and liquid materials (not including water and air) that cross the above-mentioned system boundaries within one year are counted as material flows in MFA. The unit of measurement is tonnes. There is a highly advanced and internationally harmonised methodology which can be used in compiling an MFA (Eurostat 2001, Eurostat 2009 a) to the development of which Austria made a decisive contribution.[9] A brief description of the MFA method and references to further technical literature (methods, results, analyses) are provided in Annex 1. In Austria, MFA is available as a time series from 1960 onward; each year the most recent data are added by the Austrian Federal Statistical Institute (Statistics Austria 2011 d).

8 In MFA, all persons and artefacts as well as the productive livestock (incl. fish in aquaculture) are by convention considered parts of the socioeconomic system (Eurostat 2001: 17). Artefacts include infrastructures, buildings, vehicles, machinery as well as durable consumer goods. Agricultural plants and forests are not considered part of the socioeconomic stocks.

9 Apart from its role in major international processes (EU/Eurostat, OECD, UN), MFA also has a long tradition in Austria itself. Its successful development and implementation was based on the close cooperation between politics (Lebensministerium), statistics (Statistics Austria) and science (Institute for Social Ecology – www.aau.at/socec, SERI – www.seri.at). MFA has formed an integral part of official Austrian statistics for many years.

MFA is predominantly based upon data sets from official statistics and uses estimates for the flows that are absent from or only insufficiently covered in the statistics (see Annex 3). Methods for the classification, aggregation and calculation of missing data have undergone significant advancement and harmonisation in recent years (Eurostat 2001 and Eurostat 2009 a). However, in analyses of MFA results and, above all, in international comparisons, the still ongoing developments and differences in the data quality must be taken into account. The data quality of MFA in Austria is relatively high in international comparison. Both the statistical data sources and the calculation methodology are highly developed. In Austria, for example, the method for estimating construction minerals has only recently been revised and improved in the context of the present publication (see description of data and methods in the annex or Milota et al. 2011), whereas in other countries construction minerals in particular are sometimes underrepresented in the data due to routinely inadequate statistical reporting.

Which resources are addressed in this publication?

In the present publication, resource use is discussed with a focus on "materials" and thus from a material perspective. Material flows (see Figure 4) are

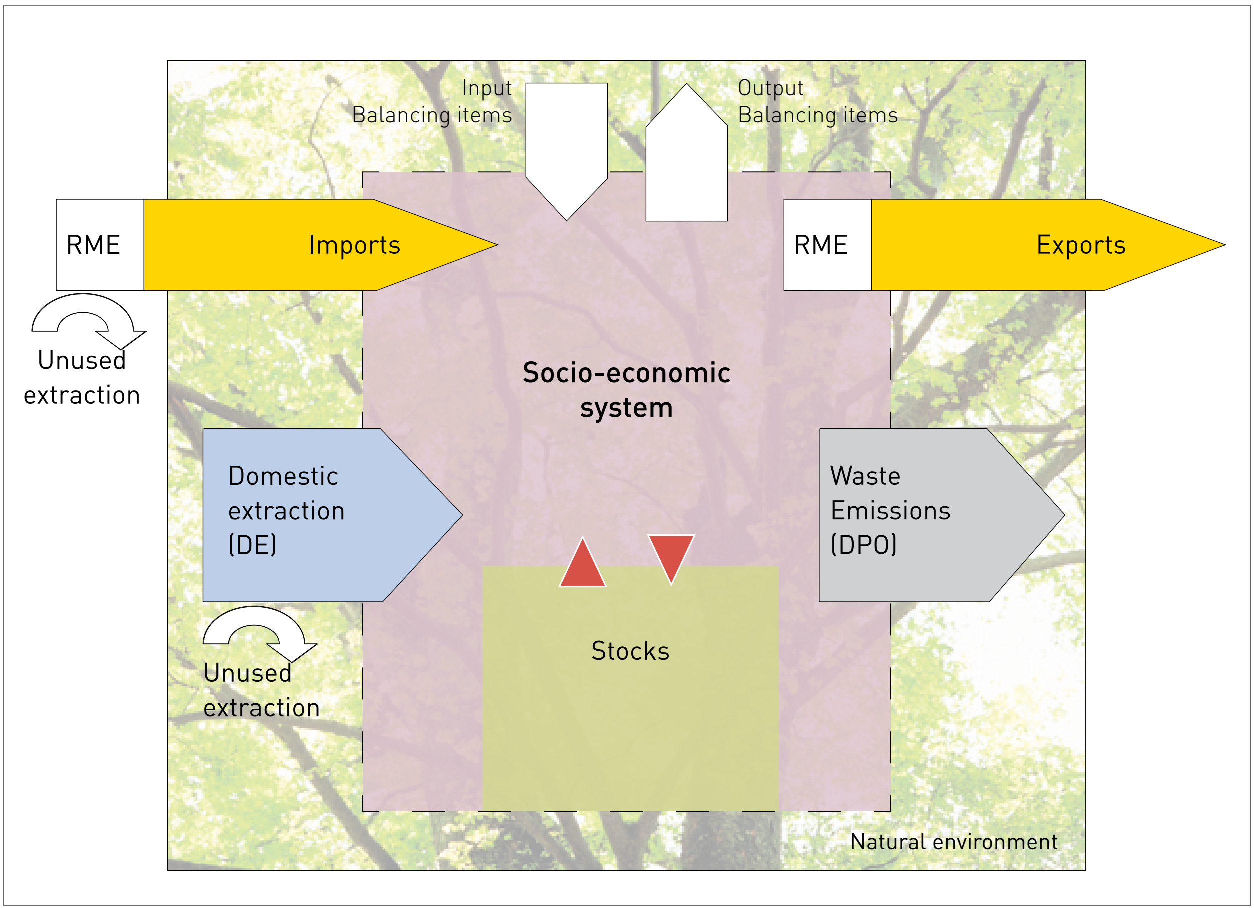


Figure 4: Schematic representation of material flow accounting (MFA)
Source: according to Eurostat 2001 and Eurostat 2009 a

MFA	**Material Flow Accounting and Analysis**
DE	Domestic Extraction
DPO	Domestic Processed Outputs
DMC	Domestic Material Consumption
RME	Raw Material Equivalents
RMC	Raw Material Consumption

Definitions and explanations are provided in the Annex from page 67 onward.

expressed in tonnes per year and across four main groups:

- Biomass
- Fossil energy carriers
- Metals
- Non-metallic minerals

Biomass comprises all resources of plant or animal origin that are extracted from the environment by humans or productive livestock. This includes agricultural production just as much as biomass taken up by grazing animals or products from fishing and hunting.

Metallic and non-metallic minerals are included in the MFA as mining raw production. Metals are recorded as crude ore. In the category of the non-metallic minerals, construction minerals prevail and they are therefore often addressed separately in the publication.

Fossil energy carriers are solid, liquid and gaseous mineral raw materials used for the generation of energy (e.g. brown coal and hard coal, petroleum, natural gas).

The following descriptions and analyses provide an overview of the domestic resource basis and of physical foreign trade. The interrelation between economic development and resource use is analysed and reflections on possible future development paths are presented.

Project "Improving statistical data in the field of natural resources"

This publication was initiated jointly by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (Lebensministerium) and the Austrian Federal Ministry of Economy, Family and Youth. In the framework of the above-mentioned project to improve statistical data in the field of natural resources (German original title: "Ressourcendaten – Verbesserung der statistischen Daten im Bereich natürlicher Ressourcen") Statistics Austria and the Institute of Social Ecology (Alpen-Adria University, Klagenfurt, Vienna, Graz) were charged with the further development of the MFA method in the field of the calculation of construction minerals. The revision of the calculation method was based upon a study of the Austrian Institute of Industrial Research IWI (Koller 2007). In the present publication, the newly revised data and other comprehensive data on resource use in Austria are published for the first time.

2

Resource Use in Austria

In Austria, mainly construction minerals and biomass are extracted from nature

In 2008 about 169 million tonnes of material were extracted in Austria in the mining, agriculture and forestry sectors. The largest share of this total was accounted for by construction minerals, which are used for the construction and maintenance of infrastructure and buildings in Austria. Somewhat more than a quarter of all domestic extraction was accounted for by biomass, that is mainly agricultural harvest and forestry production. Metals and fossil energy carriers made up only a very small portion of domestic extractions (each of them 1 % of total extraction).

Resource extraction (DE), Austria 2008, in million tonnes [10]	
Total	169
Biomass	44
Fossil energy carriers	2
Metals	2
Non-metallic minerals	120

Table 2: Resource extraction in Austria
Source: Statistics Austria 2011 d

However, the Austrian demand is not covered by domestic resources alone; a considerable amount is imported in addition. Especially in the case of fossil energy carriers and metals, Austria is dependent on imports. In 2008 alone, 28 million tonnes of fossil energy carriers, predominantly petroleum and natural gas, were imported, representing 30 % of all imported goods. The imports of metallic materials and commodities manufactured from them amounted to 20 million tonnes. As regards biomass, although Austria has access to large domestic stocks, nevertheless biomass-based goods are also imported: In 2008 these amounted to 22 million tonnes, which was a quarter of the total imported. Imported construction minerals amounted to only 11 million tonnes, being 12 % of total imports. Taking everything into account, 88 million tonnes were imported into Austria in 2008; this represents half the total domestic extraction. Although Austria's export flows remain below the imports in terms of quantity (exports amounted to 60 million tonnes in 2008), they play an essential role in the economy. Exported goods are largely more highly processed goods, which yield higher prices per weight than little processed basic materials do. The largest portion of Austria's exports is accounted for by commodities made of biomass (40 % of exports); another 25 % of exports are goods made of metallic raw materials.

Foreign trade Austria 2008 in million tonnes	Imports	Exports
Total	88	60
Biomass	22	23
Fossil energy carriers	28	6
Metals	20	15
Non-metallic minerals	11	9
Other products	6	8

Table 3: Foreign trade in Austria
Source: Statistics Austria 2011 d

In 2008 about 200 million tonnes of resources were used in Austria, that is 66 kilogrammes per capita and day

The domestic material consumption [11] comprises the quantity of resources which is used in production or consumption in Austria. In 2008, this resource consumption amounted to about 200 million tonnes.

As in the case of extraction, the non-metallic minerals (123 million tonnes, or 62 %) accounted for the biggest quantities, followed by biomass (43 million tonnes, 22 %). Austria used 25 million tonnes of fossil energy carriers (13 % of our resource use) and about 8 million tonnes of metals and metal-derived products (4 %). 86 % of the total use were covered by raw materials extracted in Austria, while the remaining part had to be imported from abroad.

Resource use (DMC), Austria 2008 in million tonnes	
Total	197
Biomass	43
Fossil energy carriers	25
Metals	8
Non-metallic minerals	123
Other (traded products and waste)	-2

Table 4: Resource use in Austria
Source: Statistics Austria 2011 d

10 Values have been rounded to whole millions; rounding differences have not been settled.
11 Domestic material consumption (DMC) = extraction + imports - exports

In 1960 Austria's resource use was only half as high

50 years ago, markedly smaller amounts of resources were used in Austria than today: In 1960, the resource use amounted to 114 million tonnes, of which 105 milion tonnes were extracted in Austria. Extraction – comprising the agricultural harvest, the quantity of timber felled and the production from mining – was thus only half that of today; nevertheless domestic extractions covered 92 % of the resource use at that time. In comparison with this, imports and exports played a minor role: 16 million tonnes were imported and 7 million tonnes were exported. In addition, the composition of resource use has changed: At the beginning of the 1960s, construction minerals dominated the material turnover as is the case today, but the share of biomass-based materials in total use, at slightly above 30 %, was significantly higher than it is today .

A driving force for growth in the 1960s: The development of consumer society and infrastructure

Figure 5 shows that the increase in resource use was most marked between 1960 and 1975. During this period of economic upswing, modern transport infrastructure was created and extended and the consumer society established itself as the standard model for modern society. During this period, the use of construction minerals, ores and fossil energy carriers in particular rose significantly. These resources were on the one hand incorporated into infrastructure and consumer goods and on the other hand, fossil energy carriers were used in the operation of modern industrial technology and of the consumer goods themselves (electrical appliances or cars). From the mid-1970s, around the time of the oil price crisis, the period of strong growth ended and resource use stabilised at a high level. At the beginning of the new millennium, as a consequence of increasing globalisation, Austria is again experiencing dynamic growth and significantly rising resource use. For the first time, this period of growth is also leading to a significant increase in the use of biomass-based resources again.

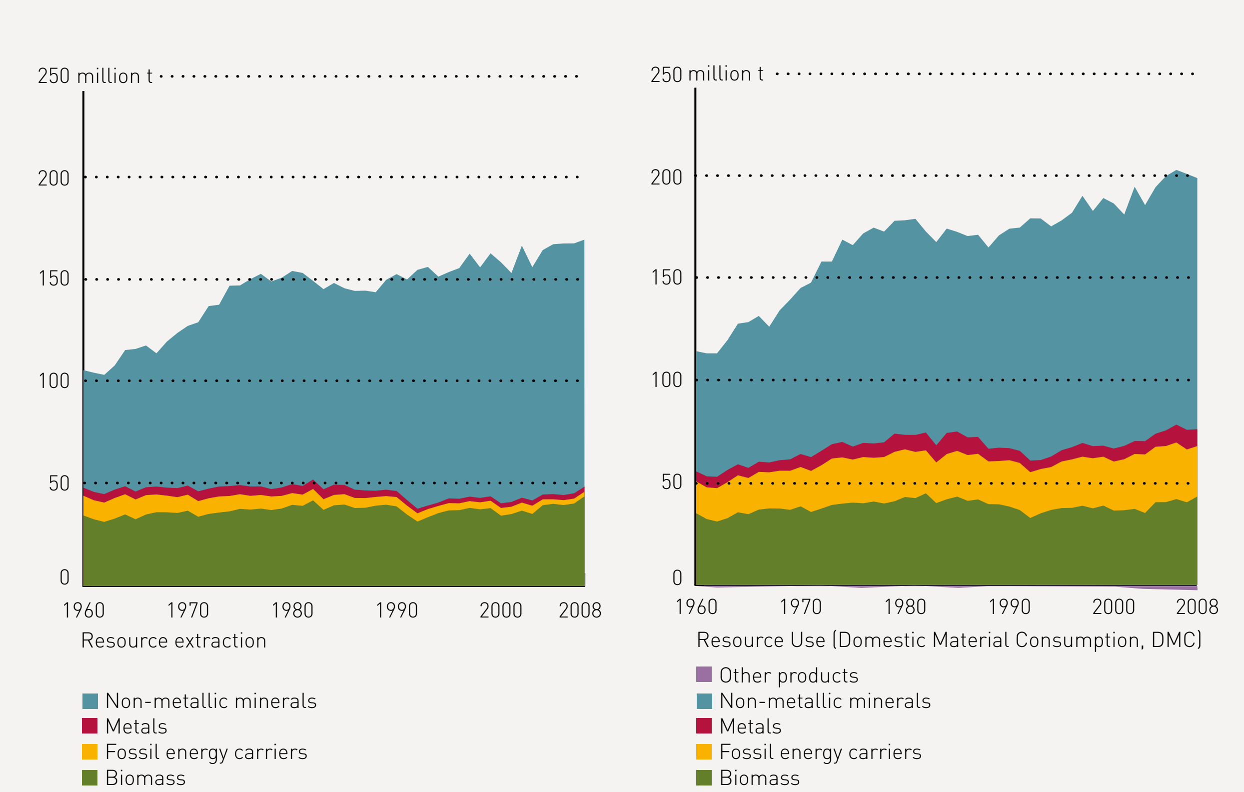


Figure 5: Resource extraction and resource use in Austria in million tonnes, from 1960 to 2008.
Source: Statistics Austria 2011 d

Internationalisation and global interconnections – the important role of foreign trade

Trade flows in particular are seeing a rapid development. Growth rates of 500–700 %[12] for the imports/exports of 2008 in comparison to 1960 have produced a situation in which imports and exports today play an important role in Austrian resource use. The rapidly rising trade figures reflect, among other things, the growing globalisation of the economy over the past few decades and of Austria's integration into the European Union.

Over the past 50 years, imports rose approximately six-fold and, in 2008, amounted to about 88 million tonnes (Figure 6). In 2008 primarily goods produced from fossil energy carriers (30 %), metals (23 %) and biomass (25 %) were imported. The export volume rose eight-fold during the same period, amounting to 60 million tonnes in 2008. The major exported goods were biomass-based commodities (40 %) and products made of metallic raw materials (24 %).

There is a special aspect to foreign trade: Foreign trade statistics record imports and exports both in physical units and in terms of their monetary value. As the products traded encompass commodities of a very different vertical range of manufacture (from the primary product to the finished product), it should be pointed out that there is a fundamental difference between the physical content and the monetary value of commercial products: Basic materials are large masses with low prices, whereas finished products are of low weight but achieve higher prices (see also Fischer-Kowalski and Amann 2001). This becomes evident when we look at the trade balances in physical or monetary units (see Figure 7). The major part of the physical imports and exports is accounted for by biomass, non-metallic minerals and fossil energy carriers. When represented in terms of monetary value, the share of these material groups is markedly lower. This means that these material groups comprise commodities which are traded in large quantities, but at relatively low prices. In contrast, metals and goods derived from metals are traded in smaller

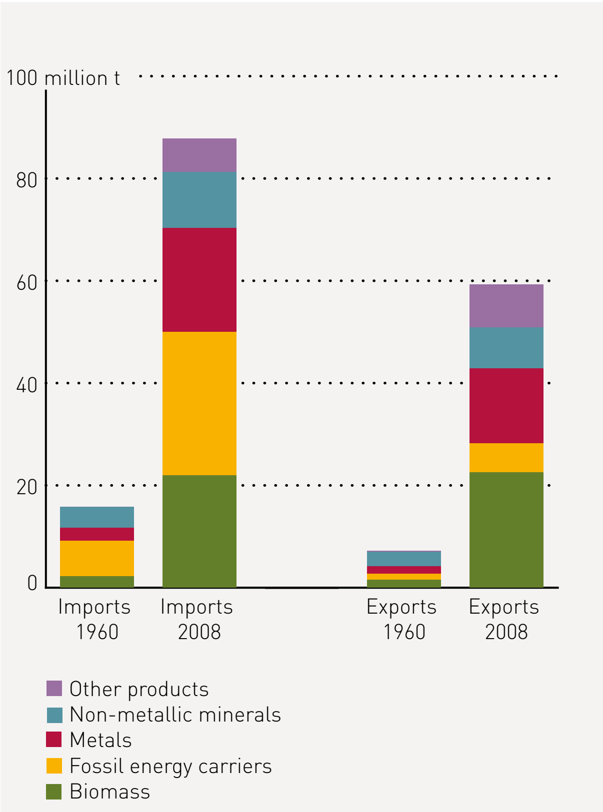


Figure 6: Austrian foreign trade flows in 1960 and 2008, in million tonnes
Source: Statistics Austria 2011 d

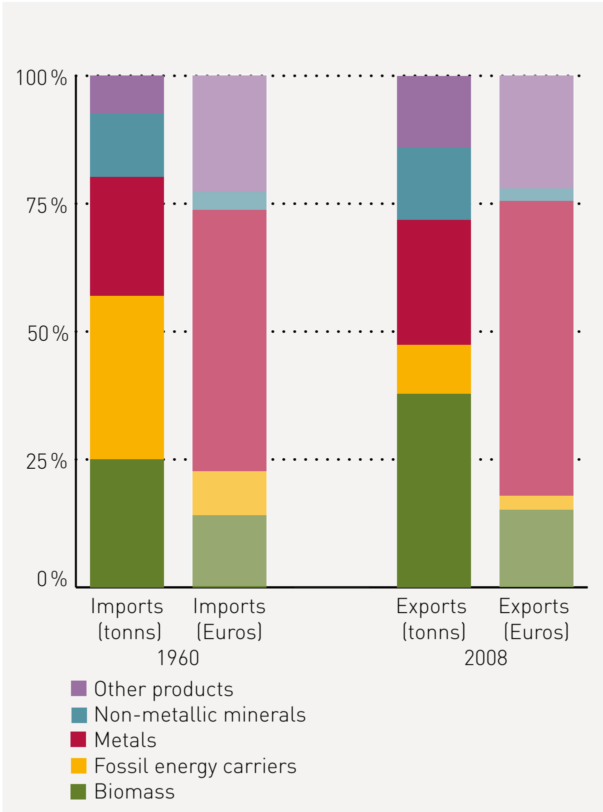


Figure 7: Imports and exports in physical and monetary units as shares in the total value, Austria 2008
Source: Statistics Austria 2011 d

12 When looking at the dynamics of this development, the fact that growth figures are very high in cases where the total amounts are rather small must be taken into account.

quantities, but at higher prices: Their shares in the monetary trade flows are therefore significantly higher than those in the physical trade flows.

Austria needs large quantities of imports both for its own use and for export products

Like many other industrialised countries, Austria imports far more goods than it exports and is thus strongly dependent on resource imports. This is obvious from the physical trade balance (= imports minus exports), which is positive for almost all material groups. Other than extraction or consumption, trade flows are dominated by fossil energy carriers (2008: 80 % of the net imports) and metals (2008: 20 % of the net imports). Fossil energy carriers are imported to guarantee Austria's energy supply. Hardly any fossil energy carriers are exported. Metallic commodities again are imported in large quantities, processed in Austria, and then exported again in the form of more highly processed products.

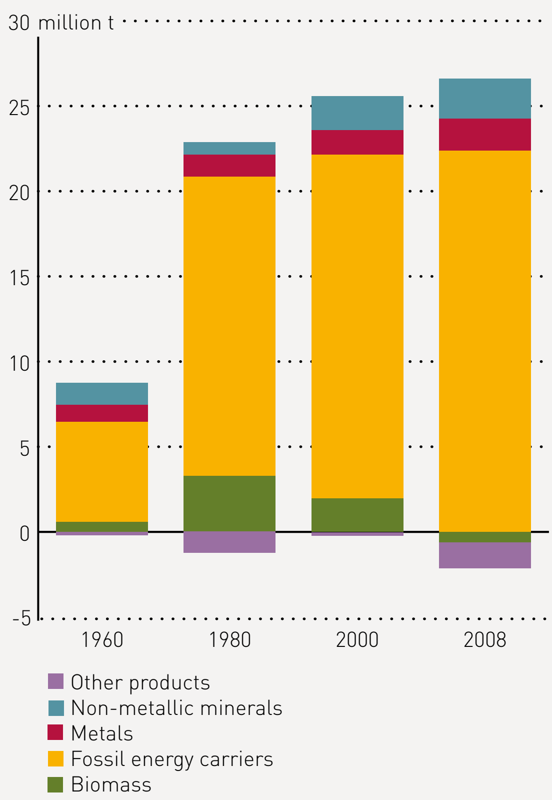


Figure 8: The Physical Trade Balance for Austria (imports minus exports) in million tonnes
Source: Statistics Austria 2011 d

Figure 8 illustrates the development of the physical trade balance since 1960 for four selected years. What is particularly striking is the marked preponderance of imports in the case of fossil energy carriers: In 1960, the imports of fossil energy carriers exceeded the exports by approximately six million tonnes. In 2008, they were already almost four times as high (more than 22 million tonnes). A different development was observed for the imports and exports of biomass: Until the year 2000, the imports were higher than the exports; after that, a slight export surplus began to appear (presented as a negative value in the Figure). This reflects among other things the targeted support for agricultural and forestry exports. The category of "Other products" also exhibited a negative trade balance in 2008. This group includes all highly processed commodities that cannot be clearly assigned to any of the material categories, such as, for example, electrical appliances, furniture, or pharmaceutical products. The Physical Trade Balance in the form presented above is therefore characteristic of an industrialised economy: Minimally processed basic materials and semi-finished products are imported and highly-processed goods and finished products are exported.

