RESOURCE USE IN AUSTRIA
REPORT 2015

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RESOURCE USE IN AUSTRIA

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FOREWORDS

Natural resources form the basis of our quality of life. Ensuring that we have a future-oriented domestic economy and can preserve and protect the basis of life in an Austria worth living in depends upon sustainable, efficient and responsible use of our natural resources. The BMLFUW initiatives for a modern environmental and resource use strategy, such as the R*esource Efficiency Action Plan*, *RESET 2020 – Resources.Efficiency.Technologies* or *Growth in Transition Initiative*, with its discourse about a sustainable economic and social system, we make a significant contribution towards this goal.

In order to apply targeted measures, high quality and comprehensive data as well as good analytical research are essential. The resource use reports provide not only usable data but also trends and factors influencing domestic resource use, and also reveal those areas in which action is required. The report 2015 is the second of the series *Resource Use in Austria*.

This year's report focuses on biomass as a key area of concern, which, besides hydro power, covers a major share of the energy requirements through renewable energies. We will only be able to significantly reduce CO_2 emissions, take a real step closer to achieving Austria's climate targets and implement a consistently sustainable resource use strategy if we make efficient use of renewable raw materials.

I wish you an interesting and informative insight into the issues addressed here!

Yours, ANDRÄ RUPPRECHTER
Federal Minister for Agriculture, Forestry, Environment and Water Management

Supplying domestic companies in a sustainable way with raw and basic materials appropriate to their needs is an indispensable basis for a functioning economy. This applies particularly to those industrial raw materials for which there is a high reliance on imports, yet is also at issue in the case of construction minerals (such as gravel), which cannot be traded internationally yet are essential for the construction and maintenance of our infrastructure for example. Key technologies required to secure the future performance of the Austrian economy and that contribute to solving specific problems regarding the central challenges of e.g. climate and energy, health, nutrition, mobility, security and communication, can only be implemented through adequate access to the required raw and basic materials. The efficient use of these materials should be regarded as a win-win situation for both economy and environment. The analyses of sectoral trends in resource use presented in *Resource Use in Austria*– Report 2015 constitute the basis for a forward-looking resource use strategy.

In the framework of the *European Innovation Partnership on Raw Materials*, to whose Steering Group I belong, innovative solutions along the entire raw materials value chain are being developed. These aim to reduce Europe's dependence on imports, to ensure sustainable supply with affordable raw materials and to ensure these are used efficiently over the long term, thereby strengthening the competitiveness of European industry.

Yours, REINHOLD MITTERLEHNER
Deputy Prime Minister and Federal Minister for Science, Research and the Economy

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SUMMARY

The use of natural resources both in the past and in the present is closely linked to actual and future environmental impacts and to supply security concerns. This report, entitled *Resource Use in Austria*, presents a detailed description and analysis of the extraction, trade and use rof material resources in Austria between 1960 and 2012. Material resources encompass societal extraction and use of biomass, fossil energy carriers, metals and non-metallic minerals, together with products that are derived from these resources and then become the subjects of trade. Relevant data for Austria are available on an annual basis from the so-called material flow balance, which forms part of the environmental accounts. Because the collection and necessary compilation of material flow data result in time delays in reporting terms, only data up to and including 2012 can be presented and analysed in this report published in 2015.

In the space of only 50 years, global material resource use has risen rapidly from below 20 billion tonnes in 1960 to 70 billion tonnes in 2010, i.e. by a factor of 3.7. Although Austrian material resource use within the same time frame rose only by a factor of 1.6, per capita resource use in Austria is nonetheless at a very high level in international and European terms. At the European and Austrian level, political goals were set, which are intended to lead to reductions in resource use. In many industrialised countries, including Austria, resource use has either stagnated or even fallen slightly since the 1970s. Whether and how it might be possible in the long term to reconcile economic growth as a political goal not only with stagnation but with the reduction in resource use seen as necessary to protect the environment is a key issue regarding a sustainable future.