Import dependency and its impacts on rising resource scarcity

Imports grant Austria access to resources that are not, or no longer at sufficient quantities, available in the country itself. At the same time, however, this import orientation also means dependency on international markets. Shortages due to growing global demand, competitive distortions resulting for example from speculation activities, political tensions and their implications for availability lead to a rise in international prices and endanger supply security. Many of these mechanisms could be observed during the global food crisis of 2008: Due to extreme weather events, very poor harvests were suffered in some major exporting countries. At the same time, the increasing production of biofuels drove high demand for certain arable crops. Combined with rising oil prices, these two trends led to a significant rise in the international prices of many basic foodstuffs, to food shortages and price increases in developing and emerging economies, like Mexico, which are strongly dependent on food imports. The example of the foodstuff crisis demonstrates how scarcity can develop both absolutely (harvest loss, exhaustion of stocks) and relatively (high prices, production control) and can have significant consequences at the global level.

In Austria, for example, the greater part of iron ores, important raw materials for Austria's highly-developed steel industry, have to be imported. Even now, the clearly limited availability as well as the significantly higher raw material prices for iron ore and the raw materials needed for steel production, such as coking coal and steel stabilisers, create serious problems for domestic enterprises. Bottlenecks in supply can cause real domino effects which affect not only the steel industry but also all the economic sectors that depend upon the supply of domestic steel.

Austria's dependency on imports is particularly marked for products made of metallic raw materials and for fossil energy carriers. In 2008, these materials were for the greater part (about 90 % each) imported from abroad. In contrast, the biomass processed in Austria still came largely from domestic sources (import dependence 33 %); for non-metallic minerals, domestic production covered 90 % of the Austrian demand (import dependence 8 %). By contrast, in 1960 all resources were still largely extracted in Austria (see Figure 9). This means the dependence on resources from abroad has increased continuously recent decades. This development is a consequence of globalisation and the stronger differentation in the international division of labour.

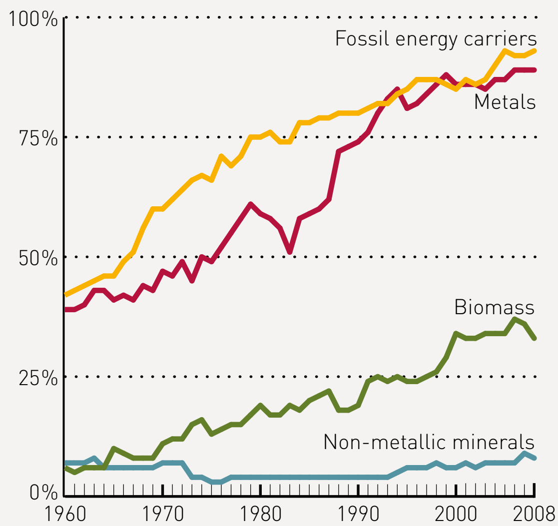


Figure 9: Share of imports in Austrian resource needs (shares of the quantities, expressed in tonnes)
Source: Statistics Austria 2011 d

International trade and the intermediate inputs of material involved in imports and exports

Where domestic material consumption is concerned, imports and exports play an ever more important role. Basic materials required for Austrian production are imported just as more highly processed goods are. At the same time, the volume of the commodities exported is also increasing. Globally, this is leading to a greater splitting of the production process and also to a more pronounced spatial distribution of the individual production steps. So when calculating and analysing resource use we have to take into account the intermediate inputs of the material and energy which is involved in the production of both the imported and exported goods: the indirect resource flows which are not directly part of the imported goods, but were used in other countries in the course of their production.

Intermediate inputs – the example of aluminium

The importance of indirect resource flows will be illustrated by the example of the production of an aluminium beverage can: The aluminium is produced from aluminium ore (bauxite) in a two-step process. First, the raw material bauxite is processed into alumina by means of a chemical reaction with caustic soda solution (Bayer process) which, by means of fused-salt electrolysis is converted into metallic aluminium. Bauxite has an aluminium content of approximately 25 %. This means that four to five tonnes of bauxite are required to produce one tonne of aluminium; the remaining three to four tonnes of barren material are waste, including so-called red mud. This, however, may also contain other raw materials. In the case of aluminium, the gallium that is naturally concentrated in bauxite can be extracted as a by-product. During the refining process,other materials are also used which are taken into account as intermediate inputs, among them limestone for the production of alumina, coal for electrolysis, etc.

After that, the refined aluminium enters the aluminium can production stage. At this point, for example, cutting losses occur and a great number of other materials are used (lubricants, varnishes, water, etc.). In addition, raw materials for energy[13] and built infrastructure (buildings, roads) as well as machinery are used to convert the raw material into the final product. All this is taken into account in the intermediate inputs of material and energy. The sum of all raw materials used to produce an aluminium can from natural bauxite (not from recycled aluminium) is 21 times as high as the raw material input (Source: Institute of Social Ecology – authors' own calculations based on Eco-Institute 2009). This means that 21 tonnes of raw material are used to produce one tonne of aluminium cans.

Along the production chain, a range of material resources, are used (intermediate inputs) which are transformed into waste and emissions. When Austria imports a ready-for-use aluminium beverage can, a calculation of the total resource use has to take into account the indirect flows (intermediate inputs) which are needed to produce the beverage can and which remain in the country of production as waste materials.

Raw material consumption calculates the use of resources including the intermediate inputs

So if we want to say something about a country's total resource use and its final consumption, the aggregate intermediate inputs has to be recorded and assigned to the final consumption of the importing countries. Only in this way is it possible to calculate the total raw material expenses of a country that should be attributed to that country's final consumption. The MFA summarises the intermediate inputs of materials involved in imports and exports as raw material equivalents (RME). When the RME is added to the domestic material consumption, one obtains the raw material consumption (RMC) of a society, including the indirect flows. Put differently: Raw material consumption comprises all the raw materials that were extracted and used on national and global level to manufacture the products consumed by all Austrians. Due to the growing importance of foreign trade, the European Union is presently intensifying its efforts to also give consideration to these indirect flows and to close the existing data gaps for the calculation of the raw material equivalents.

For Austria, the RMC – that is, resource use including the indirectly used resource flows (intermediate inputs) – was calculated for three years (1995, 2000 and 2005) (Schaffartzik et al. 2011). A brief summary of the results follows, although the empirical findings are not discussed in detail.

Austria outsources resource use to other countries

As with other importing countries, raw material consumption (RMC) – that is, the sum of all resources used, including intermediate inputs –, in Austria also far exceeds direct material consumption (DMC), which does not take account of intermediate inputs. An estimate for 2005 (Schaffartzik et al. 2011) demonstrates that in order to cover Austria's resource use, an additional 35 million tonnes of resources per year are used abroad as intermediate inputs. If all resources used are taken into account, an Austrian requires

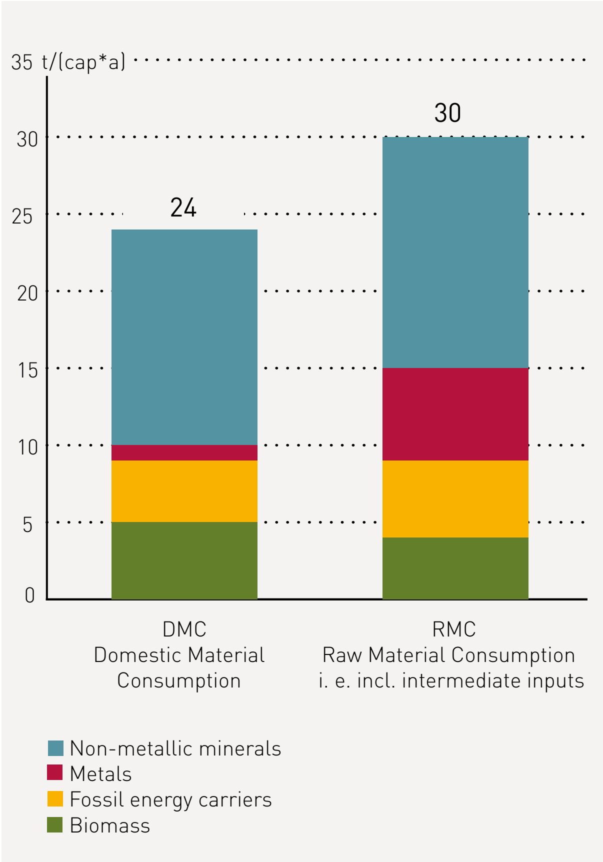


Figure 10: Resource use in Austria, 2005, in tonnes per capita – with and without consideration of the intermediate inputs involved in imports and exports
Source: Schaffartzik et al. 2011

13 The specific energy required to produce primary aluminium from bauxite amounts to about 160 – 240 MJ/kg. The production of secondary aluminium (based on scrap) requires 12 – 20 MJ/kg (Czichos and Hennecke 2008).

about 30 tonnes per person per year, or approx. 80 kilogrammes per day; this is 25 % more than the domestic material consumption, which does not consider material intermediate inputs and amounts to only 24 tonnes per year or 66 kilogrammes per day.

Taking intermediate inputs into account increases the domestic material consumption of metallic commodities (almost five times the DMC) and of fossil energy carriers (50 % higher than the DMC) in particular. In contrast to metallic commodities and fossil energy carriers, the use of non-metallic minerals changes only marginally when intermediate inputs are considered. The use of biomass is actually lower in RMC than in DMC. This is above all a consequence of Austria's high level of biomass exports (especially of animal products requiring intensive intermediate inputs). In 2005, biomass and products made of biomass accounted for over 40 % of Austria's exports and hence constituted the biggest physical export flow by far.

Through imports, industrialised countries like Austria thus outsource a considerable portion of the resource use relating to their consumption (and of the resulting environmental impact) to the producer countries[14]. It is therefore crucial to take into account also the intermediate inputs of foreign trade when assessing global resource use and a country's individual contribution to it.

Unused extraction

In an extended MFA, unused extraction is also calculated. Unused extraction encompasses all materials that are extracted from or moved in nature by means of technology without the intention of using them in the socioeconomic system or of attributing economic value to them. Examples of unused extraction are soil and rock excavated during the construction of infrastructure, overburden from mining, crop residues in agriculture, the by-catch in fishery, etc. (Eurostat 2001; Bringezu, Bleischwitz 2009; Aachener Stiftung Kathy Beys 2011).

Considering unused extraction, the following indicators can be derived in the MFA:

Total Material Requirement (TMR) comprises domestic extraction, including unused extraction, as well as the imported goods, including their intermediate inputs of materials and the unused extraction involved.
Total Material Consumption (TMC) is calculated from the TMR less exported goods and their intermediate inputs (used and unused extraction).

14 Thus securing resource supply depends upon the economical use of imported raw materials and products. In order to prevent supply shortages caused by abrupt restrictions of supply, domestic resource extraction may be relied upon, where possible. It should be taken into account, however, that in the case of abiotic resources there may be a certain time lag between searching for raw materials and their actual extraction. We know from experience that in mining, for example, up to ten years may pass until full operation commences.

Who requires which resources? Use by sector

So far, this chapter has addressed the national economy as a whole. The following text places the focus on the resource use within the Austrian economy. First, the demand and use of individual sectors will be analysed. In 2005, the direct material input (that is, domestic extraction plus imports) of the five major sectors amounted to more than 158 million tonnes; this already accounts for roughly three-quarters of Austria's total material input.

The five sectors concerned are on the one hand the four primary sectors in which Austria's domestic extraction takes place: quarrying for stones and extraction of earths; agriculture and hunting; the extraction of oil and natural gas; and forestry.

The fifth sector, on the other hand, is the construction sector, which is also involved in the direct extraction of significant resource quantities. In 2005, the highest material use, at somewhat more than 45 million tonnes, related to for the extraction of stones and earths, closely followed by the construction sector (approx. 44 million tonnes).

If, in addition to the five above-mentioned sectors, the production sector, which comprises the manufacturing of commodities from different basic materials (and construction, already mentioned above) is also taken into account, this almost covers the total material input. In terms of the four material categories, this means that: Biomass is used above all in agriculture and hunting as well as in the production of biomass-based products like wood products, food, paper, products from rubber and leather, tobacco, and in fishery. The biggest material use of fossil

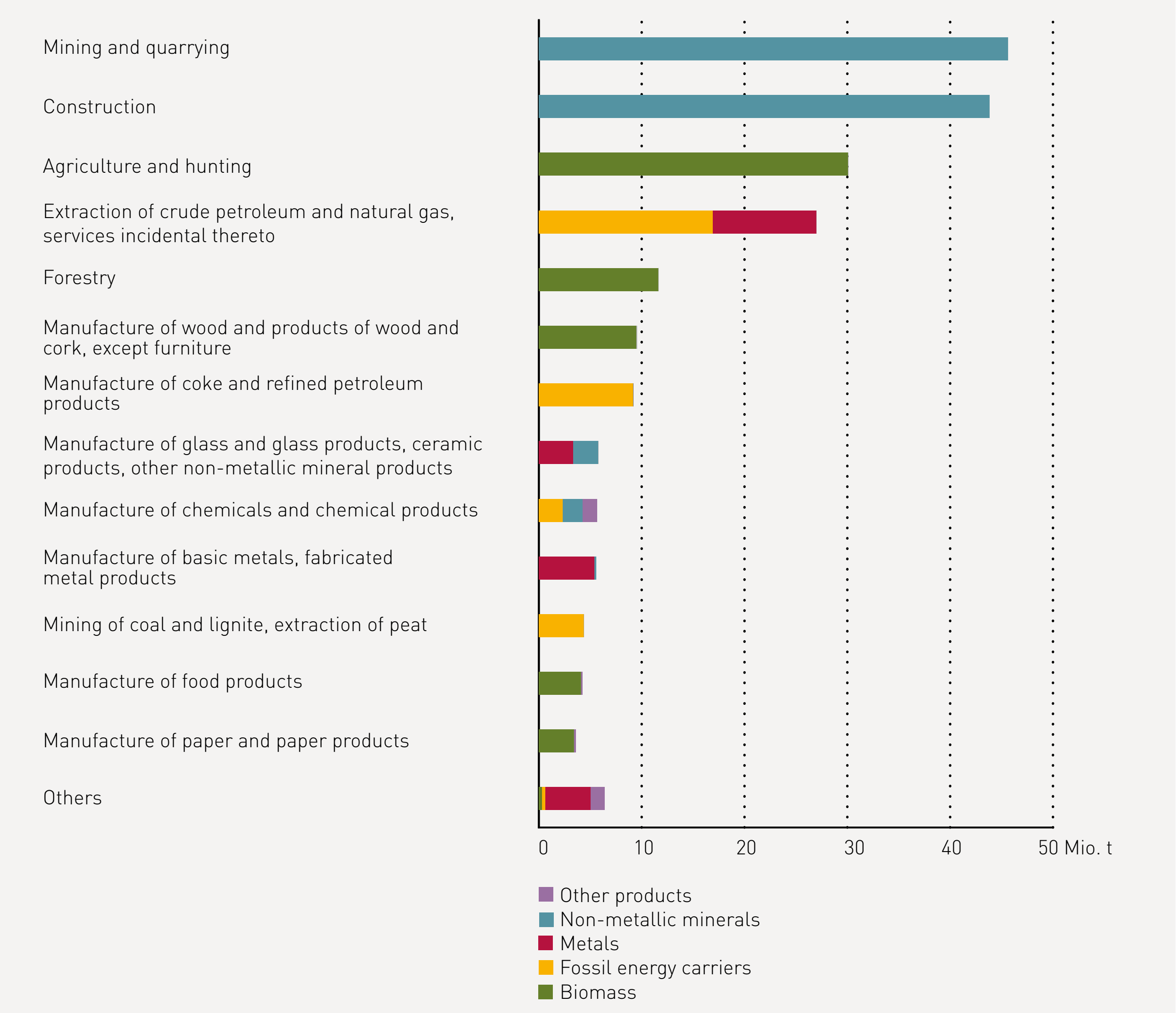


Figure 11: Material use in million tonnes by sector, Austria 2005
Source: Schaffartzik et al. 2011

energy carriers can be attributed to the sectors producing oil, natural gas and coal and to the manufacturing sectors in which fossil energy carriers are used for energy generation.

In addition, fossil energy carriers are used in the production of chemical and plastic products, where material use is also of relevance. Metals are used in the mining sectors and in the further processing of metals as well as in the production of cars and other vehicles, of other metal products, machinery and instruments (e.g. in the generation of electricity, in broadcasting equipment, data processing and the production of measuring and control instruments). The material use of non-metallic minerals occurs primarily in the mining and construction sectors. Non-metallic minerals are also used as auxiliary materials in the production of glass and ceramic products, of chemical products, and in the production and processing of metals.

Most of the materials used in Austria are used for industrial production. Consumption by private households is less important in material terms, but nonetheless becomes relevant when we look at the energy balance. In 2009, one quarter of the final energy use in Austria took place in households, another 35 % in transport, and 30 % in production. Services (10 %) and agriculture (2 %) are of negligible importance in energetic terms (Statistics Austria 2011 b).

Resource use by society can also be examined in terms of activities or areas of need. In this context, housing, transport and nutrition are generally regarded as the three areas characterised by the highest resource use or the most significant environment impacts (e.g. CO_2 emissions). At present, no analysis of this topic in greater detail is available for Austria.

Per capita use – Austria in European comparison

In 2008, the average per capita resource use (not including the intermediate inputs of the imports and exports) of individual Austrians amounted to 24 tonnes per capita. The average use in the European Union (EU-27) amounts to 16 tonnes per capita and is thus about one-third lower.

Austria's resource use is above the EU average in two material groups in particular: biomass and non-metallic minerals. In the case of biomass, the high resource use results above all from the comparatively great importance of animal farming. Being a country dominated by grassland, the number of livestock per person is higher than in other EU countries. As a consequence, the us of green fodder and other feed is also high. Forestry in Austria is also an important sector, with a higher production volume than that of other EU Member States.

The high use of construction raw materials reflects the climate and terrain of Austria as an Alpine country, which necessitates material-intensive construction methods both for buildings (e.g. thermal insulation) and for roads and other transport infrastructure (e.g. higher requirements relating to temperature fluctuations). Finally, also the comparatively low population density contributes to the high per capita demand for built infrastructure. A comprehensive network of infrastructure, less densely built-up residential areas, a higher number of detached single-family homes, large rural areas, and less urban agglomerations, etc. are factors that raise in particular the use of non-metallic minerals to a level exceeding that of more densely settled countries.

However, we would like to emphasise in this connection that a comparison between countries is always also strongly influenced by the quality of data. In the case of MFA data too, there are variations in data quality, which are particularly reflected in the volume of flows recorded, but also in the methods applied for the revision of data problems. Differences in data recording must therefore be taken into account as an additional factor during data analysis. The data quality of Austrian MFA is relatively high. Both the statistical data sources and the calculation methodology are very highly developed. This is particularly relevant for construction minerals, which are usually rather inadequately recorded in statistical reports. In Austria, the methods for estimating construction minerals are highly developed (see the description of data and methods in Annexes 1, 2 and 3); in other countries, by contrast, data on these materials involve underrepresentation in some cases.

A Finn requires 39 t per capita, a Lithuanian only 10 t per capita. Why are the differences so significant?

The level of material use in the individual EU Member States (see Figure 12) varies widely, and it also varies widely in all material groups. This shows how many different factors are of relevance in this field: Income (BIP per capita) is a crucial driving force in resource use: The higher a country's GDP is, the higher is usually its per capita resource use. However, economic performance does not explain all such differences. Because of its impact on infrastructure or on the types of settlements and the utilisation density of urban agglomerations, population density also plays an important role. Furthermore, endowment with natural resources – whether countries possess resources themselves and whether or not they can sell considerable amounts of raw materials on the global market – is a key factor. Due to the large amounts of material accrued in primary production, resource-rich, export-oriented countries tend to have a very high level of resource use. In contrast, countries with low endowments of resources depend on imports, which in most cases leads to a relatively low material use (DMC) in the home country – a consequence of the fact that indirect flows are not taken into account. Apart from import and export orientation, the further specialisation on specific economic sectors (agricultural or forestry production, mining, metal-working industry, oil production and refining, etc.) also influences the structure and composition of material use across the four material groups (see Chapter 3). Therefore all these factors have to be taken into account when interpreting the relative volume of resource use in a particular country.