Where a more sustainable concept of resource use is concerned, renewable raw materials, i.e. those biomass materials, which – in contrast to fossil energy carriers, metals and non-metallic minerals – can in principle be regenerated, play an increasingly important role. In Austria, this concept is pursued through, for example, the *Bioeconomy Action Plan* . Although biomass is regarded as "renewable", it should be borne in mind that a contribution to resource conservation, even based on renewable raw materials, can only be achieved if such biomass is produced under sustainable production conditions and if attention is paid to the fact that there is no unlimited availability of biomass. To shed light upon this key area of concern for the future, this report focuses upon renewable raw materials.

In 2012, a total of 187 million tonnes of material were used in Austria. This material consisted largely (over 50%) of non-metallic minerals, including primarily raw materials required for the construction and maintenance of buildings and infrastructure. Biomass comprised the second largest component (less than 25%) of material use, followed by fossil energy carriers and metals. If this quantity of material is calculated as a per capita figure for the Austrian population, results show a per capita use of 22.2 tonnes of materials in Austria in 2012. This is significantly higher than the global average usage of c. 10 tonnes per capita. The reason for this is primarily the comparatively high per capita use of non-metallic minerals, in particular of construction minerals, which is linked to the climatic and topographical characteristics of the alpine region and to population density in Austria. Moreover, data collection is more comprehensive in Austria than in some other European countries, due to the introduction in 2011 of a new method for estimating the extraction of non-metallic minerals. Where resource use in Austria is concerned, a very important role is played by both imports, as a source of raw materials that are not (any longer) the subject of domestic extraction, and products, which are not produced domestically. On the other hand, a significant proportion of material extraction and processing within Austria is carried out for export purposes.

A moderate approach to and efficient use of natural resources together with a reduction in overall material usage are needed both in order to protect the environment in Austria and also to contribute to a reduction in global environmental impacts such as anthropogenic climate change.

In order to reduce resource use while simultaneously achieving the goal of a continually growing economy, the size of GDP that can be achieved per unit of resource use must increase. This relationship is defined as resource efficiency. Although resource efficiency has been increasing since 1960, by generating 1,454 € per

tonne of material use Austria is slightly less efficient than the European average. This relatively low efficiency is primarily related to a high level of material use yet could perhaps improve in future, since Austrian material use has decreased slightly since 2007 and therefore indicates that more environmentally friendly economic activity would be possible. In order to reduce Austrian resource use to the current European average by 2050 despite further economic growth, resource efficiency would need to be tripled. In order to achieve a level of 5 tonnes per capita, which in global terms could lead to a reduction in material use, resource efficiency would have to be increased by a factor of seven. This generates significant challenges, which could simultaneously represent huge opportunities for the Austrian environment, economy and society.

INTRODUCTION

Whether we use them sparingly or wastefully, natural resources are used by all of us, all of the time. They provide the basis upon which our economy and way of life depend. We extract oxygen from the air for breathing or combustion processes when we heat our homes or move around. Conversely, breathing and combustion create CO_2 emissions, which we pump out into the air. We require water for our nutritional needs, to wash and to cool industrial facilities. Through agriculture and forestry as well as mining, we extract resources from the natural environment or we depend upon others doing so for our use. These natural resources, which are so important for us, include raw materials for energy, metals, minerals, biomass, water and air.

The report *Resource Use in Austria* is being published for the second time in 2015 and presents, as did the first report from 2011 (BMLFUW and BMWFJ 2011), the material use of natural resources in Austria. Material resources include societally extracted and used biomass, fossil energy carriers, metallic and non-metallic minerals and those products derived from them and subsequently traded. Regular periodic reporting on material resource use is made possible through the annual collection of relevant data within Austria. This takes place in the context of material flow accounts, which forms part of environmental accounting. In material flow accounting, the extraction of and trade in materials is recorded and reported in tonne units. This documentation enables us to maintain a clear and continuous picture of the material dimensions of the Austrian economy. This is, as described in the following chapters referring to individual material categories, closely linked to environmental impacts not only in Austria but also in the world as a whole. The frugal and efficient use of natural resources is seen as one of the key strategies for a sustainable development of the environment, economy and society. The results of material flow accounts are therefore also used in the development of political sustainability programmes and in setting targets for a more sustainable economy.

GREATER RESOURCE EFFICIENCY IN AUSTRIA AND IN EUROPE

At European level, the relevance of resource use is reflected in the flagship initiative *Resource Efficient Europe* (European Commission 2011). This envisages particularly within increased resource efficiency the opportunity to reduce resource use whilst simultaneously stimulating economic growth. Resource efficiency is understood as the relationship between gross domestic product (GDP) and material use. The more GDP a country can generate per unit of material use, the greater its resource efficiency. This initiative aims to contribute as part of the *Europe 2020 Strategy* (European Commission 2010) to smart, sustainable and inclusive growth. The Austrian federal government supports the efficient and economical use of natural resources and has dedicated a national action plan to the theme of environmental and resource conservation. The Austrian *Resource Efficiency Action Plan* (*REAP*) was developed in a process led by the Austrian Federal Ministry for Agriculture and Forestry, the Environment and Water Management (BMLFUW). This stakeholder process included civil servants and representatives of the economic, scientific and civil society sectors, together with the responsible units within provincial administrations, and set out how Austria can contribute to the European goal of resource conservation. Building on this, the *RESET 2020 – Resources.Efficiency.Technologies Initiative* was developed by the BMLFUW, aiming to implement resource efficiency in the areas of environmental technologies, sustainable production and sustainable consumption. The areas with particular potential to increase resource efficiency were also identified.

With a more environmentally friendly use of resources, so-called renewable raw materials attain a particular importance. In contrast to fossil energy carriers, metals and non-metallic minerals, biomass is replenished as a raw material over time intervals that most closely match the rates of societal use. In material flow accounts, the term "biomass" refers both to living and dead organic matter: plants, animals, deadwood, foliage, straw, etc. The fossil energy carriers that derive from biomass, including peat, are not included in calculations. The term biomass is

defined differently in other contexts – a precise definition of the term is found in Box (▶ page 39). Biomass is also accorded a key role within the strategies for renewable resource use in the Austrian *Bioeconomy Action Plan*. The measures contained within the plan are intended to encourage the use of renewable raw materials in Austria. Although biomass is regarded as "renewable", it should be borne in mind that a contribution to resource conservation, even based on renewable raw materials, will only be achieved if such biomass is produced under sustainable production conditions and if attention is paid to the fact that the availability of biomass too is not unlimited, and is linked to other limiting factors, such as competing land uses. To shed light upon this key area of concern for the future, this report focuses upon renewable raw materials.

MATERIAL FLOW DATA PROVIDE IMPORTANT INFORMATION

The questions of resource conservation and particularly of resource efficiency lie at the heart of European and Austrian sustainability strategies. In order to set goals related to resource efficiency and to monitor progress towards reaching such goals, data on resource use as well as on gross domestic product (GDP) are required. These are recorded in the material flow accounts and are the subject of this report. The results of the Austrian material flow accounts are presented and discussed in detail here. By these means, they should be accessible both for stakeholders from politics, administrative bodies and the economy, and for interested citizens, and may become the subject of debate regarding their implications for Austria's future sustainability. At first glance, material flow accounting may seem somewhat cumbersome and technical. As this report shows, however, what lies behind it is something that is of concern to us all. The data, which are presented here, are of key importance for the development of Austria's future sustainability.