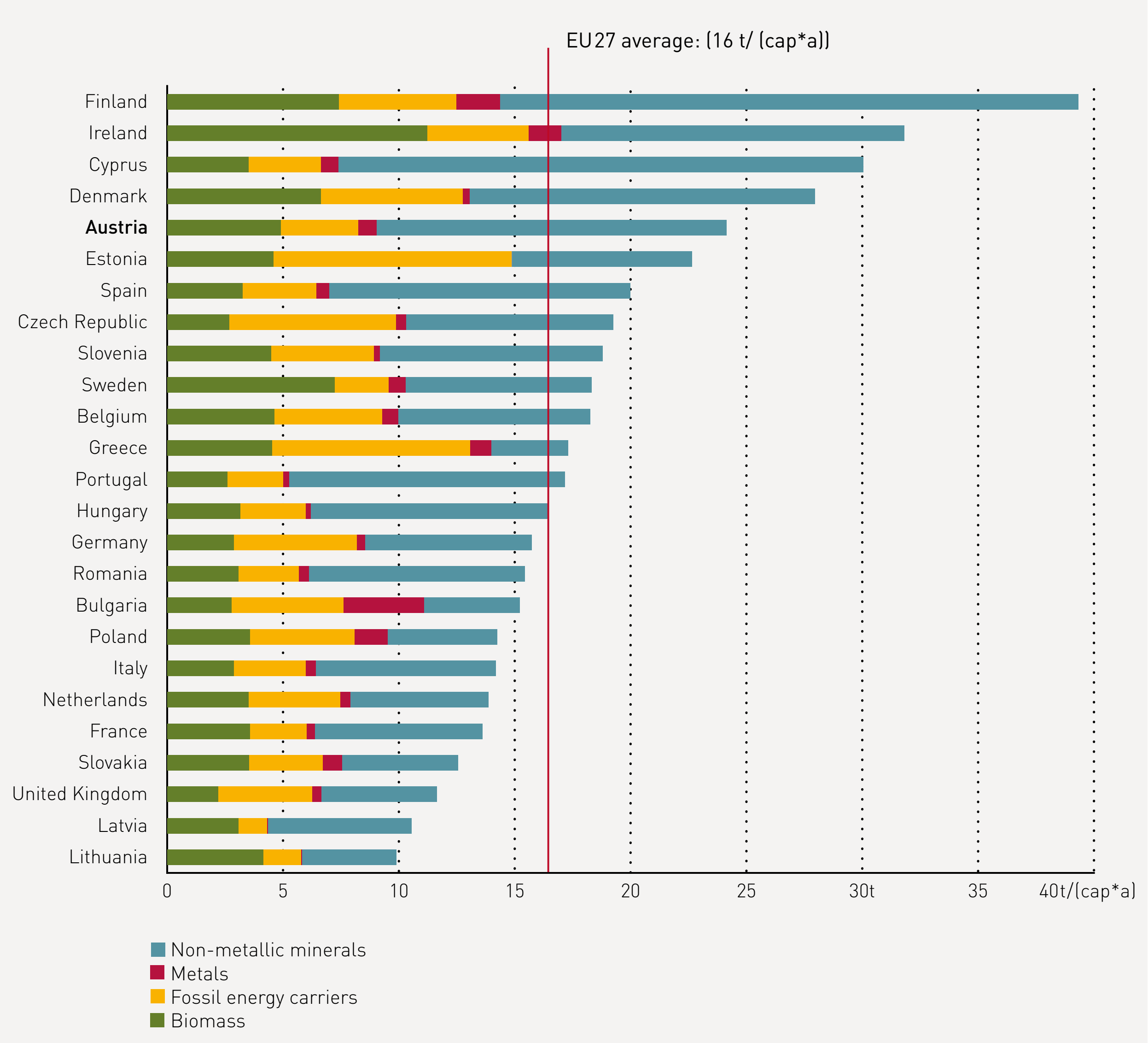


Figure 12: Austria's resource use in comparison with other European countries[15], 2005
Source: Calculated by the authors based on Eurostat 2009 b

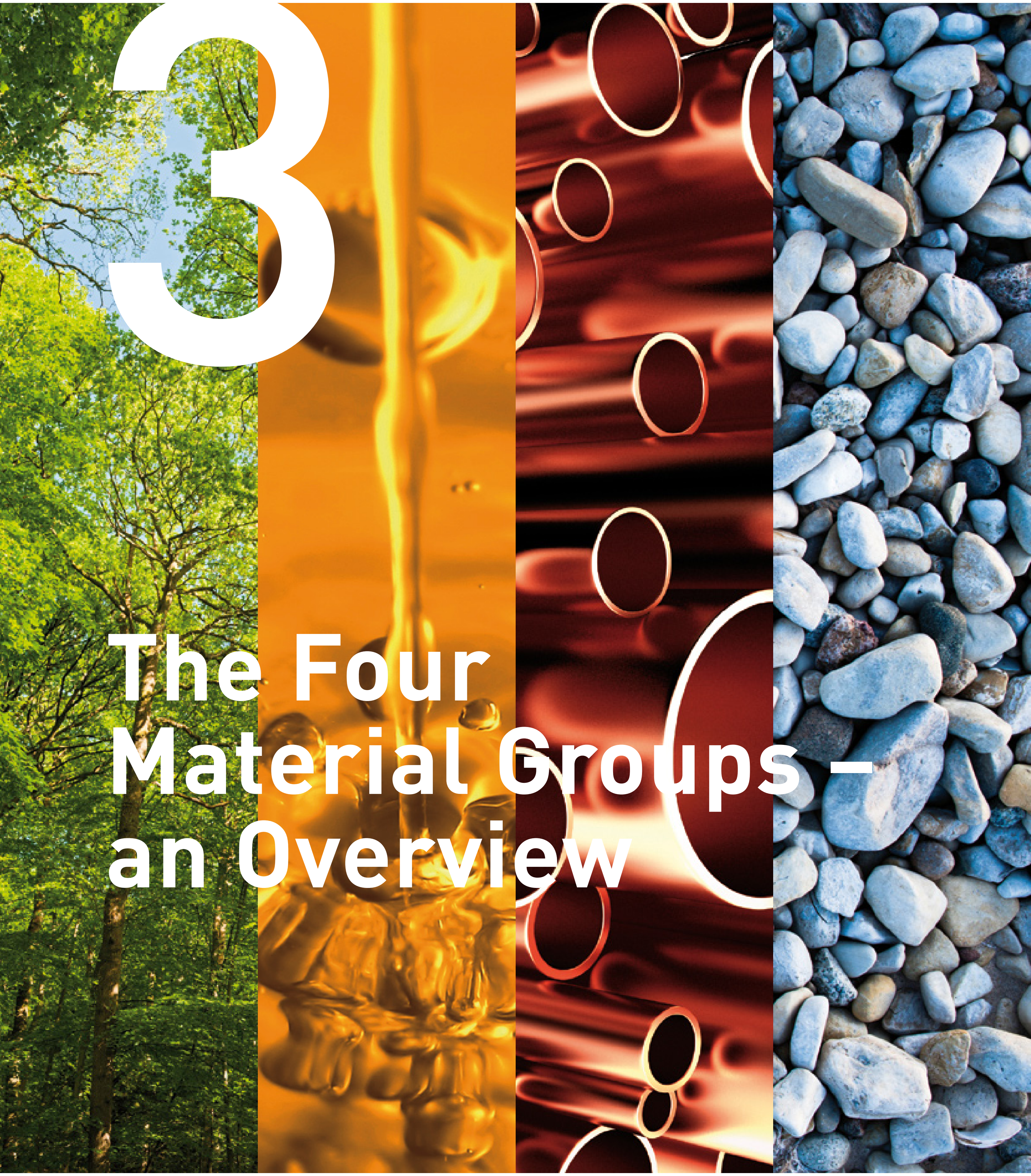
15 Two countries are missing in this presentation: Malta and Luxembourg. National MFA data for these two countries are not available.

In Finland, per capita use is extremely high: The country has one of the lowest population densities in Europe (approx. 16 inhabitants per km^2; in Austria, the figure is slightly below 100 inhabitants per km^2) while at the same time being subject to climate conditions which require high material investments in the construction of residential areas and infrastructure. In addition, the material-intensive extraction of raw materials (especially timber) plays an important role in the Finnish economy. The fact that Lithuania and Latvia as two countries that are very densely populated also have the lowest per capita resource use in the EU shows that ultimately the combination of different factors is decisive. In the case of Lithuania and Latvia, the relatively low per capita income and the rather low rate of domestic resource extraction are keys to the low domestic resource use.

The Austrian Resource Efficiency Action Plan (REAP)

Under the direction of the Lebensministerium, Austria has worked since 2010 to prepare the Austrian Resource Efficiency Action Plan. For this purpose, the essential goals, key policies and instruments for increasing resource efficiency in Austria are identified by means of a stakeholder process. The Resource Efficiency Action Plan is scheduled to be completed in 2011. Simultaneously, an Austrian "Resource Efficiency Network" is being established which brings together stakeholders from administration, the economy, research and civil society to exchange opinions on and share experience relating to focal topics or best practice examples in the framework of an annual Round Table on Resource Efficiency.

http://www.lebensministerium.at
http://www.nachhaltigkeit.at



3 The Four Material Groups – an Overview

Having thus far addressed the broad trends in Austrian resource use, this document now examines resource use in terms of the four categories of materials: biomass, fossil energy carriers, metals and non-metallic minerals.

How have domestic extraction, imports and exports developed for the four groups? Which factors are associated with this development? Which functions do these resources fulfil for us? Where do links to current socio-political issues arise? These questions will be dealt with in the following sections.

In 2008, non-metallic minerals accounted for more than half of our resource use; biomass accounted for another 25 %. Metals and fossil energy carriers were less important in terms of weight, but played a major role economically and in production processes. Figure 13 shows once again the distribution of resource use in terms of the four material categories.

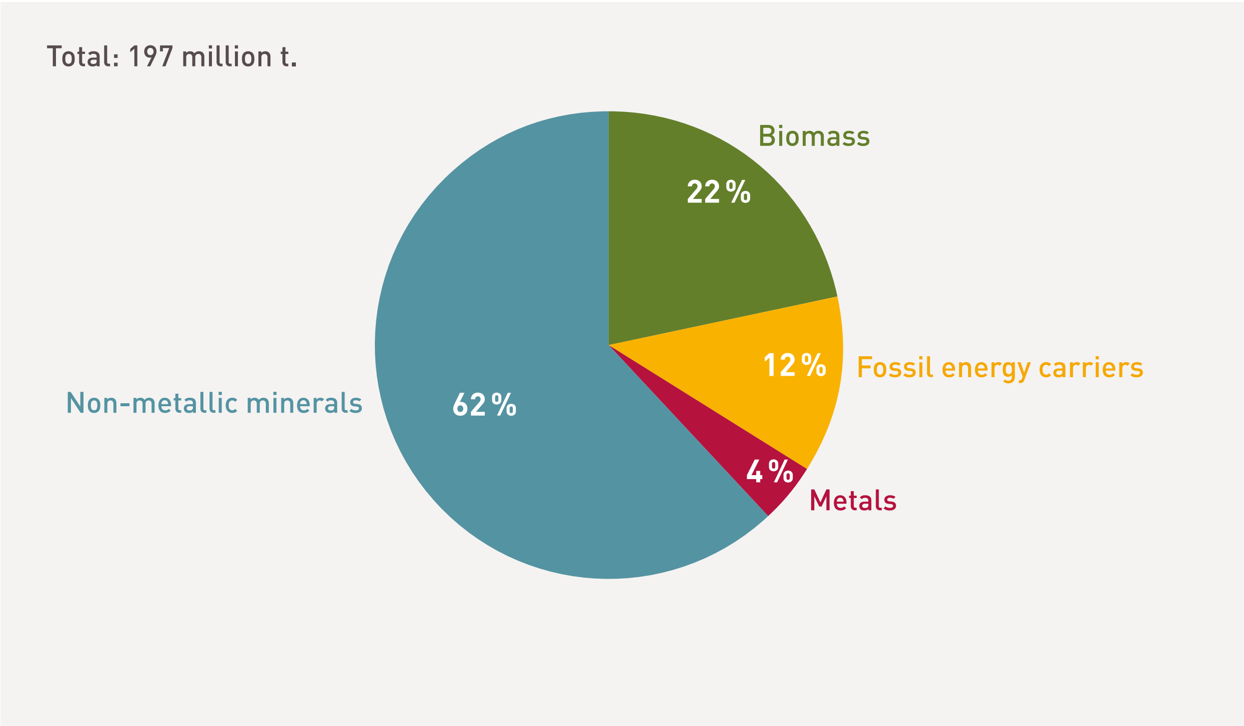


Figure 13: Resource use in Austria in tonnes in 2008 by material group
Source: Statistics Austria 2011 d

Figure 14 below shows the development over time of the four categories observed from 1960 to 2008. Domestic extraction of biomass, for example, has remained relatively stable over the past 50 years, whereas the imports and exports of biomass-based products of agriculture and forestry has risen significantly and in 2008 accounted for more than half of all domestic extraction. This means that Austria's industry, which is largely engaged in production for export, increasingly uses biomass from abroad. In contrast, metals and fossil energy carriers have seen a decline in domestic extraction, whereas cross-border trade flows have gained significantly in importance for both material groups. Although both the imports and exports of products from metal raw materials have increased, export volumes are lower by a third than the volume of imports. This is a clear indication that Austria processes products from metallic raw materials, part of which is for final consumption in Austria and the remaining part is exported again. In contrast, fossil energy carriers are almost exclusively imported for energy supply in Austria and are stored or consumed inside the country. Exports do not play a significant role in this case. In the group of non-metallic minerals foreign trade is of minor importance, showing only a small rate of growth over the time period in question.

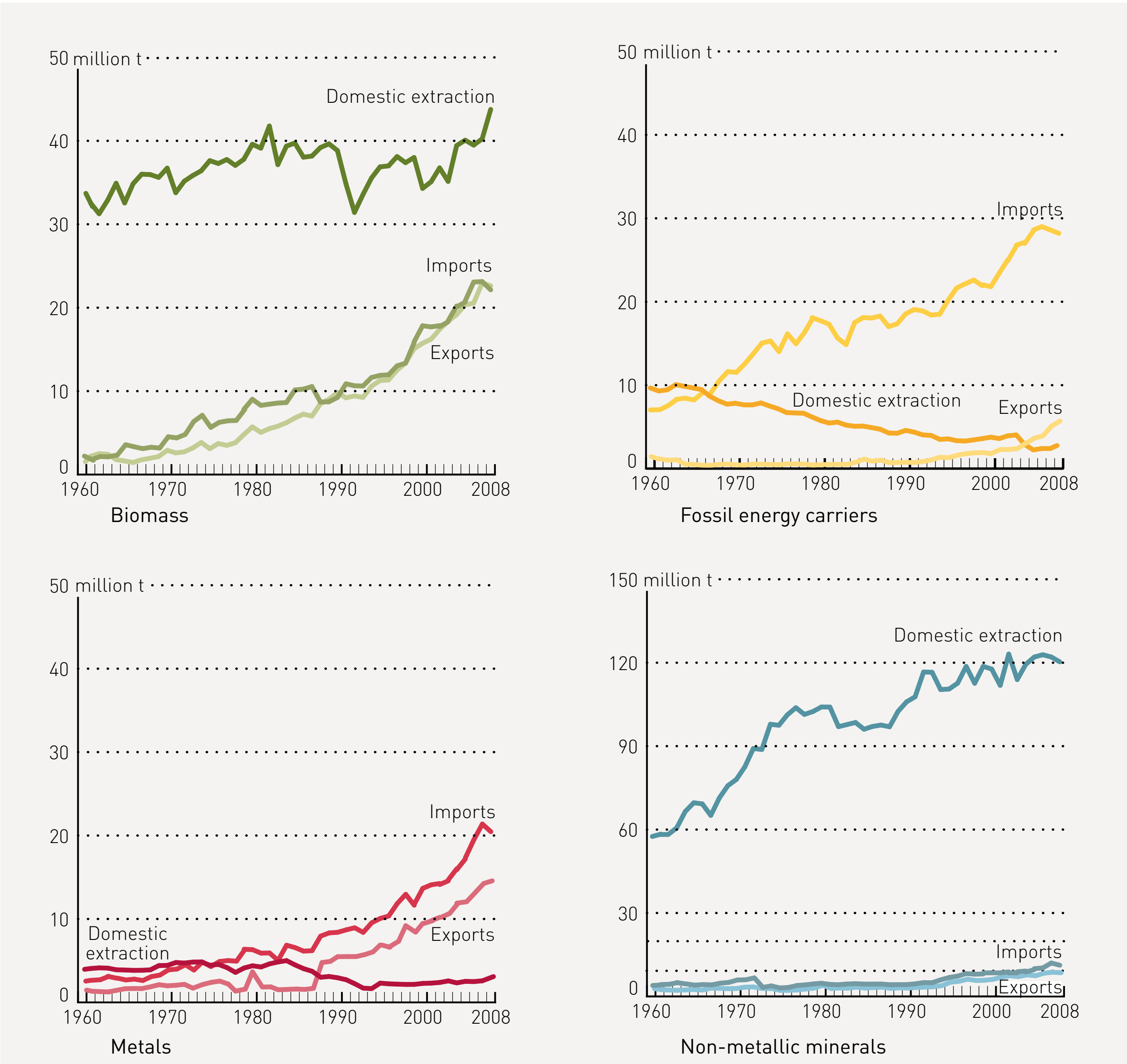


Figure 14: Development of extraction, imports and exports for the four material groups in million tonnes
Source: Statistics Austria 2011 d

Biomass

Biomass encompasses the whole range of organic matter, that is: live plants, animals, micro-organisms as well as dead organic matter (dead wood, leaves, straw, etc.). Biomass is frequently referred to as renewable raw material. It does not include fossil energy carriers which have their origin in biomass.

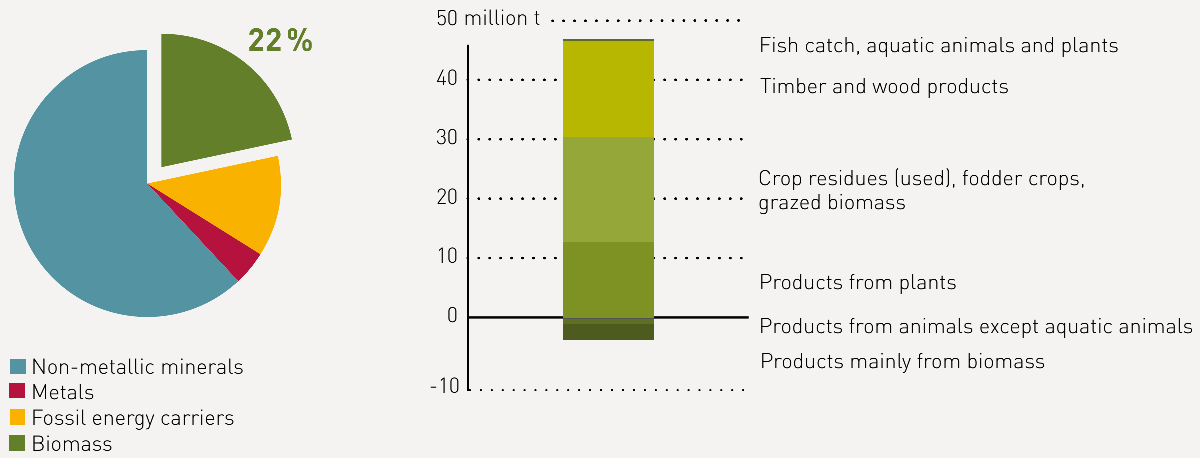


Figure 15: Resource use in Austria in 2008 and detailed view of biomass use
Source Statistics Austria 2011 d

Biomass as a material group comprises all raw materials of plant origin extracted from nature: this includes the agricultural products and all utilised by-products of harvesting, such as straw, the harvest from grassland, including the biomass grazed by livestock, and timber. In Material Flow Accounting (MFA), animal products derived from domestic agriculture (meat, milk, eggs, and fish from aquaculture) are considered as a resource flow within society and are thus not counted as direct extraction since the resource basis (fodder) is already taken into account[16].

As regards imports and exports, all goods traded are recorded, which means also products not considered in domestic extraction. They include products of animal origin as well as biomass-based commercial goods which cannot be assigned to any other biomass sub-categor. As Austria is a net exporter for both categories, its material use in these categories appears negative in the presentation (see Figure 15).

16 In contrast, animal products from hunting and fishing are taken into account as domestic extractions.

In quantitative terms, biomass is still a very important raw material.

Biomass accounts for about one-third of the resources extracted world-wide per year. In Austria, it also presently accounts for 30 %, which is a total extraction of 40 million tonnes of biomass per year. Arable crops account for about 30 %, timber for 34 % and biomass from grassland used as pasture for 35 % of total extraction. In spite of the considerable extractions inside the country, large quantities of biomass-based commodities are imported to Austria. In 2008, these imports amounted to 22 million tonnes. Almost two- thirds of these imports were timber and timber products, above all raw timber and waste paper for the wood-processing industry. In the field of agricultural biomass, mainly protein feed, sugar and food and drink preparations were imported. The exports of biomass are also considerable. Exports include above all more highly-processed products made of wood (paper, sawnwood), cereals and dairy products. As one can see in Figure 14, biomass imports and exports are growing very fast, whereas domestic extraction remains at the same level until 2008. However, the volumes of imports and exports are almost the same, so they show an equal trade balance. Although Austria is a country where agriculture and forestry are traditionally of great importance, a growing decoupling of the processing agricultural and forestry industries from the domestic resource base can be observed; this means that Austria's industry increasingly needs imports of biomass-based goods. In terms of population, each Austrian uses an average of 5 tonnes of biomass per year; this represents 14 kg per day. For comparison: Austria's total use amounted to 24 t per capita per year in 2008.

Biomass production and land use

The production of biomass is closely linked to land use. In Austria, areas used for agriculture are slowly decreasing (Figure 16); since 1960, approximately 6,600 km^2 of arable land and grassland (i. e. 21 %) have been taken out of production. Through natural succession, a major part thereof has gradually been replaced by forests and as a result, forest land is continuously increasing in Austria. Meanwhile 39,000 km^2, or half the territory of Austria, are again covered with forests. But agricultural land has also been replaced by settlement areas. According to current estimations of the Federal Environment Agency, the annual use of land for settlement and transportation amounts to about 90 km^2, if urban grassland and recreational areas are considered (Petz 2001).

However, not only the area size, but also the intensity of land use is changing. Following an increase in the intensity of use in the 1960s and 1970s, the situation has eased markedly during the past few years. Figure 17 illustrates that the consumption of mineral fertilisers in agriculture had reached a peak as early as in the 1970s. Since that time, the use of fertilisers has been declining. Because fertilisers are nowadays applied in a much more efficient way, there have been no losses concerning the growth of yields as a result. The average yields of cereals are continuously rising and, in Austria, have increased by the factor 2.5 since 1960. However, taking everything into account, the domestic extraction of agricultural biomass has declined since the 1980s. The timber harvest, on the

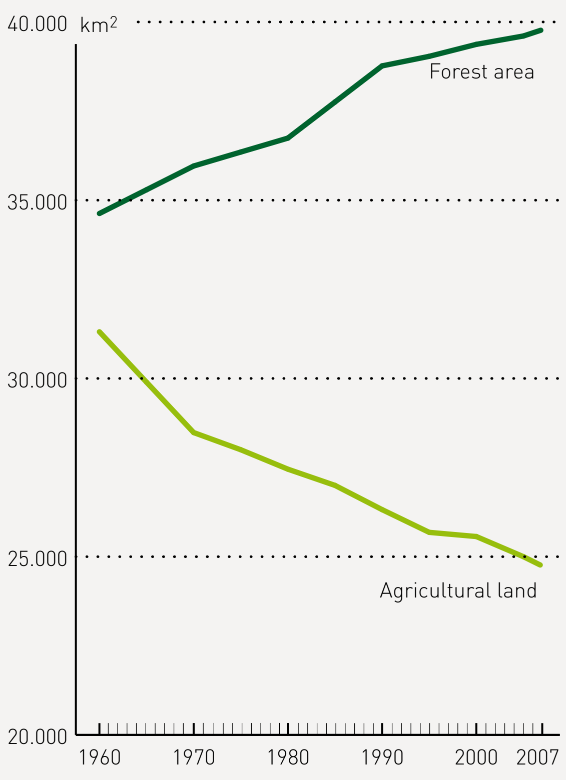


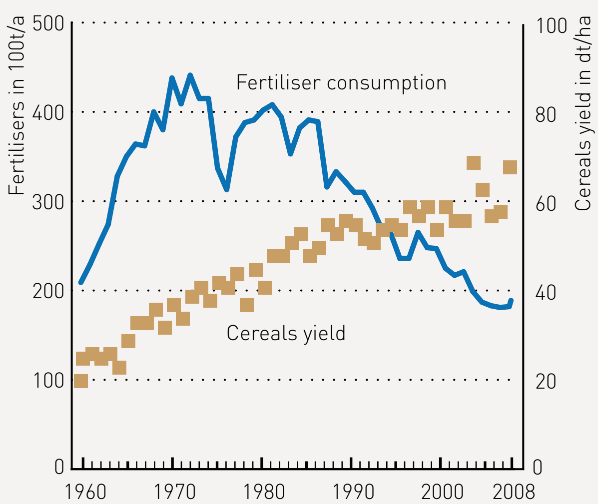
Figure 16: Land use in Austria
Source: Federal Institute of Agricultural Economics 2011, Federal Office and Research Centre for Forests (BFW) 2011, Krausmann et al. 2003

other hand, has been increasing for almost three decades. According to the most recent Forest Inventory (Federal Office and Research Centre for Forests (BFW), 2011), about three-quarters of the annual wood increment are harvested from sustainably managed forests.