STRUCTURE AND CONTENTS OF THE REPORT

The chapter *Natural Resources – the Foundation of our Society* begins the report and highlights how much and which resources are utilized in Austria. This reveals that Austrian resource use over the course of history has risen sharply, not only because we consume more as individuals but also because the functioning and the structures of Austrian society have undergone profound transformation. The relevance of this rise in resource use and of its current high level is made clear through related environmental impacts. The question of whether this trend towards increasing resource use must continue is also addressed here. To make the report more accessible to readers, this chapter also contains a brief overview of the methods used in material flow accounting. A more detailed description is found both in the annex to this report and in the report from 2011 (BMLFUW and BMWFJ 2011), which began this series.

The following chapter, *Resource Use in Austria and the World*, presents an overview of the results of the material flow accounts. This covers both resource extraction in Austria and the role of international trade in relation to materials supply. Since international trade plays an ever more significant role where resource use is concerned, new methods have now been developed in the context of material flow accounting to determine how much material is used in other countries in order to produce goods that are imported into Austria, and how much material is required in Austria for the production of goods for export. The results of these methods developed specifically for Austria show that overall, Austria indirectly uses more material in other countries than it supplies to other countries. In both international and European contexts, Austria exhibits a high level of material use. Since the financial crisis of 2007/2008, however, material use in Austria and in many other countries has either stagnated or decreased slightly. It is now more important than ever to put policy measures in place that can help to prevent a recovering economy from returning to former trends in terms of material growth. Both this and all other sustainability goals are linked to the question of what is possible in terms of living with lower levels of resource use and of whether this more frugal lifestyle must inevitably be one of great privation. The careful use of resources is a precondition for containing the many burdens, which are currently placed upon the environment – from anthropogenic climate change to loss of species diversity and threats to the supply of vital resources for future generations.

Material use data are presented in detail in the chapter *From Biomass to Minerals: Material Use in Detail*. Because different materials are utilized for very different purposes, and are either available for use in Austria or must be imported, the four material groups – biomass, fossil energy carriers, metals and non-metallic minerals – are treated separately in this chapter. In line with the overall focus of this report, renewable raw materials ("biomass" in the terminology of material flow accounting) and the role they can play in a more sustainable future are considered in this chapter. On one hand this involves considering the dimension of biomass use where the other material categories are concerned, and on the other, the description of the use of renewable raw materials in the report is based not only on material flow data but also in

a wider sense upon the extremely detailed data provided by the Austrian Energy Agency.

As political initiatives and goal-setting agendas for resource efficiency confirm, the relationship between *Resource Use and Economic Development*, to which an entire chapter of this report is dedicated, is also of particular political significance. This chapter describes the development of Austrian resource efficiency and discusses this in the context of existing political initiatives. The more resource efficient Austria becomes, the more GDP per unit of resource use can be achieved. However, in order to reduce the impacts of resource use upon the environment, resource use overall (and not only in relation to GDP) must also be reduced. An increase in resource efficiency is thus a means to contribute to a more sustainable form of growth, yet when viewed separately, it cannot be adopted as a sustainability policy goal in itself.

Whether resource efficiency increases or stagnates and how resource use in Austria can be managed in the future is the subject of the chapter *Scenarios for the Future*. In this chapter, scenarios are presented in which resource use increases, remains stable or is even reduced. The prerequisites and implications indicated by each of these scenarios are then discussed.

Overall, the report presents an informed insight into the development of Austrian resource use in the past, its current levels and composition, and potential future development paths. This information is indispensable in evaluating the possibilities and impossibilities where a sustainable future for Austria is concerned.

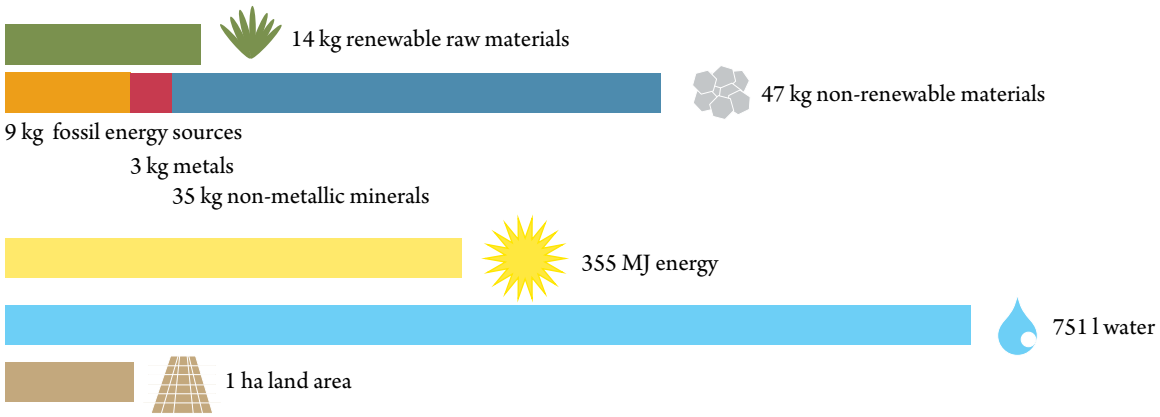
1 NATURAL RESOURCES – THE FOUNDATION OF OUR SOCIETY

From the land upon which we live, to the construction minerals from which we build our homes and high-ways, to the metals in our means of transportation and the energy sources (fossil or biogenic in origin) that provide us with power: our need for natural resources is continuous. In 2012 each person in Austria was supplied with over 60 kilograms (kg) of material, 355 million joules (megajoules, MJ) of energy, and 751 litres of water per day, together with 1 hectare (ha) of land area (▶ Figure 1, see below). This quantity of energy is equivalent to burning more than 8.5 litres of crude oil (equal to the energetic value of 154 bars of chocolate!) per person, per day. This amount of water would allow each of us to take a shower continuously for one hour each day or to flush the toilet c. 75 times daily. Were we to position ourselves at equidistant intervals across Austria, the hectare required by each person would be the equivalent of a football pitch for each individual's sole use. Of course the 14 kg of renewable raw materials required each day would have to be largely produced within this area, since biomass is only imported in small quantities.

THE WHOLE IS GREATER THAN THE SUM OF ITS PARTS

Even on those days when we consume most, we rarely consume as much individually as Figure 1 suggests we have available to us. So why do we require resources in such great quantities? An abstract answer is that our society is greater than the sum of its parts and our entire resource use in Austria is more than the sum of our respective individual amounts used. For a long time now we have been using resources primarily as a society and no longer mainly on an individual basis. The greater part of the material resources required do not find their way into our stomachs but are built into our streets, buildings and infrastructures, constituting both our residential settlements, cities and industrial facilities and our transport connections and other infrastructures between them. Most energy use also occurs not on an individual basis but through our use of services (e.g. electricity supplies, hot water, transport) or products, for the production of which this amount of energy has been required. The majority of water usage takes the form of industrial (above all, water as a coolant) and agricultural usage – and conversely we consume the products and services, which are produced by these sectors of the economy. The inclusion of these forms of water use accounts for the significant difference between the water use level for 2012 reported here and the figure of 250 litres per person and day reported in terms of water use in the 2011 report *Resource Use in Austria*. This 250 litres of water use corresponded to the direct usage (e.g. to take showers, wash clothing and flush toilets) in 2008, without taking account of agricultural and industrial water usage. The 1 ha land area calculated for each of us is not used individually for leisure activities or during work, but rather for agriculture, industry and infrastructure, while areas that are rarely or less intensively used, in which we can go for walks or providing at least some undisturbed space for other living creatures, are also included.