Biomass for human nutrition and for feeding livestock

Biomass is primarily used for human nutrition. In this function, biomass cannot be substituted by any other raw materials. However, only about 10 % of all agricultural products are directly used for the production of food.

The greater part – three-quarters of the total agricultural biomass used (in tonnes) – is fed to livestock whose products are then used for human nutrition.



The intensity of agricultural production is illustrated by comparing the consumption of mineral fertilisers (pure nutrient content of nitrogen, phosphorus and potash fertilisers) and the specific cereals yield in decitonnes (dt) / ha (1 decitonne (dt) equals 100 kg).

Figure 17: Intensity of agricultural production: Use of mineral fertilisers and specific cereals yield, Austria
Source: Federal Institute of Agricultural Economics 2011, FAOSTAT 2010, Krausmann et al. 2003

This means that on average about 5 to 10 tonnes of agricultural biomass are required to produce one tonne of animal products. Animal husbandry is therefore very material-intensive and thus significantly influences a country's biomass use. The higher the number of livestock per inhabitant, the higher is also the per capita biomass use. Due to Austria's biogeographical situation (importance of the Alps), animal husbandry plays an particularly important role in Austria (conservation of the cultivated landscape, sustainable use of grassland). The animal stock per Austrian amounts to 0.4 livestock units[17]. In Europe only Ireland with 2 LU per capita, Denmark with 1 LU per capita and Belgium/Luxembourg, the Netherlands and France with 0.5 LU per capita, have a higher animal stock per inhabitant. A large portion of high-quality domestic, but also imported products from arable farming (about one-fifth of the total agricultural biomass used in Austria), mainly barley, maize and shredded soy, are used as feed in animal husbandry and converted into animal products. However, animal husbandry also makes it possible to use land which, due to its climatic conditions or morphology, is unsuitable for arable farming, for example in the Alpine area.

Forestry plays an important role in Austria – yet large quantities of timber are imported

Timber accounts for 37 % of the biomass used. Slightly more than half of that amount is employed as a raw material by industry, mainly for the production of paper and in the sawmill industry. An increasing share of this timber, above all fuelwood, but also by-products from the timber industry, is used to produce energy. Only a few other countries approach Austria's level in terms of timber use for energy production; 10 % to 15 % of the primary energy produced in Austria is obtained from timber and other biogenic substances.

Although the extraction of wood plays an important role in Austria and the annual increment of domestic forests is not exhausted, large quantities of timber are imported – as mentioned above. In 2008, the imports amounted to 10 million tonnes. Imports are above all used in the paper and sawmill industries. A considerable portion of the products of the

17 To improve the comparability of the different farmed animals, animal stocks are not expressed per head but in livestock units per 500 kg live weight. This is about the mass of a cow.

wood-processing industry is exported. A balance of imports and exports shows that, despite being one of the countries most rich in forests in Central Europe, Austria is a net importer of raw timber and timber products. This means that, in spite of the high level of extractions, it relies on imports from other countries to satisfy the needs of its export-oriented production.

Use of biomass for industrial utilisation beyond food production

The portion of agricultural biomass used as a raw material in industrial production is rather small, but has risen in the course of the past few years. In Austria, only the industrial use of starch (from maize and potatoes) is presently of relevance in quantitative terms; every year approx. 200,000 tonnes of potatoes and approx. 360,000 tonnes of maize are processed into starch, with figures showing an upward trend, however. In the EU about half the amount of starch produced is used in the food sector, the other half for technical processes (mainly in the production of corrugated cardboard and paper). Due to the shortage of fossil energy carriers, the chemical industry too is now taking steps to increase the proportion of raw materials from agricultural production being used in the production of plastics (cf. Shen et al. 2009), which would lead to a considerable additional demand for biomass for technical uses.

Using agricultural products for energy – a promising option for the future?

The most dynamic development currently concerns the use of agricultural biomass for energy generation. By using renewable energy sources for energy generation, the use of fossil energy carriers and the production of greenhouse gas emissions, in particular of CO_2, is to be reduced. The political objectives which, in late 2008, following the approval of the European Parliament, were unanimously adopted by all EU Member States in the form of the Climate and Energy Package have boosted these developments. There are two Directives which are of importance for the energetic use of biomass, in particular in the transport sector[18], and which set the following targets:

- By the year 2020, 10 % of the energy used in transport should be obtained from renewable sources;
- By the year 2020, fuel suppliers should reduce the greenhouse gas emissions per unit of energy of the fuels or energy carriers by 6 %.

To achieve these two goals, it is necessary to increase the use of biofuels.

In order to ensure the effectiveness of these measures, the Directives also define sustainability criteria[19] for biofuels (from domestic production, but also imports), which are to be counted towards the above targets.

From a global perspective in particular, the potential of bioenergy must be seen in connection with a possible land use competition between food production and biomass production for energy purposes.

18 EU Directive 2009/28 on the promotion of the use of energy from renewable sources as well as EU Directive 2009/30 on the specification of fuels.

19 They contain mandatory environmental standards for the cultivation of agricultural raw materials which provide that such raw materials must neither be cultivated on highly biodiverse land nor obtained from tropical forests or recently deforested land, drained peatland or wetlands. It is made clear that the conversion of a forest into an oil palm plantation would not comply with the requirements of sustainability. These sustainability criteria apply both to biofuels produced inside the EU and to imported biofuels. Austria implemented the sustainability criteria for agricultural raw materials as early as in 2010 – as one of the first Member States of the European Union to do so. The introduction of the sustainability criteria also provides that only those biofuels may still be counted towards the national targets that offer a verifiable benefit with respect to the greenhouse gas emissions compared to fossil energy carriers.

Fossil energy carriers

Fossil energy carriers are non-metallic mineral raw materials which have generated from the decomposition of plants or animals in the Earth's crust over millions of years and are primarily used for the production of energy.

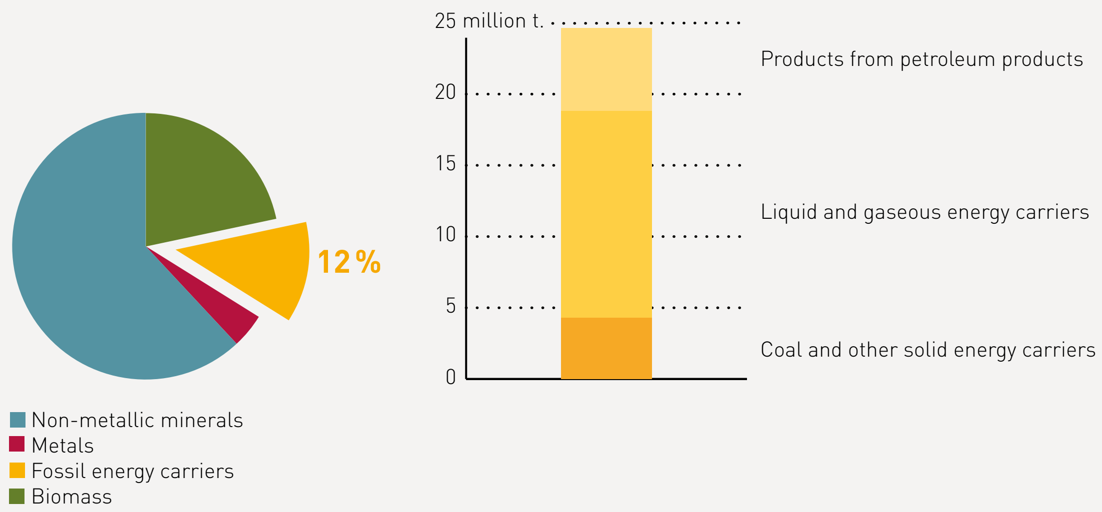


Figure 18: Resource use in Austria, 2008, and detailed view of the use of fossil energy carriers
Source: Statistics Austria 2011 d

Conventional fossil energy carriers include brown coal, hard coal, petroleum and natural gas. In the future, non-conventional fossil raw materials for energy like, for example, gas hydrate and shale gas, or oil shale and oil sands, will play a crucial role. The individual energy carriers differ both in terms of the properties of the material (solid, liquid, gaseous) and in terms of their energy content. Whereas brown coal has about the energy content of wood (< 15 MJ/kg), the energy content of petroleum is about three times that value (45 MJ/kg) (Statistics Austria 2011 b, Smil 1991).

Fossil energy carriers – strategic resources with major impacts on our climate

Fossil energy carriers serve above all the provision of energy. Only a very small portion (globally approx. 3 %) of the total amount produced is not used for energy purposes. This includes coking coal, which for example is an indispensable component in the production of pig iron, or hydrocarbons, which are used in the petrochemical industry to produce plastics, asphalt, lubricants, fertilisers, chemicals, or drugs.

The energetic use of fossil energy carriers is a leading cause of global climate change. Burning coal, oil or natural gas also produces carbon dioxide. The latter accumulates in the Earth's atmosphere and, together with other greenhouse gases, contributes to global warming and consequently to global climate change. International political programmes like the Framework Convention on Climate Change (adopted in 1992) and the Kyoto Protocol with its climate protection goals, adopted in 1997, are trying to take countermeasures against this development. Austria implements the goals adopted at international level by means of its 2002 climate strategy and the 2007 adaptation of the climate strategy. Key approaches of these documents concern efforts to improve energy efficiency and to intensify the use of renewable energy sources (Federal Ministry of Agriculture, Forestry, Environment and Water Management; Federal Ministry of Economy, Family and Youth 2010).

Reducing the use of fossil energy carriers in industrialised countries is one of the most important measures to cut CO_2 emissions and thus to mitigate climate change. This is a difficult untertaking, however, as fossil energy carriers have been, and continue to be, of great strategic importance for industrialised economies and economic growth. More than half of the fossil energy carriers produced world-wide are used in a small number of industrialised countries. As a result, the use figures of all industrialised countries, with an average of 5.4 tonnes[20] per capita and year, are far above the global average (1.6 tonnes per capita and year). Reducing the use of fossil energy carriers is one of the greatest challenges society will face over the decades to come.

Where are the deposits of fossil energy carriers to be found?

Fossil energy carriers are not evenly distributed throughout the Earth's crust, but are concentrated in deposits. This means that at certain locations, large quantities of fossil energy carriers are produced which are then distributed for use all across the globe. About 71 % of the world's conventional oil reserves and about 69 % of world's natural gas reserves are located in the "Strategic Ellipse", the area from the Middle East and the Caspian region to the north of Russia (Figure 19).

Globally, 10 countries are responsible for about 60 % of the overall extraction of fossil energy carriers. The major producers are located at large distances from the major consumers. A large portion (38 %) of the fossil energy carriers extracted world-wide is therefore distributed to countries, above all highly industrialised countries, through foreign trade activities.

Which amounts of fossil energy carriers does Austria need?

Since early 1960, the use of fossil energy carriers in Austria has more than doubled. Especially until the first oil price crisis in 1973 use rose speedily. A second period of growth can be observed as from 1994. So far, domestic use reached its peak in 2003, with almost 29 million tonnes. Since that time requirements have declined and, by 2008, had decreased by about 9 %. In that year, the per capita use of fossil energy carriers was almost 3 tonnes per year. With this figure, Austria ranks slightly below the EU average, which in 2007 amounted to about 3.5 tonnes per capita per year.

Domestic consumption is predominantly determined by oil and natural gas; the share of coal amounted to no more than 18 % in 2008. According to the Austrian Energy Balance (Statistics Austria 2011 b), 12 % of the fossil energy carriers used in Austria are used for non-energetic purposes, e.g. in the production of plastics, asphalt, lubricants and raw materials for the chemical and pharmaceutical industries as well as in the production of steel. Almost one-fifth of the fossil

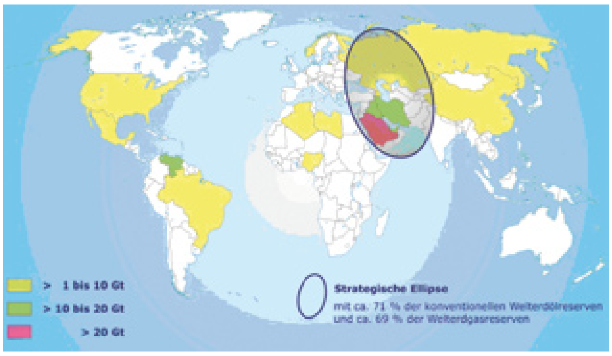


Figure 19: Global distribution of oil reserves according to BGR (Federal Institute for Geosciences and Natural Resources)
Source: BGR 2009

20 At this point it should be noted once again that material flow analysis data are used in this publication. The unit applied here is therefore metric tonnes.

energy carriers used for energetic purposes are burned in thermal power stations to generate electricity. A little more than half of the fossil energy carriers destined for final consumption is used as fuel in transport; the production sector uses 23 % and households 17 % (Statistics Austria 2011 b).

Austria has few deposits itself; the major share of fossil energy carriers is imported

For geological reasons, Austria does not have any hard coal deposits of economic relevance; brown coal mining was halted permanently in 2007, after centuries of mining activities. Petroleum and natural gas have been extracted since 1934. The search for deposits of fossil energy carriers demands great effort; high technological and energy expenditure is invested to utilise deposits at ever greater depths. The economic efficiency of deposits located at great depth, and also of non-conventional fuels such as shale gas, therefore also depends on the prices of energy.

The domestic production of fossil energy carriers thus plays an unimportant role when it comes to satisfying demand: In 2008, only 2 million tonnes of fossil energy carriers were extracted (equal shares of oil and natural gas). Production accounts for a little less than 9 % of the total amount of fossil energy carriers used, which is about 1.3 % of the total material extraction. More than 90 % of the domestic demand for fossil energy carriers is supplied by imports. In 2008, 28 million tonnes were imported – slightly more than 50 % of that amount was natural gas and petroleum (together 54 %) – in addition, coal (15 %) and products made of fossil energy carriers (30 %) were imported.

As with most industrialised nations, almost all European countries also depend strongly on imports of fossil energy carriers to be able to meet their energy demand. For the EU, the dependence on imports amounts to approximately 64 %. This high dependence on imports is not unproblematic for an economic system. The past few years in particular have shown that the global demand for fossil energy carriers is increasing rapidly (for example, as a result of the rising consumption in rapidly growing economies like China or India) and that this leads to strategic shortages. This often results in a rise of international prices.

Oil, for example, has seen rapidly increasing prices and historic price peaks during the past few years: In 2001, the price of one barrel of Brent was still around 20 dollars; after that, the oil price rose continuously and reached almost 150 dollars per barrel in mid-2008. In late 2008, the oil price dropped again to 30 to 40 dollars and after that rose to almost 120 dollars for Brent oil in early 2011. Artificial shortages were also the cause of the natural gas crisis relating to the dispute between Ukraine and the formerly Russian Gazprom, which resulted in a real shortage of natural gas in Europe in 2005. Rising prices do not necessarily reflect the supply/demand ratio. Speculative elements likewise influence pricing. When oil prices reached their peak in 2008, the daily price fluctuations exceeded even the level of the average price of 2001.

Coal – important also in the future?

At present, petroleum and natural gas are the two fossil energy carriers that dominate use. But deposits are limited and experts expect that the peak output rates will be reached soon and production will decline as a consequence. In comparison with the other non-renewable raw materials for energy, coals are, from a global perspective, those of which the largest reserves exist (Federal Institute for Geosciences and Raw Materials (BGR) 2009). Although coal use is stagnating or showing a downward trend in Europe, it has seen a speedy rate of increase in Asian countries during recent years (Federal Institute for Geosciences and Raw Materials (BGR) 2009). Coal will also continue to be a raw material of strategic importance in the long term. However, the future use of coal as a raw material for energy production is seen as closely linked to the development of clean coal technologies, i. e. technologies which allow low-emission combustion. However, in consideration of sustainable energy supply and the associated CO_2 problem, coal should, from the Austrian point of view, gradually be abandoned as a source of energy.

However, coal is indispensable in the blast furnace process for the production of pig iron: The production of one tonne of pig iron requires one tonne of coking coal, which is 0.6 tonnes of coke (VOEST Alpine 2010). Moreover, coals contain many rare metals, such as gallium, germanium, beryllium, and indium, which are enriched in the combustion residues. Utilising these valuable potentials of metals could spare primary resources and thus protect the environment.

Renewable energy in Austria

Renewable sources of energy traditionally play an important role in Austria. In 2009, the share of total energy consumption pertaining to renewable energy reached 30.1 % (with reference to Austria's gross final energy consumption). The renewable share of Austria's final energy production rests on two pillars: the energetic use of biomass and the use of hydropower.

The utilisation of renewable energy sources helps keep the CO_2 emissions from energy provision as low as possible. Nonetheless, it should not be forgotten that the utilisation of renewable energy sources also involves material flows, material use and waste (for example when building new infrastructure facilities, power stations, dams, turbine wheels, permanent magnets in wind turbines, photovoltaic modules, etc.), although the material flows triggered by renewable energy sources remains far below that induced by conventional fuels.

The significance for the domestic economy of renewable energy sources is among other things due to the positive effect on revenue and employment. The intensified use of renewable energy enhances also the degree of energy self-sufficiency; it reduces the dependence on imports of fossil energy carriers and thus the vulnerability of the national economy.

In this context, Austria has to comply with international obligations like the Kyoto Protocol or the objectives of the EU Climate and Energy Package 2020. Key obligations are to raise the share of renewable energy sources in the gross final consumption of energy to 34 percent, while at the same time reducing greenhouse gas emissions in the sectors not subject to emission trade by at least 16 percent (with reference to the emissions of 2005). Both targets are to be achieved by the year 2020. Furthermore, energy efficiency is to be increased by 20 percent compared to 2005 – again by the year 2020.

Austria also pursues the vision of achieving energy independence by 2050, based on renewable energy resources. The technical feasibility study on energy independence in Austria ("Energieautarkie Österreich 2050", Streicher et al. 2010), prepared on behalf of the Lebensministerium, assumes that Austria will achieve self-sufficiency by means of energy generated from wind, solar energy, water power, and biomass by the year 2050.

Metals

Metals include mineral materials ranging from ores to processed metals. In raw materials science, ores are defined as mineral materials from which metals can be extracted with economic benefit.
Ores are subdivided in raw materials science into three groups, namely iron ores and steel stabilisers, non-ferrous metals and precious metals. In material flow analysis, metals are subdivided into iron ores and non-ferrous ores.

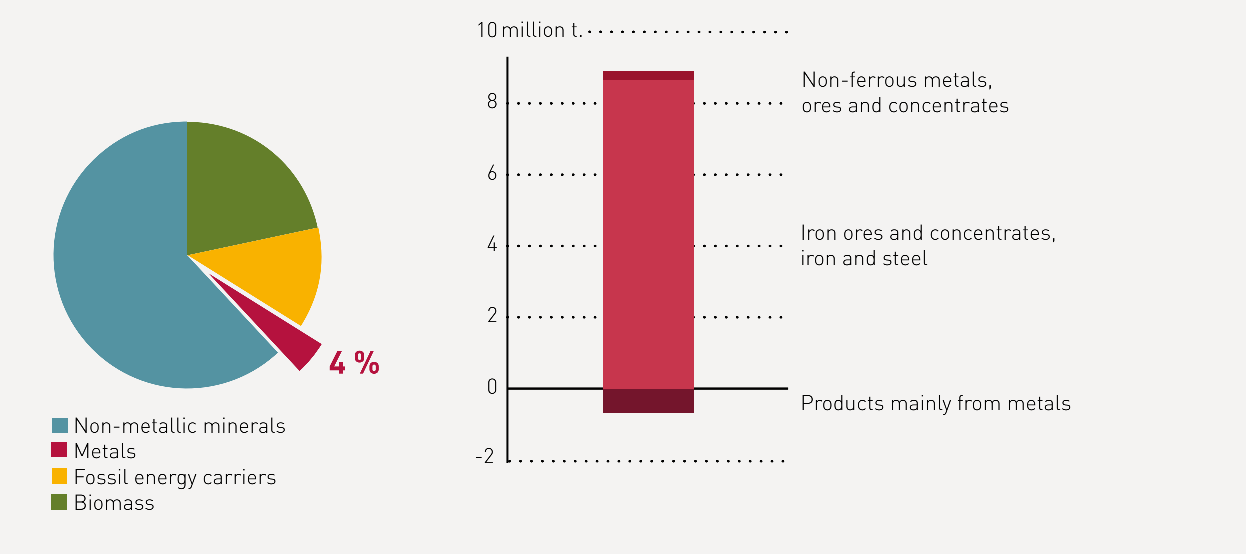


Figure 20: Resource use in Austria in 2008 and detailed view of metal use
Source: Statistics Austria 2011 d

The metals group encompasses a large number of very different ores and derived products. Metals are found in the Earth's crust in the form of ores; the concentrations of individual metals in ores can differ widely: The economic profitability of the metal contents in the Earth's crust ranges from about 30 % in the case of iron to approx. 5 g/t (= 5 ppm or 0.0005 %) for the precious metals gold or platinum. Ores are found sporadically in deposits which often contain a combination of several different valuable metals. Selenium, for example, is a minor constituent of many copper deposits and rhenium can be found as an addition in molybdenum deposits. However, in many cases deposits are not fully utilised, which means that not all of the great number of different metals are eventually used. Conversely, due to the combination of several metals, metals not intended to be mined are also often extracted and their future use must be provided for economically.

Domestic extraction plays no significant role in Austria (2008: 2.5 million tonnes); most of the metals used in Austrian production are imported (90 % of the material input). Imports (2008: 20 million tonnes) and exports (2008: 15 million tonnes) of metals or derived goods are important as well. The greatest share of domestic use relates to products made of iron ore and steel. Metallic finished products are those commodities that cannot be assigned to either of the two other sub-categories. Since Austria exports more of these metallic finished products than it imports, material use is negative in these categories.

Austria is rich in poor deposits

For geological reasons, the presence of large deposits such as those found in Australia, South Africa or Brazil cannot be expected in Austria. However, the many small deposits which have been used for over 4000 years have constituted an important basis for the country's economic and cultural development.

In Austria about 2 million tonnes of iron ores are mined annually as raw materials for the steel production. The high demand for steel, in particular for infrastructure and products of daily life (e.g. cars), has led to a marked increase in the demand for iron ore. Simultaneously the demand for the steel stabilisers like chromium, titanium and tungsten, is also rising. Austria has considerable deposits of tungsten and is among the top six producers world-wide (Weber 2011 b). The processing of tungsten into high-quality products also takes place in Austria. Nonetheless, the major share of the metals processed in Austria is imported. The dependence on imports has continuously risen during recent years and amounted to 90 % in 2008.