Figure 1: Resources either available or used on average per capita in Austria in 2012



Data source: BMLFUW 2014; Statistics Austria 2014a, 2014b

INDUSTRIALISED SOCIETIES REQUIRE 20 TIMES THE ENERGY REQUIRED BY HUNTER-GATHERERS

The scale of resource requirements is thus significantly determined by factors that relate not only to the way of life of individuals but also to the structures of entire societies. To cover our basic requirements for energy just for survival, i.e. for our so-called individual metabolism, we require c. 3 gigajoules per capita and year (GJ/cap/a). This represents only c. 8 MJ per person and day, in other words, only a small part of what we consume in Austria according to the energy balance. Even a society that hunts and gathers as a community requires a per capita amount that is three to four times the quantity required for individual metabolism. An agricultural society has a requirement that is 16–17 times higher and an industrialised society has a requirement that is greater by a factor of more than 65. In 2012, Austria lay in the mid-range among industrial societies, with a value of 130 GJ/cap/a (▶ Figure 2, see below).

Since the Industrial Revolution, ever more countries (and regions within these countries) are completing a transition to become industrialised societies. This also necessarily brings with it a rapid growth in global material and energy requirements and in the environmental impacts that accompany this, whilst greater material wealth is also created. Between 1950 and 2010, global material use increased from 12.6 billion tonnes to 71 billion tonnes (Schaffartzik, Mayer, et al. 2014). During the same period from 1950, population and income (GDP) and the use of energy and water, of fertilizers, tourism and transport also rapidly increased in a process described as the *great acceleration* (Steffen et al. 2015).

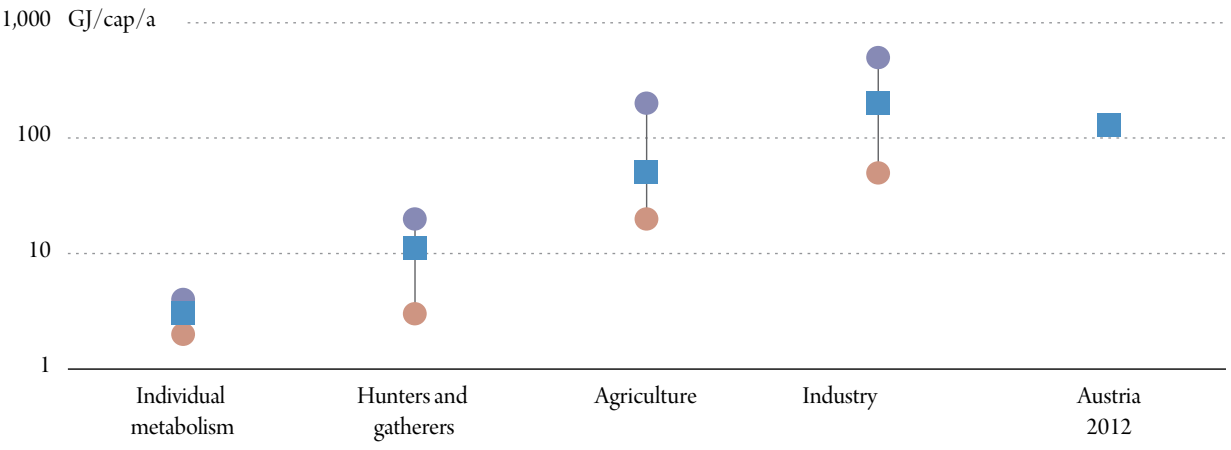
THE NEGATIVE IMPACTS OF HIGH RESOURCE USE

The *great acceleration* and the current high levels of global resource use it has caused are of great significance to society, because they are linked directly and indirectly to growing environmental burdens and the impacts upon the environment which stem from these. In many places, these environmental burdens are already reducing the quality of life or indeed even threatening the natural conditions upon which life depends. If there is no global turnaround in constantly increasing use of ever more scarce resources and land areas, ever growing numbers of people – including those of us in Austria – will be affected as a result.