Although no large quantities are mined (any longer) in Austria, the metal-processing industry still plays an important role in Austria: metal processing accounts for 10 % of Austria's gross domestic product (Statistics Austria 2011 e). The domestic industry primarily produces for export: In 2008, 15 million tonnes of metal products were exported. These represent 64 % of the metallic commodities produced from domestic extraction or imports.

Toxic waste, a major environmental problem in metal processing

Dissolved or in the form of dust, many of the metals used in products can have toxic properties even in small amounts. In the event of industrial accidents occurring in the course of metal processing, these toxic substances can cause considerable problems; examples from the recent past include the spill of heavy metal sludge caused by a dam failure at the ore preparation plant of Aznacollar (Spain) in 1998, the spill of cyanide solution near a gold preparation plant at Baia Mare (Romania) in 2000, and the red mud disaster caused by the breach of a dam of the Kolontar aluminium production plant (Hungary) in 2010. It is vital, therefore, that great care is exercised during production, and particularly during the processing of these raw materials and the depositing of generated waste.

Great diversity, complex usage, difficult recovery

There are also diverse possibilities for using metals: Metals and an entire range of alloys are used in the communication technology (cables and wires), in machines and in transportation means, as well as in infrastructure and in many electrical household appliances. The metal content of the final product can differ widely and ranges from large amounts of iron/steel to tiny traces of so-called 'spice metals', like molybdenum or metals of the rare earths which are used above all in electronic devices. A computer, for example, contains 32, a mobile phone even 45 different metals (Weber 2011 a).

These complex uses make the recovery of individual raw materials a great challenge. Whereas the recycling rates of a few industrially utilised metals, for example lead, iron or copper, are high, at 59 %, 55 % and 54 % respectively (Czichos and Hennecke 2008), other metals, above all those of which only tiny amounts are contained in the individual products or which are used in complex alloys, can for technical or economic reasons rarely be recovered.

Growing stocks in society provide opportunities for recycling and "urban mining"

The major share of metals accumulates in society in the form of stocks (also referred to as anthropogenic stocks, Rechberger 2009, Brunner and Rechberger 2002) (in buildings, infrastructure, household appliances, but also in landfills). So-called anthropogenic stocks can be substantial and have in part reached quantities similar to those of natural reserves (Rechberger 2009, Müller et al. 2006). In Vienna, for example, the per capita stock is estimated at 4,500 kg of iron, 340 kg of aluminium, 200 kg of copper, 40 kg of zinc, or 210 kg of lead (RMA 2011). Thus there is huge potential for recycling. The actual recycling rate is presently about 40 % for iron/steel (RMA 2011) and only about 1 % for some special metals (European Commission 2010). In the future, urban mining and the recycling of metals will (as for construction minerals) play an important role in supply security.

Critical situation concerning special metals

The global demand for metals has increased strongly over recent years, primarily as a consequence of the high demand in rapidly growing economies like China and India. This has already caused serious supply bottlenecks. A European Commission study (European Commission 2010) has identified 14 raw materials whose supply, in particular for key technologies, must be viewed as critical for the economy. The most prominent example concerns the rare earths, a group of 17 different elements utilised primarily in permanent magnets and in special alloys used, for example, in wind turbines, cars, plasma and LCD displays, or LED bulbs (Weber 2011 a).

In addition to the growing demand, there are mineral raw materials for which a few producing countries or individual companies acting on a global scale control the market (raw material oligopoly[21]); China, for example, is the top producer world-wide for about half of all metals and contributes about 90 % to the global production of rare earths. Export restrictions and other policies, such as different pricing for the same raw material in different countries (= dual pricing[22]), lead to competitive distortion and force up prices further.

Developments of this kind are not exceptions; rising prices of raw materials, above all of metals, were clearly evident at the start of the 21st century (Figure 21).

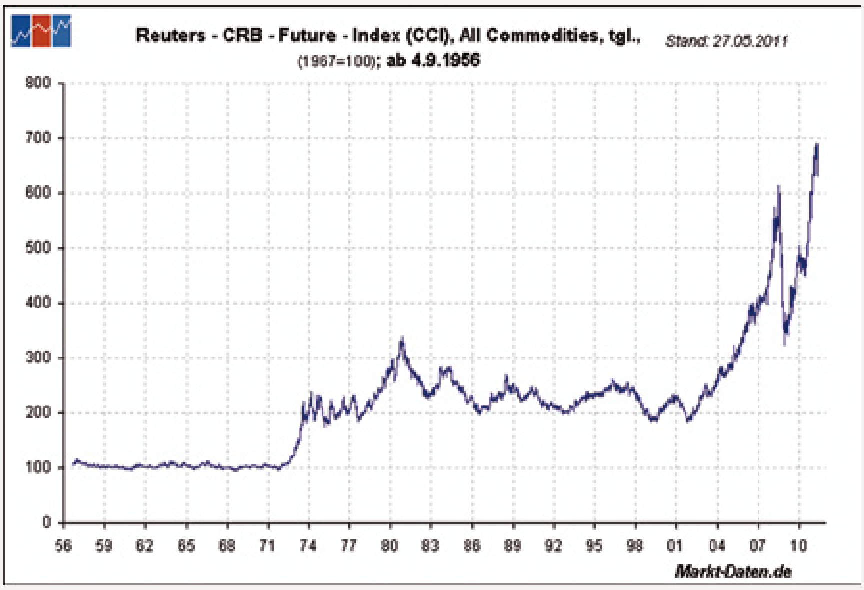


Figure 21: Price development of the Reuters CRB Index[23] for raw materials, 1956 – 2010
Source: Markt-Daten.de 2011

21 In an oligopoly, a few suppliers control the market.
22 Dual pricing means selling raw materials and basic materials at different prices in domestic and foreign markets, a practice which is inconsistent with WTO rules and leads to competitive distortion.
23 The Reuters CRB Index considers 28, lately 17 raw materials: Energy, cereals, industrial minerals, livestock, precious metals, softs (Markt-Daten.de 2011).

Iron ore: a key raw material

Mineral raw materials form the indispensible basis for an entire range of goods used in daily life. The demand for raw materials can be used very well as an indicator for a country's industrialisation and as a barometer for its economic activity. In China, for example, the annual per capita use of steel, which is generally irreplaceable in building construction and for the production of other commodities such as, for example, motor vehicles, has risen dramatically in the course of the past decade. Whereas in 2002 the annual per capita use of steel still amounted to approx. 287 kg, it rose to over 400 kg by 2009 and is presently even higher than in the EU-27 area.

The key raw materials for the production of steel are iron ores. Due to the huge requirements of China, which the country cannot remotely cover from its own deposits, the availability of this raw material on global markets is severely restricted. This has already triggered significant increases in raw material prices. However, other raw materials are also needed for steel production, among them coking coal as an energy source and carbon carrier, but also magnesite for the production of highly refractory products for the lining of blast furnaces.

For the production of special steels, different metals are required in the refining process (e.g. manganese, chromium, vanadium, nickel, titanium, tungsten, etc.). The strongly growing requirement for steel is therefore also leading to rising demand for these metals.

An important area of use for steel is the vehicle industry. For example, each conventional vehicle requires a lead-acid starter battery as well as copper for the vehicle's electrical system. Hence, the 'knock-on effect' of iron ore concerns also non-ferrous heavy metals, light metals and special metals. Although smaller amounts of steel are required in the electric vehicle technology, other raw materials, like aluminium, lithium or rare earths, are needed instead.

Even though in some technologies the use of steel may decline in the future, iron ore will in the long run remain the key raw material for industry. Depending on the demand for iron ore, raw materials directly or indirectly required in the manufacture of steels or their processed products will also be required in the future.

Non-metallic minerals

The term 'non-metallic minerals' as used in this publication denotes construction minerals and industrial minerals.

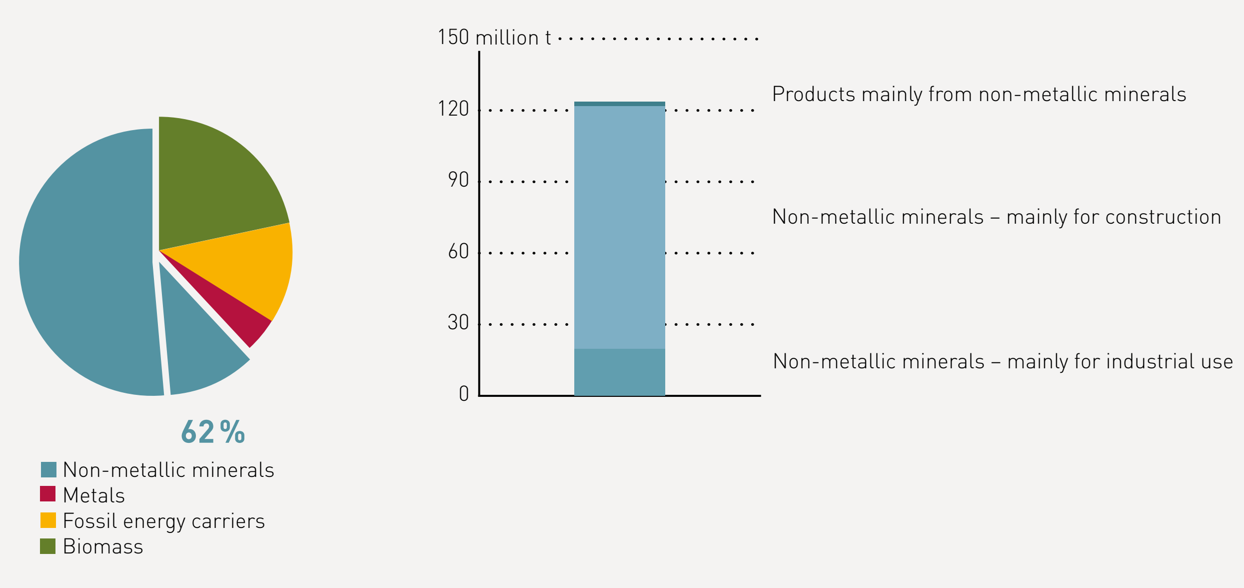


Figure 22: Resource use in Austria, 2008, and detailed view of the use of non-metallic minerals
Source: Statistics Austria 2011 d

Non-metallic minerals encompass construction minerals and industrial minerals. The two sub-categories differ not only in respect of their areas of use, but also in terms of the quantities utilised:

The group of construction minerals includes mainly large material flows, primarily sand and gravel, which are used in concrete production or road construction.

Industrial minerals include minerals which are used in industrial production outside the construction sector, such as phosphates, which are used in large quantities especially as fertilisers, but also table salt or diamonds which, compared to other raw materials, are required only in small quantities.

However, the subdivision also reflects the quality of the relevant data: The extraction of these great amounts of construction minerals is commonly inadequately recorded in statistical reports, whereas industrial minerals, which are also generally more expensive, tend to be well represented. If we compare the price of one tonne of diamonds to one tonne of sand, this difference is obvious.

However, since there are raw materials which are used both for construction and in industrial production, it is not always possible to distinguish clearly between construction minerals and industrial minerals. Limestone, for example, plays an important role as a construction mineral in the production of cement, but is also used as a filler in certain industrial processes and as a fertiliser in agriculture.

Construction minerals

Construction minerals are non-metallic mineral raw materials of which great amounts are needed for construction.

Construction minerals (e.g. sand, gravel, quarry stones) are used to establish and maintain buildings and infrastructure (e.g. roads, airports, canals). The quantities required of these raw materials account for about half of Austria's total material use. In 2008, use amounted to approximately 102 million tonnes. The major part of the construction minerals used in Austria is extracted close to users, as transport costs would otherwise exceed the – compared to other raw materials – relatively low prices. The maximum haulage distance is about 30 km (Forum Rohstoffe 2007). Construction minerals are therefore imported and exported only in border areas and the quantities traded internationally are, although large in themselves, small when compared to domestic extraction.

The use of construction minerals is closely coupled to economic growth

The use of construction minerals has grown continuously over the past 50 years. Starting with an extraction rate of slightly below 60 million tonnes in 1960, the demand and use of construction minerals has approximately doubled over the past 50 years. Growth was most significant from the first years of data collection (from 1960 onward) until the mid-1970s. Urbanisation and the establishment of large infrastructures (road network, dams, waste disposal systems) were the driving forces for the high growth rates in use at that time. Whereas in industrialised countries the annual use usually amounts to over 10 tonnes per capita and in Austria is even about 15 tonnes per capita, the use of developing countries is often less than one tonne per person. This emphasises the importance of construction minerals in the process of industrialisation. Especially in times of rapid economic growth, large quantities of construction minerals are used, which today is reflected above all in the resource use of the emerging economies. Yet in industrialised economies too, the demand for construction minerals has remained high: The existing built infrastructures account for several hundred tonnes per capita (an estimate for Austria for 2006 puts the figure at about 260 tonnes p.c; Daxbeck et al. 2009) and maintaining or renewing these requires additional resources. Furthermore, new stocks are still being created. In times of crisis in particular, investments in large construction projects are used to give fresh impetus to the economy, which in turn boosts resource use.

The use of construction minerals is closely coupled to the use of fossil energy carriers

The use of construction minerals is for various reasons closely coupled to the utilisation of fossil energy carriers. On the one hand, the production and processing and, in particular, the transport of the large quantities involved all require huge amounts of energy: Almost 50 percent of all goods transported on roads are mineral raw materials (Nötstaller and

24 The use of construction minerals is closely linked not only to the use of fossil energy carriers but also to other raw materials, most notably metals. These include iron/steel, aluminum, or copper, for example, all of which are also important resources for the construction industry.

Wagner 2007), with a considerable impact on the climate-relevant CO_2 emissions. On the other hand, the expansion of the transport infrastructure is related to the rising demand; rising use of construction minerals therefore leads to an increase in fuel consumption.

Shortages due to limited access

The continuously rising demand for construction minerals (formerly referred to as "bulk materials") was for a long time not considered as a problem because the raw materials were thought to be available everywhere. However, this view has changed over the past few years. From the geological point of view, construction minerals are abundant, but, as a result of land use, it is becoming more and more difficult to access these reserves (Weber 2007). This fact may be illustrated using the following example of a supply region (see Figure 23): The geological potential in terms of sand and gravel is huge and covers more than half of the region. However, if we take into account that, due to conflicts of use (protection of groundwater, residential areas), extracting construction minerals is in many areas out of the question and the actually available potential is small. Scarcity is therefore not only due to the size of natural stocks, but is in many cases a consequence of conflicting user interests in society.

"Urban mining" and recycling as future options to spare natural stocks

Achieving a change in demand is essential, if material use is to be reduced. Growing social mobility (transport of goods and individual traffic) leads to the continuous expansion of infrastructure. The increase in stocks means that, in the future, construction minerals will be needed to maintain existing infrastructure; the use of construction minerals thus commits societies to the future use of resources in considerable quantities. Apart from an absolute reduction in the use of construction minerals, the recovery of building residues can also help relieve the pressure upon natural resources. The recycling potential is considered to be very high for construction minerals. Practical experience gained in Austria shows that presently as much as 70 % of the building residues produced (2007: slightly below 8 million tonnes, RMA 2011) are indeed used in Austria. However, an examination of the overall material flow relativises this impressive recycling rate: Of the 120 million tonnes of construction minerals used in Austria per year, only a little less than 5 % are from recycling sources. "Urban mining" – essentially "cities as resource reserves" – can be an important element in the future development of the extraction of non-metallic construction minerals (Rechberger 2009, RMA 2011).

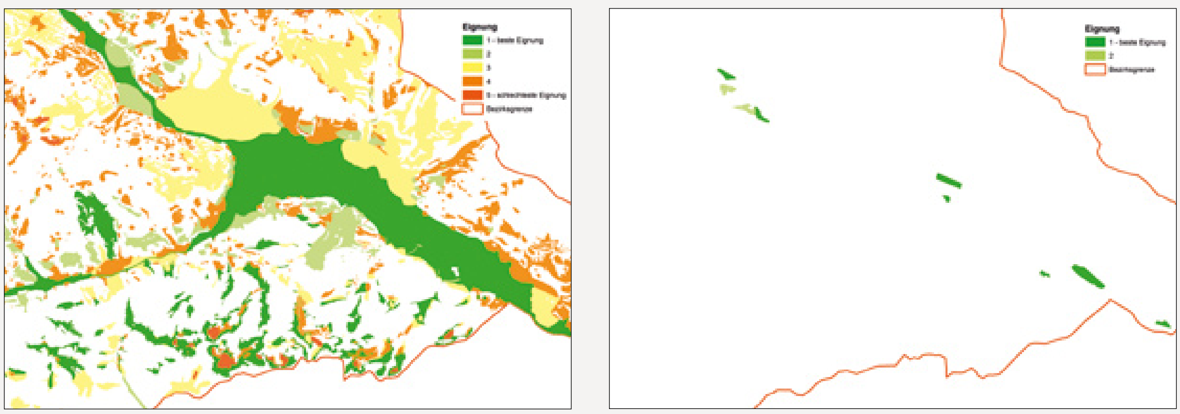


Figure 23: Austrian Mineral Resources Plan; left: Example of the distribution of sand and gravel of different quality (= suitability); right: Example of the distribution of sand and gravel of different quality, minus area planning prohibitive and conflict zones.
Source: Weber 2007

The Austrian Mineral Resources Plan

The Austrian Mineral Resources Plan has been developed by the Austrian Federal Ministry of Economy, Family and Youth with the aim of ensuring that area planning policy preserves exploitable reserves of construction minerals, ores, industrial minerals, and energy resources as identified objectively by means of an innovative methodological approach.

Since, due to the geological situation, raw material deposits occur only at specific sites, it is necessary to evaluate and resolve any conflicts that might occur with other potential users of the natural area.

The raw material deposits found at locations determined by area planning to be least required for other forms of use are to be protected in area planning regulations to ensure that they will also be available for future generations.

Work on the Austrian Mineral Resources Plan should be understood as a dynamic process which must continuously be adapted to spatial and economic developments by both the federal and the provincial governments together. The European Commission has chosen the methodological approach applied in the evaluation of deposits, the assessment of the demand for mineral raw materials and the conflict management approach as a Best Practice Method.

http://www.bmwfj.gv.at/EnergieUndBergbau/Rohstoffplan/Seiten/default.aspx

Industrial minerals

Industrial minerals are non-metallic mineral raw materials which, due to their chemical or physical properties, can be directly used in a production process. Industrial minerals do not comprise ores, construction minerals or raw materials for energy.

Industrial minerals are non-metallic minerals which are not used for construction or energetic purposes. In comparison to construction minerals, they are extracted in much smaller quantities in Austria.

There are numerous different ways of using industrial minerals: In many industrial and agricultural production processes, industrial minerals play an important role. Salt is an important raw material in industry; phosphates and potash salts are basic materials for fertilisers. Limestone and kaolin are used as fillers in the paper industry, clay and feldspar for ceramic products.

In 2008, 21 million tonnes of industrial minerals were used in Austria, which corresponds to 11 % of Austria's total material use. About two-thirds of Austria's demand for industrial minerals is covered by domestic extraction. The most important of these are salt (3.7 million t), quartz sands (2 million t), talcum, gypsum (1 million t) and magnesite (0.8 million t). Large amounts of salt are used as industrial salt and thawing salt, and only smaller amounts as table salt. Quartz sands are the basic material for the production of glass; gypsum is an important raw material for cement and construction materials.

Austria's production of talcum is of international importance: Globally, Austria ranks twelfth in the production of talcum. Austria's market leadership in the refractory products sector is due to the extraction and processing of high-quality magnesites in the country.

From a socio-political point of view, the use of specific industrial minerals is primarily of relevance due to the environmental pollution caused on the output side. For example, the use of phosphates as fertilisers in agriculture or the use of de-icing salt can cause pollution in soils, groundwater and surface waters.

4 Resource Use and Economic Development

Whereas the elaborations above have dealt mainly with the absolute figures on natural resource use in Austria, the following chapters include a consideration of economic development in Austria in their analysis. Economic growth and resource use are discussed together and in relation to each other. Questions including the following are addressed: How closely is resource use linked to economic growth? Can there be economic growth without rising resource use?

In the past, economic growth and increases in natural resource use showed a very similar development path: Typically, resource use rose in tandem with GDP. This development implies that economic growth in Austria has been and continues to be closely linked to the use of natural resources. But the problems inherent in continuously rising resource consumption are becoming ever more visible. On the one hand, an increase in the use of material and energy is also leading (albeit sometimes with a time lag) to an increase in the quantities of waste and emissions generated and in the related negative environmental impacts. On the other hand, rising use on a global scale is creating shortages of certain key resources. Strategies for sustainable development therefore require the decoupling of resource use from economic growth (Commission of the European Communities 2005, Fischer-Kowalski et al. 2011). This means that natural resource use should decline, while the economy continues to develop independently of that fact.

Efficient use of resources is increasing in Austria

Resource efficiency has improved in Austria over the past decades, which means that higher economic output has been generated using the same amount of resources. In concrete terms, resource efficiency has improved by a factor of 2.5 in the course of the past 50 years: In 1960, a converted GDP of 550 Euro was generated per tonne of material used[25] , by 2008 this figure had already risen to 1,353 Euro. In spite of this considerable improvement in efficiency by a factor of 2.5 (or 146 %), absolute material use increased. During the same period, the economy grew by a factor of 4.3, that is 325 %.

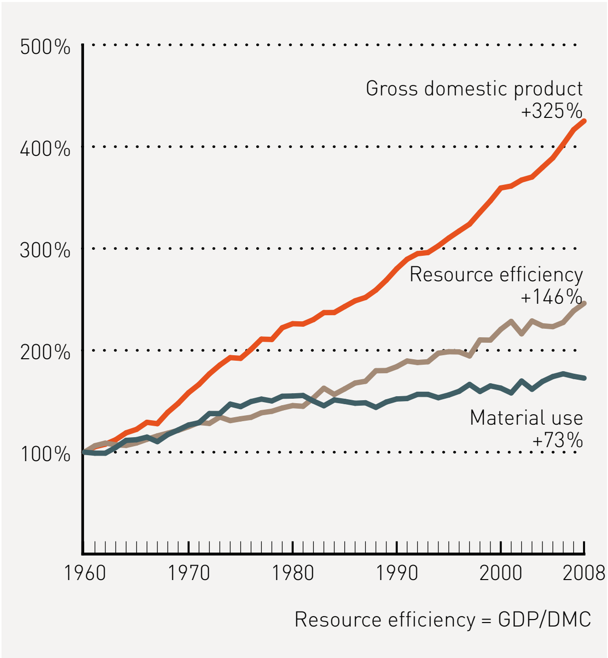


Figure 24: Economic growth, material use and resource efficiency in Austria, 1960 – 2008, 1960 = 100 %
Economic growth as real gross domestic product (GDP), concatenated volume data 2005
Source: Statistics Austria 2011 d; Havel et al. 2010

Resource efficiency measures the economic output that can be generated per unit of resource input. The overall economic resource efficiency (also referred to as resource productivity) is expressed as gross domestic product (GDP) per domestic material consumption (DMC).

25 Real GDP, concatenated to volume data for 2005 (Havel et al. 2010). In an analysis over a certain period of time resource efficiency therefore has to be calculated with the real GDP (at constant prices) to avoid distortions resulting from changes in prices (e.g. due to inflation).

In an European comparison of resource efficiency, Austria ranks in the upper third

In 2007, resource efficiency in the EU-27[26] amounted to approximately 1,510 Euro per tonne of material used. Variations within the EU are, however, considerable. Resource efficiency is highest in the Netherlands, where almost 3,300 Euro of GDP are generated per tonne of material. With 1,368 Euro per tonne[27], Austria ranks ninth in the list of EU Member States, slightly below the EU-27 average. What is striking here is the low resource efficiency of the new EU countries, where an average of only 482 Euro per tonne was generated in 2007.

A direct comparison of resource efficiency beyond national borders is difficult, however. Apart from the very different patterns of resource use (due to population density, climatic differences, economic specialisations, etc. – see Chapter 1, page 10), there is also a systematic connection between resource efficiency and the level of GDP (Steinberger, Krausmann 2011). Since resource use usually grows more slowly than the economy in industrialised countries , richer countries almost automatically have higher resource efficiency than countries with a low per capita GDP.

This is evident also in the low efficiency determined for the new EU Member States. Country rankings in terms of resource productivity are thus essentially the same as lists prepared in terms of income (in GDP per capita). Comparisons of resource productivity are therefore useful and informative above all over longer periods of time.

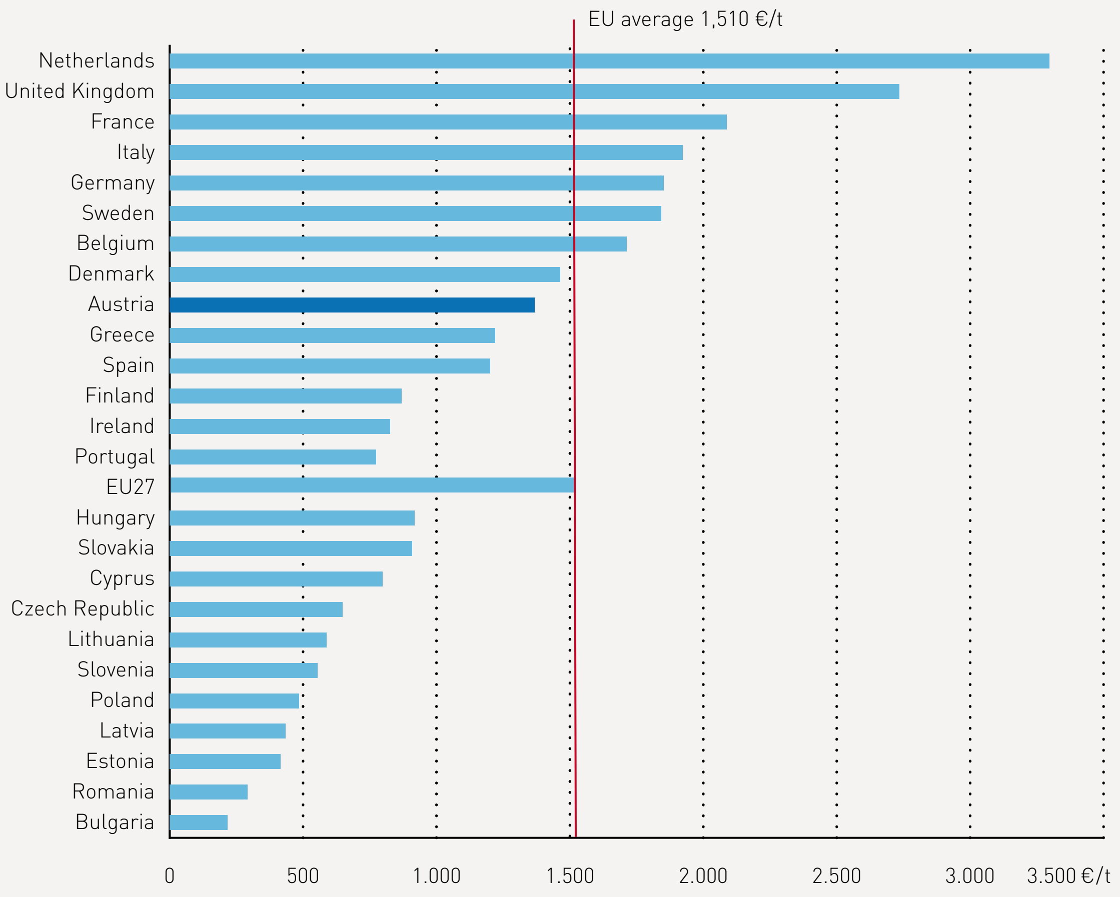


Figure 25: Resource efficiency in the Member States of the EU-27 in 2007 as GDP/DMC in €/t
Resource efficiency is calculated from GDP/DMC. GDP was calculated as the gross domestic product at market prices (Eurostat 2011).

26 Due to data problems, Malta and Luxembourg have not been considered in the calculation of the EU-27 average. However, due to their comparatively small size their omission does not influence the result.
27 The resource efficiency for the EU-27 has been calculated using GDP at market prices (nominal GDP).

Decoupling does not automatically mean declining resource use

Successful decoupling of economic growth and resource use is reflected in higher resource efficiency (also referred to as 'resource productivity'). In the case of materials, resource efficiency is calculated by dividing the economic output by the material use (GDP/DMC). An increase in resource efficiency means that less material is used to produce the same economic output. However, such an increase does not automatically mean a reduction in resource use in absolute terms, but only indicates that the economy is growing faster than resource use does. For this reason a distinction is made between two cases of decoupling:

- **Decoupling with rising resource use ("relative decoupling"):**
  Both economic performance and resource use grow, but the growth rate of resource use is lower than that of the economic growth. As a consequence, resource productivity increases. This is the norm in most industrialised countries.

- **Decoupling with declining resource use ("absolute decoupling"):**
  In this case economic growth is achieved while resource use falls in absolute terms. Resource productivity grows faster than the economy does. For longer periods of time, such a development has been observed in only a few cases which, however, have remained exceptions thus far.

What does this mean for Austria? In the course of the past 50 years, Austria's resource efficiency has increased by 146 %, resource use by 73 %, and economic performance by about 325 % (see Figure 24). Austria has thus managed to decouple its economic growth from resource use, yet its overall resource use has nonetheless continued to rise.

Reduction of resource use thus far only in combination with modest economic growth

A vital issue in the analysis of resource efficiency is whether or not a country achieves an actual reduction of resource use. Only three European countries have managed to do so during recent decades: Great Britain, Germany and Italy. The reasons for this are very different; radical de-industrialisation or the outsourcing of material-intensive production play an important role. It has however not yet been possible to deduce general patterns, but an international comparison does however show that countries only manage to reduce their resource use over several years during periods of weak economic growth (below 2 % p.a.). As soon as economic growth exceeds 2 %, resource use also increases (Krausmann et al. 2011). Further analyses will be required to show whether it is really possible to provide empirical evidence for the interrelation – weak economic growth as an indispensable prerequisite for an absolute reduction in resource use.

The rebound effect: Rising resource use in spite of gains in efficiency

When looking at the development of resource efficiency in European countries, one can see many cases of "relative" decoupling (as in Austria), but only exceptional cases where a real reduction of resource use has been achieved. One of the reasons why resource use continues to increase in most cases is the so-called rebound effect (Weizsäcker et al. 2009): Savings from efficiency gains are used to increase production and/or consumption. This is due to the fact that improvements in efficiency are an important driving force for economic development. Savings resulting from higher efficiency are usually not realised, but instead are (over)compensated by increased production (Polimeni et al. 2008). This means that smaller amounts of resources are used per output (efficiency gains), but that the total output increases, and to an extent which exceeds the efficiency gains per unit. Efficiency gains translate into price advantages which drive the consumption of the relevant service and consequently further increase the use of resources.

From labour productivity to resource productivity

Over the past centuries, labour productivity in economic production has seen remarkable growth rates. For example, labour productivity increased at first by one percent annually and, from the mid-20th century onward, even by 2 – 3 % annually (Weizsäcker et al. 2009). Due to growing awareness of the limited availability of natural resources and, even more, due to dramatically rising raw material prices, experts anticipate that the economy will in the future pay greater attention to resource productivity. It is therefore expected that the growth rates of resource productivity will outpace those of labour productivity and that the efficient use of resources will become a key issue in technology development (Weizsäcker et al. 2009).

Economic growth and quality of life – are the two inseparable?

The question of decoupling resource use and economic growth is also discussed in a broader context. Attention focuses on the question of what economic growth is like; the quality of growth is gaining in importance. So what is this new debate on economic growth about?

For many years, the production of goods and services has exhibited significant growth. Large sectors of society and many countries in the world have attained a high level of material wealth in this way. Economic growth has contributed much to prosperity during the past few decades, yet the "side effects" should, however, not be neglected. These include on the one hand the negative impacts of our excessive use on nature and the environment. Natural resources are becoming ever more scarce, biodiversity is declining, and our climate is changing. On the other hand, economic growth has had little impact upon the unequal distribution of assets and income within most societies and between the individual regions of the world. Numerous international studies show that material wealth (e.g. income) plays an important role in personal happiness, but that when a certain level of prosperity is attained, this its significance ceases to grow. Greater consumption no longer increases happiness. Rather, social cohesion, good health and an intact environment gain in significance and become equally important factors for quality of life.

These findings have reignited the debate surrounding economic growth. This debate focuses on how an economy that is not dependent on permanent growth could look like. There is a call for an economic development that goes beyond quantitative growth ("beyond growth") – and is instead attuned to the goals of sustainability. Prosperity and quality of life are to be central rather than the permanent expansion of economic production (measured by the GDP).

Initiative "Growth in Transition"

In 2008, the initiative "Growth in transition" was launched in Austria, based on the idea that a shift is needed from quantitative growth (increase in economic performance) towards qualitative growth (increase in well-being and quality of life). The initiative focuses on the question of how to ensure the long-term environmental and social sustainability of our economic model, also in order to make the economy more immune to crises. In this context, the introduction of new methods of measuring prosperity and quality of life going beyond gross domestic product are necessary.

The discussion in the context of this initiative concerns a great number of themes such as: money and the financial system, growth and resource use, social justice and poverty, sustainable production and sustainable consumption, regional aspects, macroeconomic questions, quality of life and the measuring of prosperity, work, governance and sustainable management. More can be read about the various arguments on this theme in the publication "Welches Wachstum ist nachhaltig?" (Hinterberger et al. 2009).

A central plank of this initiative is that work on the topic comes under the aegis of several relevant ministries and is supported by over 15 partner organisations.

The question "What kind of growth is needed for sustainable development?" was also the central focus of an international conference with about 550 participants, held in January 2010 in Vienna. Numerous other events have already been organised in the framework of the initiative "Growth in transition" and more activities are set to follow.

www.growthintransition.eu

5 Scenarios for the Future

The preceding chapters have shown that resource efficiency in Austria has increased over recent years. However, resource efficiency has grown at a slower pace than the economy, so that resource use has not decreased in absolute terms. One of the reasons for this is the so-called "rebound effect" (see above).

In the final chapter of this publication, different scenarios are presented that show how resource use and resource efficiency in Austria might theoretically develop by 2020 or 2050. These did not involve complex model calculations, but rather simple assessments and extrapolations of possible development paths. The scenarios depicted do not therefore represent real forecasts, but offer instead a glimpse into the future of how resource use in Austria might develop according to changing variables. The results are meant to foster discussion and to provide a sense of the magnitude of the reductions in resource use that are necessary.

Seven scenarios have been calculated based on the following assumptions: For population development, we used the forecast provided by Statistics Austria (Hanika 2010). Regarding economic growth, it was assumed that annual growth rates will continue to decline between 2008 and 2050; in other words, a linear development from 2 % in 2008 to 1 % in 2050 was assumed. Development was extrapolated based on these assumptions and the targets set for the scenarios. Feedback loops or rebound effects were not taken into account. The scenarios begin in the year 2008 and extend to 2020 or 2050, as indicated.

Table 5 summarises the initial situation relating to resource use in and growth rates up to 2008. The results of the scenarios can thus be compared with these initial values.

Resource use, Austria 2008		DMC: 197 million t DMC per capita: 24 t/(cap*a)
Growth	Growth rate 1996 – 2008 total	Average annual growth rate (Ø p.a.)
GDP real GDP = Gross Domestic Product	34 %	2,5 %
DMC DMC = Domestic Material Consumption	8 %	0,6 %
RE RE = Resource efficiency = GDP/DMC	24 %	1,8 %

Table 5: Resource use in Austria in 2008 and growth rates of the economy, of material use (DMC) and resource efficiency between 1996 and 2008

Scenario 1: Business as usual

Resource use Austria 2020	Growth*	Total	Ø p.a.
213 million t	GDP:	25%	1,9%
24 t per capita	DMC:	8%	0,6%
	RE:	15%	1,2%

The assumption in Scenario 1 is that the developments observed in recent years will continue until 2020 ("business as usual"), and the economy (GDP) will as expected experience slower growth (on average 1.9% annually or a total growth rate of 25% for the period between 2008 and 2020). Total resource use (DMC) would grow by 0.6% per year and, in 2020, would be 8% higher than in 2008. In this case, resource efficiency (RE) would exhibit an annual increase of 1.2% or an overall increase of 15%. The per capita resource use would hardly change in comparison to 2008 and would amount to approximately 24 tonnes in 2020.

Scenario 2: Freezing resource use

Resource use Austria 2020	Growth*	Total	Ø p.a.
197 million t	GDP:	25%	1,9%
23 t per capita	DMC:	0%	0%
	RE:	25%	1,9%

In Scenario 2, resource use – measured as domestic material consumption (DMC) – is "frozen" at the level of 2008. Resource use thus grows by 0%, which means it does not increase further. The economy, on the other hand, grows by 1.9% annually, or by 25% altogether. As a result, resource efficiency increases at the same pace as the economy grows, which is by 1.9% p.a. The per capita resource use would decline only insignificantly, to 23 tonnes per person, due to a slight growth in population.

Scenario 3: Resource efficiency increases by 3% annually

Resource use Austria 2020	Growth*	Total.	Ø p.a.
172 million t	GDP:	25%	1,9%
20 t per capita	DMC:	-13%	-1,1%
	RE:	43%	3%

Scenario 3 assumes that resource efficiency improves by 3% annually. With an economic growth rate of 1.9% p.a. this would cause resource use to decline by 1.1% per year or by 13% overall. This would mean a "saving" of 4 tonnes per capita for each Austrian by 2020 compared to 2008; material use would thus decrease to 20 tonnes per person.

*) GDP = Gross Domestic Product
DMC = Domestic Material Consumption
RE = Resource efficiency = GDP/DMC
Growth relates to the periods 2008 – 2020 or 2008 – 2050, respectively.
Ø p.a. = average annual growth rate

Scenario 4: Absolute resource use decreases by 20 %

Resource use Austria in 2020	Growth*		Total	Ø p.a.
157 million t		GDP:	25 %	1,9 %
18 t per capita		DMC:	-20 %	-1,8 %
		RE:	56 %	3,8 %

The first three scenarios were not very ambitious, if one considers that they did not lead to any significant reduction in resource use. If Austria really wants to play a leading role here, then more courageous steps will have to be taken. Reducing absolute resource use by 20 % would constitute a clear signal and would set an example at the international level. But what would this mean? Resource efficiency would have to rise markedly by 2020, more specifically by 3.8 % p.a., or by 56 % across the whole period. The level of per capita resource use would, at 18 t per capita, be a whole 6 t per capita lower than today – an ambitious but entirely feasible goal.

For the first four scenarios, we focused on changes by the year 2020. However, improvements in resource efficiency in the interests of sustainable development require a more long-term perspective. Three further scenarios are presented below that extend to the year 2050.

Scenario 5: Halving resource use by 2050

Resource use Austria in 2050	Growth*		Total	Ø p.a.
98 million t		GDP:	87 %	1,5 %
10 t per capita		DMC:	-50 %	-1,6 %
		RE:	274 %	3,2 %

If one considers sustainability over a rather longer term and in the global context, more significant savings in the industrialised countries are indispensible if the so-called developing countries are to have adequate opportunities for their economic and social development. Halving resource use (in the industrialised countries) by 2050 is a great challenge, but one that is both appropriate and necessary, and it has been called for by many scientists (recently in Fischer-Kowalski et al. 2011). In this scenario, resource efficiency would have to increase by a total of 274 % or 3.2 % p.a. Per capita resource use in Austria would decline enormously, namely to 10 tonnes per person by 2050.

*) GDP = Gross Domestic Product
DMC = Domestic Material Consumption
RE = Resource efficiency = GDP/DMC
Growth relates to the periods 2008 – 2020 or 2008 – 2050, respectively.
Ø p.a. = average annual growth rate

Scenario 6: Factor 4 by 2050

Resource use Austria in 2050	Growth*		Total	Ø p.a.
49 million t		GDP:	87 %	1,5 %
5 t per capita		DMC:	-75 %	-3,2 %
		RE:	647 %	4,9 %

As early as the 1990s, Ernst Ulrich von Weizsäcker, Amory and Hunter Lovins (Weizsäcker et al. 1995) put forward the concept of Factor Four: "doubling wealth, halving resource use".[28] If the present unequal distribution of resource use between highly developed industrialised countries and the so-called developing countries is taken into account and equal opportunities are claimed for all, the Factor Four concept must be applied at the global level. In this case, the industrialised countries would have to reduce their resource use by at least 75 % so as not to impair the development of the so-called developing countries. The present calculation therefore assumes a reduction of DMC by 75 % (factor 4). For Austria, a reduction of resource use by a factor of 4 would mean that per capita resource use would have to decrease to 5 t per capita, which is significantly below the present global average of approx. 9 t per capita.

By comparison, the last time that material use in Austria was at such a low level was around 1800 at 4 t per capita (Krausmann et al. 2008). In this scenario, resource efficiency would rise by 4.9 % each year until 2050 (647 % for the entire period).

Scenario 7: Factor 10

Resource use Austria in 2050	Growth*		Total	Ø p.a.
20 million t		GDP:	87 %	1,5 %
2 t per capita		DMC:	-90 %	-5,3 %
		RE:	1769 %	7,2 %

Also in the 1990s, Friedrich Schmidt-Bleek went a step further in his deliberations relating to the concept of dematerialisation and called for the reduction of resource use by a factor of 10 (Schmidt-Bleek and Bierter 1998). If we apply this scenario to Austria under the above-mentioned conditions for GDP and population growth, material use would have to be reduced by 90 % (factor 10) and resource efficiency would have to rise by 7.2 % annually (a total increase of 1769 %). In this case, only 2 tonnes of material per capita would still be available for use by each Austrian. The intermediate inputs ("ecological rucksacks", detailed above), which play a critical role in dematerialisation are not taken into account.

*)GDP = Gross Domestic Product
DMC = Domestic Material Consumption
RE = Resource efficiency = GDP/DMC
Growth relates to the periods 2008 – 2020 or 2008 – 2050, respectively.
Ø p.a. = average annual growth rate

28 In a more recent publication Ernst Ulrich von Weizsäcker now argues the case for Factor Five (Weizsäcker et al. 2009).

Resource-efficient Austria: Summary of the 7 scenarios

		Resource use (DMC)		Increase in resource efficiency		
		Million t	t / capita	p.a.	Total	Factor
2020	1) Business as usual	212	24	1,2%	15%	1,2
2020	2) Freezing resource use	197	23	1,9%	25%	1,2
2020	3) Resource efficiency increases by 3%	172	20	3,0%	43%	1,4
2020	4) Resource use decreases by 20%	157	18	3,8%	56%	1,6
2050	5) Halving resource use	98	10	3,2%	274%	3,7
2050	6) Factor 4	49	5	4,9%	647%	7,5
2050	7) Factor 10	20	2	7,2%	1769%	19

Sustainable and efficient use of resources in the future means a carefully approach to raw materials, the natural environment and its cycles. Sustainable development also means the just distribution of resources, and of development opportunities, on a global scale. Resource efficiency will no longer be a marginal issue in the future and its implementation will entail the employment of measures on many different levels: from the full exploitation of technological potential, the strengthening of a closed-circle economy, the economic utilisation of secondary raw materials and the creation of a resource-efficient form of production across the entire life cycle to the restructuring of our society and the rethinking of societal values to move towards a new understanding of consumption. The goal must be to attain an approach to nature, its natural resources and raw materials, which is both more just and more considerate. A dramatic increase in resource efficiency opens up enormous opportunities for Austria's environment, economy, and society.

Bibliography

Aachener Stiftung Kathy Beys (2011): Sustainable Resource Management Needs to Consider Both Used and Unused Extraction. Aachen.
Ayres, Robert U. (1994): Industrial Metabolism: Theory and Policy. In: Ayres, Roger U.; Simonis, Udo. E. (Ed.): Industrial Metabolism: Restructuring for Sustainable Development. Tokyo, New York, Paris: United Nations University Press, pp. 3 – 20.
Bringezu, Stefan; Bleischwitz, Raimund (2009): Sustainable Resource Management. Global Trends, Visions and Policies. Sheffield, UK: Greenleaf Publishing Limited.
Brunner, Paul H.; Rechberger, Helmut (2002): Anthropogenic Metabolism and Environmental Legacies. In: Encyclopedia of Global Environmental Change 3, pp. 54 – 72.
Commission of the European Communities (2005): Thematic Strategy on the Sustainable Use of Natural Resources. Brussels: Commission of the European Communities (CEC).
Czichos, Horst; Hennecke, Manfred (2008): Hütte – Das Ingenieurwissen. Berlin: Springer.
Daxbeck, Hans; Buschmann, Heinz; Neumayer, Stefan; Brandt, Bernd (2009): Methodology for Mapping of Physical Stocks. Resource Management Agency (RMA).
Eco-Institute (Institute for Applied Ecology) (2009): Global Emission Model of Integrated Systems (GEMIS) 4.5. Darmstadt: Eco-Institute.
Erb, Karl-Heinz; Krausmann, Fridolin; Schulz, Niels B. (2001): Der ökologische Fußabdruck des österreichischen Außenhandels. Social Ecology Working Paper 62. Vienna: IFF Social Ecology.
European Commission (2010): Europa 2020. A Strategy for Smart, Sustainable and Inclusive Growth. Brussels: European Commission.
European Commission (2011 a): Tackling the Challenges in Commodity Markets and on Raw Materials. Brussels: European Commission.
European Commission (2011 b): A Resource-Efficient Europe – Flagship Initiative under the Europe 2020 Strategy. Brussels: European Commission.
European Commission and Eurostat (2011): Environmental Economic Accounts (EA). http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/introduction.
European Commission (2008): The Raw Materials Initiative. Meeting Our Critical Needs for Growth and Jobs in Europe. Brussels: European Commission.
European Commission (2010): Critical Raw Materials for the EU. Report of the Ad-hoc Working Group on Defining Critical Raw Materials. Brussels: European Commission. Enterprise and Industry, pp. 1 – 85.
European Commission und Eurostat (2011): Physical and Hybrid Environmental Accounts. http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/publications/physical_and_hybrid_environmental_accounts.
Eurostat (2001): Economy-wide Material Flow Accounts and Derived Indicators. A Methodological Guide. Luxembourg: Eurostat, European Commission, Office for Official Publications of the European Communities, pp. 1 – 92.
Eurostat (2009 a): Economy-wide Material Flow Accounts. Compilation Guidelines for Reporting to the 2009 Eurostat Questionnaire (Version 01 – June 2009). Luxembourg: European Statistical Office.
Eurostat (2009 b): Material Flow Data (MFA data collection 2007). Luxembourg: Eurostat.
Eurostat (2010 a): Revised European Strategy for Environmental Accounting. http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/documents/ESEA_REVISION_2008_0.pdf.
Eurostat (2010 b): Environmental accounts (EA). http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/introduction.
Eurostat (2011): National accounts (incl. GDP). http://epp.eurostat.ec.europa.eu/portal/page/portal/national_accounts/introduction.
FAOSTAT (2010): FAO Statistical Database. Rom: Food and Agriculture Organization (FAO) http://faostat.fao.org/site/573/default.aspx#ancor.
Federal Institute of Agricultural Economics (AWI) (2011): Daten und Fakten. http://www.agraroekonomik.at/index.php?id=datenfakten.
Federal Institute for Geosciences and Natural Resources (BGR) (2009): Energierohstoffe 2009 – Reserven, Ressourcen, Verfügbarkeit. Hannover: BGR.
Federal Ministry of Economy, Family and Youth (BMWFJ) (2010): Der Österreichische Rohstoffplan (The Austrian Mineral Resources Plan). http:www.bmwfj.gv.at/EnergieUndBergbau/Rohstoffplan/Seiten/default.aspx.

Federal Ministry of Economy, Family and Youth (BMWFJ); Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) (2010): Energiestrategie Österreich. Vienna.
Federal Office and Research Centre for Forests (BFW) (2011): Österreichische Waldinventur 2007/09 – Hauptergebnisse. Vienna.
Fettweis, G. B.; Lechner, E.; Schmidt, W. J. (1987): Leitlinien der Entwicklung im Bergbau auf feste mineralische Rohstoffe. In: Bergbau im Wandel. Essen: Akad. Druck- und Verlagsanstalt, Graz. Verlag Glückauf GmbH.
Fischer-Kowalski, Marina (1998): Society's Metabolism. The Intellectual History of Material Flow Analysis, Part I: 1860 – 1970. In: Journal of Industrial Ecology 2(1), pp. 61 – 78.
Fischer-Kowalski, Marina; Amann, Christof (2001): Beyond IPAT and Kuznets Curves: Globalization as a Vital Factor in Analysing the Environmental Impact of Socio-Economic Metabolism. In: Population and Environment 23(1), pp. 7 – 47.
Fischer-Kowalski, Marina; Haberl, Helmut (1997): Stoffwechsel und Kolonisierung: Konzepte zur Beschreibung des Verhältnisses von Gesellschaft und Natur. In: Fischer-Kowalski, M. et al. (Ed.): Gesellschaftlicher Stoffwechsel und Kolonisierung von Natur. Amsterdam: Gordon & Breach Fakultas, Vol. 1.1, pp. 3 – 12.
Fischer-Kowalski, Marina; Haberl, Helmut; Hüttler, Walter; Payer, Harald; Schandl, Heinz; Winiwarter, Verena; Zangerl-Weisz, Helga (1997): Gesellschaftlicher Stoffwechsel und Kolonisierung von Natur. Ein Versuch in Sozialer Ökologie. Amsterdam: Gordon & Breach Fakultas.
Fischer-Kowalski, Marina; Hüttler, Walter (1998): Society's Metabolism. The Intellectual History of Material Flow Analysis, Part II: 1970 – 1998. In: Journal of Industrial Ecology 2(4), pp. 107 – 137.
Fischer-Kowalski, Marina; Swilling, Mark; Weizsäcker, Ernst U. v.; Crane, Wendy; Siriban-Manalang, Anna B.; Ren, Yong; Moriguchi, Yuichi; Krausmann, Fridolin; Eisenmenger, Nina; Giljum, Stefan; Lankao, P. R.; Kemp, Rene (2011): Decoupling the Use of Natural Resources and Environmental Impacts from Economic Activity: Scoping the Challenges. Nairobi: United Nations Environmment Programme.
Forum Rohstoffe (2007): Die volkswirtschaftliche Bedeutung mineralischer Rohstoffe in Österreich. Vienna. pp. 1 – 14.
Gierlinger, Sylvia; Krausmann, Fridolin (2011): The Physical Economy of the United States of America: Extraction, Trade and Consumption of Materials from 1870 to 2005. In: Journal of Industrial Ecology; submitted March 2011.
Giljum, Stefan (2004): Trade, Material Flows and Economic Development in the South: The Example of Chile. In: Journal of Industrial Ecology 8 (1 – 2), pp. 241 – 261.
Hanika, Alexander (2010): Bevölkerungsvorausschätzung 2010 – 2050 sowie Modellrechnung bis 2075 für Österreich (Hauptszenario). Vienna: Statistik Austria.
Havel, Ursula et al. (2010): Volkswirtschaftliche Gesamtrechnungen 1978 – 2009, Hauptergebnisse. Vienna: Statistik Austria.
Hinterberger, Friedrich; Hutterer, Harald; Omann, Ines; Freytag, Elisabeth (Ed.) (2009): Welches Wachstum ist nachhaltig? Vienna: Mandelbaum-Verlag.
Kneese, Allen V.; Ayres, Robert U.; d'Arge, Ralph (1970): Economics and the Environment. A Materials Balance Approach. Washington, D.C.: Resources for the Future, INC.
Koller, Wolfgang (2007): Die volkswirtschaftliche Bedeutung mineralischer Rohstoffe in Österreich. Endbericht zur IWI-Studie. Wien: Industriewissenschaftiches Institut on behalf of the Forum für Mineralische Rohstoffe.
Kovanda, Jan; Havranek, Miroslav; Hak, Tomas (2007): Calculation of the "Net Additions to Stock" Indicator for the Czech Republic Using a Direct Method. In: Journal of Industrial Ecology 11(4), pp. 140 – 154.
Krausmann, Fridolin; Fischer-Kowalski, Marina; Schaffartzik, Anke; Steinberger, Julia K.; Eisenmenger, Nina; Weisz, Ulli (2011): Trends and Developments of the Use of Natural Resources in the European Union. Social Ecology Working Paper 123. Vienna: IFF Social Ecology.
Krausmann, Fridolin; Fischer-Kowalski, Marina; Schandl, Heinz; Eisenmenger, Nina (2008): The Global Socio-Metabolic Transition: Past and Present Metabolic Profiles and their Future Trajectories. In: Journal of Industrial Ecology 12(5/6), pp. 637 – 656.
Krausmann, Fridolin; Gingrich, Simone; Eisenmenger, Nina; Erb, Karl-Heinz; Haberl, Helmut; Fischer-Kowalski, Marina (2009): Growth in Global Materials Use, GDP and Population during the 20th Century. In: Ecological Economics 68(10), pp. 2696 – 2705.
Krausmann, Fridolin; Haberl, Helmut; Schulz, Niels B.; Erb, Karl-Heinz; Darge, Ekkehard; Gaube, Veronika (2003): Land-Use Change and Socio-Economic Metabolism in Austria. Part I: Driving Forces of Land-Use Change: 1950 – 1995. In: Land Use Policy 20(1), pp. 1 – 20.
Lebensministerium – Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) (2011): WASSERnet: Wasserverbrauch allgemein. http://www.wassernet.at/article/articleview/56056/1/5740.

Lebensministerium – Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), Statistics Austria, Federal Environment Agency (Umweltbundesamt GmbH) (2011 a) http://www.umweltgesamtrechnung.at/.
Markt-Daten.de (2011): Reuters CRB Index. http://www.markt-daten.de/charts/rohstoffe/rohstoffindices/crb.htm.
Milota, Eva; Schaffartzik, Anke; Eisenmenger, Nina (2011): Ressourcendaten – Verbesserung des statistischen Datenmaterials im Bereich natürliche Ressourcen. Projektbericht. Vienna: Statistik Austria.
Ministry of the Environment (2007): Material Flow Account for Japan. Tokyo, Japan: Ministry of the Environment.
Müller, Daniel B.; Wang, Tao; Duval, Benjamin; Graedel, T. E. (2006): Exploring the Engine of Anthropogenic Iron Cycles. In: Proceedings of the National Academy of Sciences of the United States of America 103(44), pp. 16111 – 16116.
Nötstaller, Richard; Wagner, Horst (2007): Überlegungen zum Rohstoffbedarf und zur Rohstoffpolitik. In: BHM Berg- und Hüttenmännische Monatshefte 152(12), pp. 383 – 390.
Petz, Karl C. (2001): Vergleichende Abschätzung des Flächenverbrauchs in Österreich. In: Umweltbundesamt (Ed.): Versiegelt Österreich? Der Flächenverbrauch und seine Eignung als Indikator für Umweltbeeinträchtigungen. Wien: Tagungsunterlage des Umweltbundesamtes, pp. 5 – 9
Polimeni, John M.; Mayumi, Kozo; Giampietro, Mario; Alcott, Blake (2008): The Myth of Resource Efficiency. The Jevons Paradox. London: Earthscan.
Rechberger, Helmut (2009): Die anderen Tonnen. In: Urban, Arnd I.; Halm, Gerhard (Ed.): Kasseler Modell – mehr als Abfallentsorgung. Schriftenreihe des Fachgebietes Abfalltechnik. Kassel: kassel university press GmbH. pp. 171 – 177.
RMA (2011): Schätze in der Stadt. Wien: Ressourcen Management Agentur (RMA) in cooperation with the Federal Ministry of Economy, Family and Youth and the Federal Ministry of Agriculture, Forestry, Environment and Water Management.
Schaffartzik, Anke; Krausmann, Fridolin; Eisenmenger, Nina (2011): Der Rohmaterialbedarf des österreichischen Außenhandels. Social Ecology Working Paper 125. Vienna: IFF Social Ecology.
Schmidt-Bleek, Friedrich (1994): Wieviel Umwelt braucht der Mensch? MIPS – das Maß für ökologisches Wirtschaften. Berlin-Basel-Boston: Birkhäuser.
Schmidt-Bleek, Friedrich; Bierter, Willy (1998): Das MIPS-Konzept: weniger Naturverbrauch – mehr Lebensqualität durch Faktor 10. München: Droemer Knaur.
Shen, Li; Haufe, Juliane; Patel, Martin K. (2009): Product Overview and Market Projection of Emerging Bio-Based Plastics. Utrecht, Netherlands: Utrecht University.
Singh, Simron J.; Krausmann, Fridolin; Gingrich, Simone; Haberl, Helmut; Erb, Karl-Heinz; Lanz, Peter (2011): India's Biophysical Economy, 1961 – 2008. Sustainability in a National and Global Context. In: Regional Environmental Change; submitted 2/2011.
Smil, Vaclav (1991): General Energetics. Energy in the Biosphere and Civilization. Manitoba, New York: John Wiley & Sons.
Statistics Austria (2010): Input-Output-Statistik. http://www.statistik.at/web_de/statistiken/volkswirtschaftliche_gesamtrechnungen/input-output-statistik/index.html.
Statistics Austria (2011 a): Das System der Volkswirtschaftlichen Gesamtrechnung (VGR). http://www.statistik.at/web_de/statistiken/volkswirtschaftliche_gesamtrechnungen/index.html.
Statistics Austria (2011 b): Energiebilanzen. http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/energiebilanzen/index.html.
Statistics Austria (2011 c): Energiegesamtrechnung. http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/energiegesamtrechnung/index.html.
Statistics Austria (2011 d): Materialflussrechnung. http://www.statistik.at/web_de/statistiken/energie_und_umwelt/umwelt/materialflussrechnung/index.html.
Statistics Austria (2011 e): Produktion und Bauwesen: Leistungs- und Strukturdaten. http://www.statistik.at/web_de/statistiken/produktion_und_bauwesen/leistungs_und_strukturdaten/index.html.
Steinberger, Julia K.; Krausmann, Fridolin (2011): Material and Energy Productivity. In: Environmental Science and Technology 45(4), pp. 1169 – 1176.
Steinberger, Julia K.; Krausmann, Fridolin; Eisenmenger, Nina (2010): Global Patterns of Material Use: A Socioeconomic and Geophysical Analysis. In: Ecological Economics 69(5), pp. 1148 – 1158.
Streicher, Wolfgang; Schnitzer, Hans; Titz, Michaela; Tatzber, Florian; Heimrath, Richard; Wetz, Ina; Hausberger, Stefan; Haas, Reinhard; Kalt, Gerald; Damm, Andrea; Steininger, Karl; Oblasser, Stephan (2010): Energieautarkie für Österreich 2050. Feasibility Study. pp. 1 – 240.
UN, EC, IMF, OECD, World Bank (2003): Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003. New York: United Nations.

UNSD (2010): Environmental-Economic Accounting.
http://unstats.un.org/unsd/envaccounting/.
UNSD (2011): The System of National Accounts (SNA).
http://unstats.un.org/unsd/nationalaccount/sna.asp.
VOEST Alpine (2010): Personal communication.
Weber, Leopold (2007): Der österreichische Rohstoffplan als Werkzeug einer langfristigen Rohstoffsicherung. In: BHM Berg- und Hüttenmännische Monatshefte 152, pp. 252–258.
Weber, Leopold (2011 a): Die österreichische Rohstoffpolitik – Strategie für eine nachhaltige Sicherung mit mineralischen Rohstoffen.
Weber, Leopold (2011 b): World Mining Data. Vienna (Federal Ministry of Economy, Family and Youth).
Weizsäcker, Ernst U. von; Hargroves, K.; Smith, M. H.; Desha, C.; Stasinopoulos, P. (2009): Factor Five. Transforming the Global Economy through 80 % Improvements in Resource Productivity. London: Earthscan.
Weizsäcker, Ernst U. von; Lovins, Amory B.; Lovins, Hunter L. (1995): Faktor Vier – Doppelter Wohlstand, halbierter Naturverbrauch. Der neue Bericht an den Club of Rome. München: Droemer Knaur.

Internet links:

Eurostat: Environmental Accounts (EA).
http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/introduction.
Eurostat: National Accounts (including GDP).
http://epp.eurostat.ec.europa.eu/portal/page/portal/national_accounts/introduction.
Federal Ministry of Economy, Family and Youth (BMWFJ): Der Österreichische Rohstoffplan.
http://www.bmwfj.gv.at/EnergieUndBergbau/Rohstoffplan/Seiten/default.aspx
Federal Ministry of Economy, Family and Youth (BMWFJ):
http://www.bmwfj.gv.at/
Federal Institute of Agricultural Economics (AWI): Daten und Fakten.
http://www.agraroekonomik.at/index.php?id=datenfakten.
Growth in Transition:
http://www.growthintransition.eu
Institute of Social Ecology:
http://www.uni-klu.ac.at/socec/
Institute of Social Ecology: Materialflussdaten und Analysen.
http://www.aau.at/socec/inhalt/1088.htm
Lebensministerium – Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW):
http://www.lebensministerium.at/
Lebensministerium – Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), Federal Environment Agency: Österreichische Umweltgesamtrechnungen.
www.umweltgesamtrechnung.at
SERI: Materialflussdaten.
www.materialflows.net
Statistics Austria: Energiebilanzen.
http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/energiebilanzen/index.html.
Statistics Austria: Energiegesamtrechnung.
http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/energiegesamtrechnung/index.html.
Statistics Austria:
http://www.statistik.at/
Statistics Austria: Materialflussrechnung.
http://www.statistik.at/web_de/statistiken/energie_und_umwelt/umwelt/materialflussrechnung/index.html.
UNSD: Environmental-Economic Accounting.
http://unstats.un.org/unsd/envaccounting/.
UNSD: The System of National Accounts (SNA).
http://unstats.un.org/unsd/nationalaccount/sna.asp.

Annex 1: Material Flow Analysis – Concept, Method, Data Base

Concept

Material flow accounting and analysis (MFA) is an EU-wide harmonised accounting tool for the material inputs, stocks and outputs of a socioeconomic system. It accounts for solid, gaseous and liquid materials, excluding water[29] and air, and is presented in physical units (mass, mostly in tonnes). MFA is organised in analogy to the economic System of National Accounts (SNA).

Material flow accounting measures all material flows that are required for the establishment, operation and maintenance of a society's biophysical structures. These biophysical structures (or "stocks") by definition include all humans and artefacts as well as the entire productive livestock (animal husbandry and aquaculture). Artefacts include the entire infrastructure, buildings, vehicles and machinery, analogous to the SNA, as well as, contrary to the SNA, durable goods. To be able to record the material exchange processes of a socioeconomic system (a national economy) two system boundaries have to be defined in the framework of the MFA:

1. The border between the socioeconomic system and its natural environment from which material is extracted and into which emissions and wastes are released.

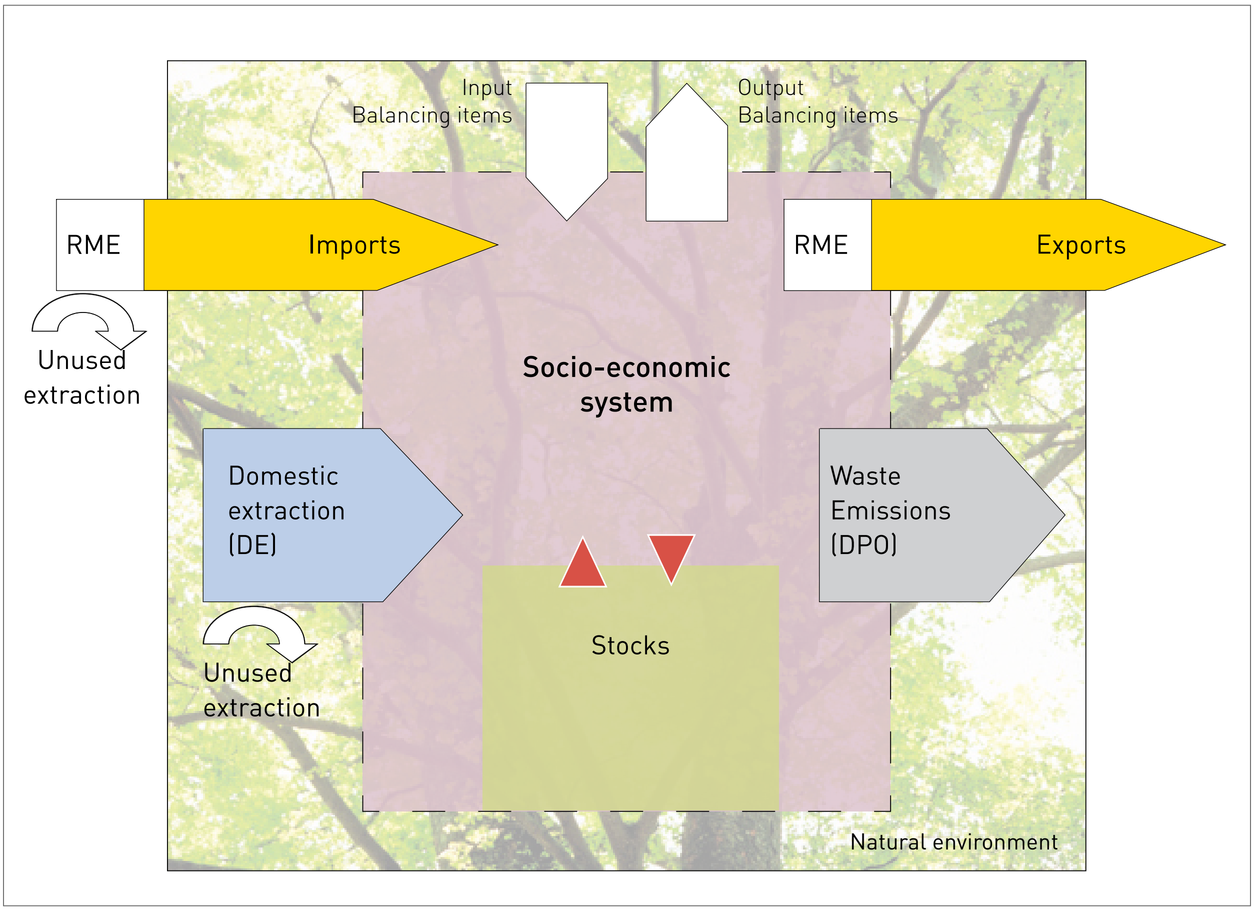


Figure 26: Schematic representation of the system of material flow accounting (MFA)

29 However, water contained in raw materials or goods is taken into account. This concerns harvested cereals, fruit, vegetables and all goods of external trade. In the case of grazed biomass, harvesting by-products and timber, the water content is conventionally calculated to be 15%.

2. The border between the socioeconomic system and other socioeconomic systems (national economies) from which goods are imported and/or to which goods are exported (Figure 26).
Inputs into the socioeconomic system are primarily raw materials extracted in the home country (domestic extraction) as well as imported raw materials and processed goods (imports). **Domestic extraction** is accounted for in terms of all raw materials extracted from nature. This includes raw materials from agriculture and forestry (e.g. arable crops, grazed biomass, timber) and from mining (e.g. coal, iron ore, limestone, salt). Imports, on the other hand, comprise products of very different levels of manufacturing, ranging from iron ore to the mobile phone. Outputs of the socioeconomic system are on the one hand waste and emissions (also **DPO, domestic processed output**) and on the other hand exports. The intermediate material use of imports and exports can be expressed in **raw material equivalents (RME)**. RME encompass the mass of the traded commodity itself as well as all the material inputs that were used in the upstream production process. They are calculated in order to make the effects of outsourcing caused by external trade visible.

In the course of extraction from nature materials are also moved which do not enter the socioeconomic system as utilised extraction, meaning no use by society may be attributed to them. In material flow accounting these movements are jointly referred to as **unused extraction**. The latter includes for example the overburden from mining activities, soil excavated when establishing infrastructure, or crop residues. Other environmental impacts (e.g. soil erosion) resulting from society's use of resources are not considered in MFA; for this purpose, other measuring and observation tools are available.

A decisive factor for ensuring the consistency of a material flow account is the application of the conservation of mass principle. This principle states that, in a closed system, materials and energy can neither be created nor destroyed. Therefore the following equation must be fulfilled:

Inputs = outputs +/- stock changes

In order that the material balance can be closed, **balancing items** have to be introduced into the MFA both on the input and on the output side (water vapour, air as entry into combustion processes, etc.). Those interested to find a detailed description of the treatment of such balancing items may do so in the methodological guides published by Eurostat (Eurostat 2001 and Eurostat 2009 a). Information about the history of material flow accounting and an extensive discussion of the theoretical considerations behind the system of MFA and its conventions can be found in Fischer-Kowalski (1998) and Fischer-Kowalski et al. (2011).

Material flows are usually presented according to **four material categories**: Biomass, non-metallic minerals, metals and fossil energy carriers. Biomass comprises all resources of plant origin extracted from the environment by humans or animals. It therefore includes also grazed biomass. In addition, this category encompasses fishing and hunting, that is, biomass of animal origin extracted from stocks living in the wild. Metals and non-metallic minerals are included in the MFA as ores ("run-of-mine"). This means that minerals are considered with the mass with which they leave the mine – and thus include also the waste rock. Fossil energy carriers (also energy sources) encompass non-metallic mineral raw materials which developed from biomass in the geological past. Conventional energy sources include brown coal, hard coal, petroleum and natural gas. In the future, non-conventional energy sources like, for example, gas hydrate and shale gas will play a crucial role.

In the **basic MFA module** (economy-wide MFA) all direct movements that cross the above-mentioned system boundaries (domestic extraction, imports, exports) are taken into account. The data on domestic extraction, imports and exports collected in the framework of MFA allow the calculation of various indicators, among them also **domestic material consumption (DMC)**, which is used as a key indicator by the Statistical Office of the European Union. It comprises domestic material extraction plus imports minus exports. Domestic material consumption includes all materials that were used in the socioeconomic system, whether in economic production processes or in final consumption. Put differently, DMC may be taken as the measure of the total amount of materials that remain in society and are converted into waste or emissions.

Imports and exports play an increasingly important role in domestic material consumption. On a global level, this leads to the outsourcing of production stages: The production of imported, but also of exported goods, involves intermediate inputs of material and energy that are not taken into account in domestic material consumption. If we calculate the material use taking into account the intermediate inputs involved in the imported and exported goods, we obtain the **raw material consumption** (**RMC**). The RMC thus describes all raw materials used in the production of goods for domestic consumption. In other words, the RMC measures the global raw material requirement of national consumption.

Data sources and methods

The MFA is compiled using the data sets from official statistics. Depending on the relevant material category, Austria's **domestic extraction** (**DE**) is determined based on the following statistical documents:

Biomass:

- Plant Production (STAT)
- Statistics of Agriculture (STAT)
- Timber Felling Report (Federal Ministry of Agriculture, Forestry, Environment and Water Management – BMLFUW)

Fossil energy carriers:

- Energy Balances (STAT)

Non-metallic minerals:

- Mining Data (BMLFUW)
- Short Term Statistics (STAT)
- Supply and Use Tables (STAT)

Metals:

- Mining Data (BMLFUW)

The foreign trade statistics of Statistics Austria, in which both the value and the mass of all goods traded are recorded, is used to determine the quantities of imported and exported materials.

In addition to compiling the data, it is necessary in many cases to convert figures into metric tonnes as a common unit. In Austria, the quantity of timber felled is reported in solid cubic metres, the wine harvest in hectolitres, and the production of natural gas and brine in cubic metres. Moreover, some of the flows of domestic extraction are represented in statistics either poorly or not at all. In such cases the missing data have to be estimated.

Not all raw materials used by society are recorded in official statistics. These material flows, which are in some cases very large in scale, have to be estimated using procedures specifically developed for the purpose:

The domestic extraction of **crop residues** (mainly straw and plant leaves used as bedding material or fodder) and **grazed biomass** is not reported in the agricultural statistics. To estimate the amount of available crop residues information on typical corn to straw ratios for different cultivars are used. It is further assumed that 75% of the available residues are extracted for further use. The residual 25% are left on the field as unused extraction and are therefore not included in the MFA. Also biomass directly grazed by livestock is not covered by the statistics. The amount of grazed biomass is estimated by using a feed balance approach. The calculated feed demand of grazing animals (cattle, sheep, horses) is compared to information on the supply of marketable feed (concentrates) and fodder crops. It is assumed that the difference between available feed and calculated demand is met by grazing. A detailed description of these estimation procedures is provided in the Eurostat MFA Compilation Guide (Eurostat 2009a) or in the Project Report of Statistics Austria (Statistics Austria 2011d).

The extraction of **construction minerals** is insufficiently recorded in official statistics. In Austria, a three-step procedure is implemented which has been developed based on a study of the Institute of Industrial Research (Industriewissenschaftliches Institut – IWI) (Koller 2007). In this procedure, data from the Short Term Statistics ("Konjunkturstatistik") and the Material Input Statistics ("Gütereinsatzstatistik") are used to extrapolate the non-reported extraction. Enterprises below a certain size (cut-off criterion) and the production outside the production sector are not covered by the Short Term Statistics. In both cases the missing data have to be estimated to achieve maximum data completeness for the extraction of construction minerals. The Structural Business Statistics ("Leistungs- und Strukturstatistik") were used to calculate the extraction by smaller enterprises. These data allow for the calculation of the entire amount of the characteristic production of construction minerals. In contrast to the Short Term Statistics, the Structural Business Statistics also cover smaller enterprises. To determine factors for the required estimation of missing data, the production reported in the Structural Business Statistics was related to the production recorded in the Short Term Statistics. The second step of estimating missing data concerns the extraction of construction minerals in the non-producing sector, which also includes the fields of agriculture, trade and transport. Production in these sectors was extrapolated by means of the Austrian Supply and Use Tables (Statistics Austria 2010). These tables report the production of construction minerals in the non-producing sector in monetary values. Based upon the supply table, first the monetary value of the construction minerals production in the non-producing sector was determined. After that, the annual average prices for the two groups of commodities, which were determined from the extrapolated total production, were used to calculate the mass in tonnes, which corresponds to the value of the missing data to be estimated.

Statistical implementation

The material flow account for Austria exists as a time series from 1960 onward and is updated annually by Statistics Austria. At the European level, data from national material flow accounts are collected and published annually by Eurostat. For the EU 15, a time series exists for the years from 1970 onward; for the countries of the EU 27, the MFA time series starts in the year 2000.

Material flow analysis in Austria

For two decades, Austria has played a leading role within Europe in the development of material flow analysis and the associated methodology and has made an important contribution to the establishment of material flow accounting in European Environmental Statistics. Austrian research institutes which – in many cases with the support of the Lebensministerium – deal with various aspects of the material flow analysis include the Institute of Social Ecology of the Alpen-Adria University, Klagenfurt, Vienna, Graz (http://www.aau.at/socec/), the Sustainable Europe Research Institute – SERI (http://seri.at/) and the Institute for Water Quality, Resource Management and Waste Management of the Vienna University of Technology. Material flow accounts for Austria are compiled annually by Statistics Austria.

Data on material use

Over the past few years, data on material use in Austria, the EU and many countries of the world have systematically been made publicly available and can be used via different institutions: Current data on material use in Austria are available at Statistics Austria (Statistics Austria 2011 d). Material flow accounts for the EU Member States can be obtained via the data server of EUROSTAT, the Statistical Office of the European Union (Eurostat 2010 b Environmental Accounts). The Institute of Social Ecology offers access to several national and global data sets and analyses on material use on its homepage http://www.aau.at/socec/inhalt/1088.htm. With the support of the Lebensministerium, the Sustainable Europe Research Institute maintains the web page www.materialflows.net, which provides data on global material extraction by countries since 1980.

Annex 2: Glossary

Environmental accounts are accounts in monetary and physical units which supplement the national accounts so as to provide a comprehensive overview of the interplay between the economy and the environment. For this purpose physical data, concerning raw material, energy, water or land use, waste and waste water disposal as well as atmospheric emissions, are set against economic data, including gross domestic product, income, consumption, investments, etc. Environmental accounts are structured according to the European Union guidelines on environmental indicators and a green national accounting system (Lebensministerium et al. 2011 a, European Commission and Eurostat 2011, UN et al. 2003).

The basis for environmental accounts is still comprised of voluntary recommendations under the European Strategy for Environmental Accounting (ESEA. Eurostat 2010 b or Eurostat 2010 a) or the UN Handbook of National Accounting: Integrated Environmental and Economic Accounting (SEEA. UNSD 2010 or UN et al. 2003). A legal basis, the "Regulation of the European Parliament and of the Council on European Environmental Economic Accounts", was adopted on 6 July 2011.

The System of National Accounts (SNA) is, in principle, a closed system of accounts in which substantial macroeconomic factors are reported as transactions or balances (e.g. gross domestic product (GDP), gross national income, available household income, net lending/net borrowing by the state, private consumption, investments), based on the notion of an economic cycle (Statistics Austria 2011 a).

The SNA has been internationally harmonised by the United Nations System of National Accounts (UNSD 2011). A variant specifically tailored to European conditions is the European System of National Accounts (ESNA 1995 and ESA 1995, see Eurostat 2011). Whereas the SNA is a recommendation, the ESNA is legally binding (EU Regulation).

The term society as used in this publication is complementary to nature (or the "natural system"). Society is a communication system which is coupled with the natural system via biophysical structures. The communication system of society comprises subsystems like the economy, law, politics, and education. Biophysical elements of society include the human population, its infrastructures and artefacts, as well as, by definition, productive livestock. Society must reproduce itself both in respect of culture and communication and biophysically. For biophysical reproduction, that is, the establishment and maintenance of the physical structures of society, resources are used. Furthermore, the term "socioeconomic" as used in the text is synonymous with "social" to point out that the terms "society" or "social" also include the economy.

The concept of social metabolism (Fischer-Kowalski et al. 1997) assumes that in analogy to a biological organism, society also operates in a "metabolism" (or an exchange) with its natural environment. During this process, inputs (e.g. material, energy, water, air) from nature are used, transformed, and partly integrated into its stocks. Sooner or later all these inputs become outputs again, which society discharges to its environment in the form of wastes or emissions. Physical accounts can be used to take stock of this metabolism.

Material Flow Analysis or Material Flow Accounting (MFA, Eurostat 2001, Eurostat 2009 a) is an accounting tool for the material inputs and outputs of a socioeconomic system. The MFA is complementary to economic national accounts and forms part of the environmental accounts. It records all material extractions in the country, imports and exports as well as changes in stock and outputs to nature. The socioeconomic system studied, the economy, is defined analogously to the System of National Accounts (SNA) and the boundaries to the natural environment and to other economies are set accordingly. From the natural environment resources extracted from the domestic territory (domestic extraction, DE) enter the system as inputs and flow back to it as emissions and waste (DPO, domestic processed output). Imports enter the system from other economies and exports leave the system to flow into other economies.

Resources include all physical raw materials and stocks that are intentionally extracted or transformed in nature by society with the objective of generating economic value. The physical resources themselves are not lost when used, but instead are transformed. The specific quality which makes them useful for society is usually consumed and lost in this process. The term "natural resources" refers to raw materials for material or energetic use (also referred to as "materials" and "energy carriers"), to water and land. These natural resources are used by society or enter the process of use by society in that they are processed into derived products and then used. In the empirical analysis, the present publication focuses on material resources, that is, on biomass, fossil energy carriers, metallic and non-metallic minerals.

The term "**material**" is used for the material aspect of resources. Material flows are expressed in metric tonnes and according to four main groups: Biomass, fossil energy carriers, metals and non-metallic minerals. Material flows, as recorded in material flow accounting, can also comprise materials that have been processed into products.

Biomass encompasses the whole range of organic matter: Live plants, animals, micro-organisms, and also dead organic matter (dead wood, leaves, straw, etc.). Biomass is frequently referred to as renewable raw material. It does not include the fossil energy carriers that have their origin in biomass.

Fossil energy carriers are non-metallic minerals which have generated from the decomposition of plants or animals in the Earth's crust over millions of years and are primarily used for the production of energy.

Metals include mineral materials ranging from ores to processed metals. In raw material science, ores are defined as mineral materials from which metals can be extracted with economic benefit. Ores are subdivided into three groups in raw material science, namely ores of iron and steel stabilisers, non-ferrous metals, and precious metals. In material flow analysis, metals are subdivided into iron ores and non-ferrous ores.

The group of the **non-metallic minerals** comprises construction minerals and industrial minerals. Construction minerals are non-metallic mineral raw materials, such as sand and gravel, of which great amounts are needed for construction purposes. Industrial minerals are mineral raw materials which, due to their chemical or physical properties, can be directly used in production processes. Industrial minerals do not include ores, construction minerals and raw materials for energy.

Fossil energy carriers, metallic and non-metallic minerals together are also defined as **mineral raw materials.** Mineral raw materials are anorganic and organic mineral substances in a solid, liquid or gaseous state which developed through geological processes by natural means, were enriched in deposits and, due to their utility value, can be exploited economically.

Domestic extraction (DE) encompasses all domestically extracted materials. This includes the agricultural harvest, the timber felled and the products of mining.

Physical **imports** and **exports** comprise all goods traded at the weight they exhibit at the time of crossing the border. The goods include products from widely varying stages of production, ranging from simple products to semi-finished and finished products. In the MFA, the products traded are allocated to one of the four material categories depending on their main components. There are products which cannot be assigned to any of the four material categories; they are subsumed under the category "Other products". Examples of such products are factories, antiques, optical elements.

Domestic material consumption (DMC) describes the share of materials which remains in a national economy. The DMC therefore equals the domestic material extraction plus imports and minus exports.

Physical trade balance (PTB) is calculated by subtracting the exports from the imports. It is defined reverse to the monetary trade balance (which equals exports minus imports). This indicates that money and material move in opposite directions in economies (imports mean that money flows abroad while material enters the country in the form of the product). A positive PTB (imports exceed exports) means that the country is a net importer of materials and thus depends on the supply of materials from abroad, whereas a negative PTB characterises countries which offer materials on the global market for use in other countries.

Raw material equivalents (RME) of the imports and exports are composed of the entire material inputs that were required in the production of the traded goods (intermediate inputs of material), plus the mass of the imports and exports themselves. RME correspond to the entire raw materials from which an import or export is constituted, regardless of where (i. e. in which economy) the raw materials were used in the course of production.

Raw material consumption (RMC) is the domestic material consumption expressed in raw material equivalents. It therefore consists of the domestic extraction plus the imports expressed in RME and minus the exports expressed in RME. The RMC thus describes the total demand for raw material which a country uses on a national and global level as a result of its final use.

Resource efficiency (observing material flows as GDP/DMC) describes the relation between monetary output and resource input: How many Euros of GDP can be generated by means of the materials used? Resource efficiency is a relative value. An increase can thus be achieved through rising GDP or through diminishing material use.

An **increase in resource efficiency** (or resource productivity), or a decoupling of economic output and resource use occurs in cases where the economic growth exceeds the growth of resource use. An increase in resource efficiency therefore implies that a smaller amount of resources is used to provide the same economic output. However, an increase in resource efficiency does not automatically mean a reduction of resource use in absolute terms, but only that the economy is growing faster than resource use. Therefore a distinction is made between two cases of decoupling: Decoupling with rising resource use ("relative" decoupling), where resource productivity grows more slowly than the economy, and decoupling with declining resource use ("absolute" decoupling), where resource productivity grows faster than the economy.

Annex 3: Material Flows Numbers – Data Tables

Table A-1: Overview of material flows (DE, imports, exports, DMC)

Values have been rounded to the nearest integer; rounding differences remain.
Negative values occur in those categories which primarily depict processed products and thus trade flows. If the imports are smaller than the exports in such a category, the domestic material consumption (DMC) in this category is negative.

	Material flows in million tonnes		Increase in %	Share of total flow in %	
	1960	2008		1960	2008
Domestic extraction (DE)	**105**	**169**	**60 %**		
Biomass	34	44	27 %	33 %	26 %
Fossil energy carriers	10	2	-77 %	9 %	1 %
Metals	4	2	-37 %	4 %	1 %
Non-metallic minerals	57	120	110 %	54 %	71 %
Imports	**16**	**88**	**455 %**		
Biomass	2	22	891 %	14 %	25 %
Fossil energy carriers	7	28	299 %	44 %	32 %
Metals	2	20	715 %	16 %	23 %
Non-metallic minerals	4	11	167 %	26 %	12 %
Other products[1]	-	6	-		7 %
Exports	**7**	**60**	**725 %**		
Biomass	2	23	1.291 %	22 %	38 %
Fossil energy carriers	1	6	395 %	16 %	10 %
Metals	1	15	872 %	21 %	24 %
Non-metallic minerals	3	9	207 %	38 %	14 %
Other products[1]	0	8	4.347 %	3 %	14 %
DMC[2]	**114**	**197**	**73 %**		
Biomass	35	43	23 %	31 %	22 %
Fossil energy carriers	16	25	58 %	14 %	13 %
Metals	5	8	67 %	4 %	4 %
Non-metallic minerals	59	123	109 %	51 %	62 %
Other products[1]	-0	-2	891 %	-	-1 %

1 Products which cannot be assigned to any single material category; traded waste
2 Domestic Material Consumption (DMC) = domestic extraction + imports - exports

Table A-2: Material use (DMC) per capita

Values have been rounded to millions; rounding differences remain. Negative values can occur in those categories which primarily depict processed products and thus trade flows. If the imports in such a category are smaller than the exports, the domestic material consumption (DMC) in that is negative.

	Material flows in tonnes per capita		Increase in %
	1960	2008	
DMC[1] per capita	**16,2**	**23,6**	**46 %**
Biomass	5,0	5,2	4 %
Fossil energy carriers	2,2	3,0	34 %
Metals	0,7	1,0	41 %
Non-metallic minerals	8,3	14,7	77 %
Other products[2]	-	-0,2	-

1 Domestic Material Consumption (DMC) = domestic extraction + imports - exports
2 Products which cannot be assigned to any of the material categories and traded wastes

Table A-3: Material use (DMC) and resource efficiency

Values have been rounded to millions; rounding differences remain.

	DMC, GDP, resource efficiency		Increase in %
	1960	2008	
DMC[1] (in mio. tonnes)	114	197	73 %
GDP[2] (in billion euro)	63	266	325 %
Resource efficiency[3] (in €/t)	550	1.353	146 %

1 Domestic Material Consumption (DMC) = domestic extraction + imports - exports
2 Gross domestic product
3 Presented as resource productivity = GDP/DMC

Table A-4a: Domestic extraction (DE) in million tonnes

Values have been rounded to millions; rounding differences remain.

	Biomass	Fossil energy carriers	Metals	Non-metallic minerals	Total
1995	37	4	2	111	153
1996	37	3	2	113	155
1997	38	3	2	119	162
1998	37	3	2	113	156
1999	38	4	2	119	162
2000	34	4	2	118	158
2001	35	4	2	112	153
2002	37	4	2	123	166
2003	35	4	3	114	156
2004	39	3	2	119	164
2005	40	2	3	122	167
2006	39	2	2	123	167
2007	40	2	3	122	167
2008	44	2	2	120	169

Table A-4b: Imports in million tonnes

Values have been rounded to millions; rounding differences remain.

	Biomass	Fossil energy carriers	Metals	Non-metallic minerals	Other products[1]	Total
1995	12	20	10	7	4	53
1996	12	22	10	7	4	55
1997	13	22	12	8	4	59
1998	13	23	13	8	4	61
1999	16	22	12	8	4	61
2000	18	22	14	8	4	65
2001	18	23	14	8	5	68
2002	18	25	14	8	5	70
2003	18	27	15	9	5	73
2004	20	27	16	9	5	77
2005	21	28	17	10	6	81
2006	23	29	19	10	6	87
2007	23	28	21	12	6	91
2008	22	28	20	11	6	88

1 Products which cannot be assigned to any of the material categories and traded wastes

Table A-4c: Exports in million tonnes

Values have been rounded to millions; rounding differences remain.

	Biomass	Fossil energy carriers	Metals	Non-metallic minerals	Other products[1]	Total
1995	11	1	7	5	4	28
1996	11	1	7	5	4	29
1997	13	1	7	6	4	32
1998	13	2	9	6	5	35
1999	15	2	8	6	5	36
2000	16	2	9	6	5	38
2001	16	2	10	7	5	40
2002	17	2	10	7	6	43
2003	18	2	11	7	6	44
2004	19	3	12	8	6	48
2005	20	3	12	7	7	50
2006	21	4	13	8	7	53
2007	23	5	14	9	8	59
2008	23	6	15	9	8	60

1 Products which cannot be assigned to any of the material categories and traded wastes

Table A-4d: Domestic material use[1] in million tonnes

Values have been rounded to millions; rounding differences remain.
Negative values can occur in those categories which primarily depict processed products and thus trade flows. If, in such a category, the imports are smaller than the exports, the material consumption is negative.

	Biomass	Fossil energy carriers	Metals	Non-metallic minerals	Other products[2]	Total
1995	37	23	5	112	-0	178
1996	38	24	6	115	0	182
1997	39	24	7	121	-0	190
1998	37	24	6	115	-1	182
1999	39	24	5	121	-1	188
2000	36	24	6	120	-1	186
2001	36	25	6	113	-1	180
2002	37	27	6	124	-1	194
2003	35	29	6	115	-1	184
2004	40	27	6	120	-1	193
2005	40	27	8	124	-1	199
2006	42	28	9	124	-1	202
2007	40	26	10	125	-2	199
2008	43	25	8	123	-2	197

1 Domestic Material Consumption (DMC) = domestic extraction + imports - exports
2 Products which cannot be assigned to any of the material categories and traded wastes

Table A-4e: Domestic material use[1] in tonnes per capita

	Biomass	Fossil energy carriers	Metals	Non-metallic minerals	Other products[2]	Total
1995	4,7	2,9	0,7	14,1	-0,0	22,4
1996	4,7	3,0	0,7	14,4	0,0	22,9
1997	4,8	3,0	0,8	15,1	-0,0	23,8
1998	4,7	3,1	0,7	14,4	-0,1	22,8
1999	4,8	3,0	0,7	15,1	-0,1	23,5
2000	4,5	3,0	0,8	14,9	-0,1	23,2
2001	4,5	3,1	0,8	14,1	-0,1	22,4
2002	4,6	3,3	0,8	15,4	-0,1	23,9
2003	4,3	3,5	0,8	14,2	-0,1	22,7
2004	4,9	3,3	0,8	14,7	-0,1	23,6
2005	4,9	3,3	0,9	15,1	-0,1	24,1
2006	5,1	3,3	1,1	15,0	-0,1	24,4
2007	4,9	3,1	1,2	15,1	-0,2	24,0
2008	5,2	3,0	1,0	14,7	-0,2	23,6

1 Domestic Material Consumption (DMC) = domestic extraction + imports - exports
2 Products which cannot be assigned to any of the material categories and traded wastes

Table A-4f: GDP, DMC and resource efficiency

	GDP[1] in billion Euros	DMC[2] in million tonnes	Resource efficiency[3] in Euros per t
1995	194	178	1.091
1996	199	182	1.090
1997	203	190	1.069
1998	210	182	1.155
1999	217	188	1.154
2000	225	186	1.212
2001	226	180	1.255
2002	230	194	1.188
2003	232	184	1.257
2004	238	193	1.231
2005	244	199	1.226
2006	252	202	1.249
2007	261	199	1.312
2008	266	197	1.353

1 Real GDP, concatenated volume data 2005 (Havel et al. 2010). In an analysis across a given period of time, resource efficiency must to be calculated using real GDP (at constant prices) to avoid distortions due to changes in prices (e.g. as a result of inflation)
2 Domestic Material Consumption (DMC) = domestic extraction + imports - exports
3 Presented as resource productivity = GDP/DMC

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