Our earth has spatial limitations: Under the headline *planetary boundaries* (Rockström et al. 2009), political and scientific discussions are currently considering what these boundaries mean in relation to a sustainable and secure future. On one hand, these boundaries ensure that all the materials we utilize are finite. Where fossil energy carriers and strategically important metals are concerned, this understanding is increasingly moving into the foreground of economic and political action (see, for example, European Commission, DG Enterprise and

Figure 2: Energy requirement in gigajoules per capita and year (GJ/cap/a) for individual metabolism, for societal types and for Austria in 2012

The vertical lines between the higher and lower points show the range of observed values. The vertical axis y is scaled logarithmically, i.e. values increase exponentially (by a factor of 10) rather than additively.



Data source: Fischer-Kowalski et al. 2014; Fischer-Kowalski and Haberl 2007

Industry 2014). But even the "renewable raw materials" that are produced in agriculture and forestry have limits placed upon them. We do not have more land available to us than is represented by the landmasses of our continents. A portion of the land that could be used for agricultural production is already being lost through rising sea levels, erosion, the loss of soil fertility and the expansion of built-up areas. At the same time, the expansion of areas given over to agricultural or forestry use and the increase in soil sealing for built environments and infrastructure mean that there is less space available for other creatures along with humans. The destruction of tropical rainforest, for example, is linked to an irrevocable loss of species diversity, which in turn threatens the fragile balance of natural ecosystems. However, human conflicts are also already becoming more frequent as a consequence of competing needs for land use: for example, the use of land areas for subsistence economies, i.e. for agricultural production which primarily serves self-sufficiency requirements and the products of which are not usually the subject of trade, is in competition with industrial agriculture.

CONSUME TODAY AND DISPOSE OF TOMORROW

Yet it is not only on the extraction side that the high levels of resource use represent an environmental burden. Sooner or later, all material utilized by societies is converted into emissions and waste products. As is well known, burning fossil fuels produces greenhouse gas emissions, primarily CO_2, which in turn lead to anthropogenic climate change, i.e. climate change caused by human activities. Furthermore, emissions can also produce local instances of pollution with possible serious consequences for health. Yet not only the emissions but also the steel and concrete in the buildings and infrastructure we use daily will one day e.g. through repair or demolition, become waste material. This day becomes more distant the more of the materials in durable products, infrastructure and buildings is returned to raw material extraction processes, e.g. through recycling and reprocessing, reuse and repair. Material use can therefore also be interpreted as an indicator for the "expected waste volume", which is automatically reduced when material use decreases. Material input determines the size of output and consequently the environmental burdens through waste disposal and emissions.

Although negative environmental consequences of high levels of resource use are already impacting on other countries and regions far more significantly, these impacts are also observable in Austria. Extreme weather events such as floods are increasing and in the Alps, glaciers are melting – both consequences of global climate change, to which the intensive use of fossil fuels contributes. The limited availability of natural resources also means, however, that resources with strategic scarcity could become significantly more expensive if high demand remains unchanged. In recent years, we have experienced this repeatedly in the case of high oil and gas prices. However, not only are fossil fuels subject to strategic scarcity and the price swings that accompany this: During the global food crises of 2008 and 2011, the price of e.g. wheat increased significantly and led to price rises for some other foodstuffs. With its limited access to raw materials storage space, Austria is dependent on imports in a number of areas. This dependency combined with rising prices is already beginning to put pressure on many businesses today. The

RESOURCES AND MATERIALS IN THE MATERIAL FLOW ACCOUNTS

Resources comprise material and energetic usage of raw materials, water, air, land and also special ecosystem functions – in other words, everything provided by nature and (able to be) used by human societies. From this range of resources, this report focuses on materials, i.e. materially used resources such as biomass, fossil energy carriers, and metallic and non-metallic minerals. These are recorded in the material flow accounts, regardless of whether they are used as material or energy, to provide a wealth of data material for Austria, the European Union and the wider world. The indicators provided in the material flow accounts are also increasingly used in political programmes and target setting at national, European and international levels, which are also subjects of this report.

situation is similar throughout the entire EU region and has already led to political responses (see e.g. European Commission 2008; European Commission 2015).

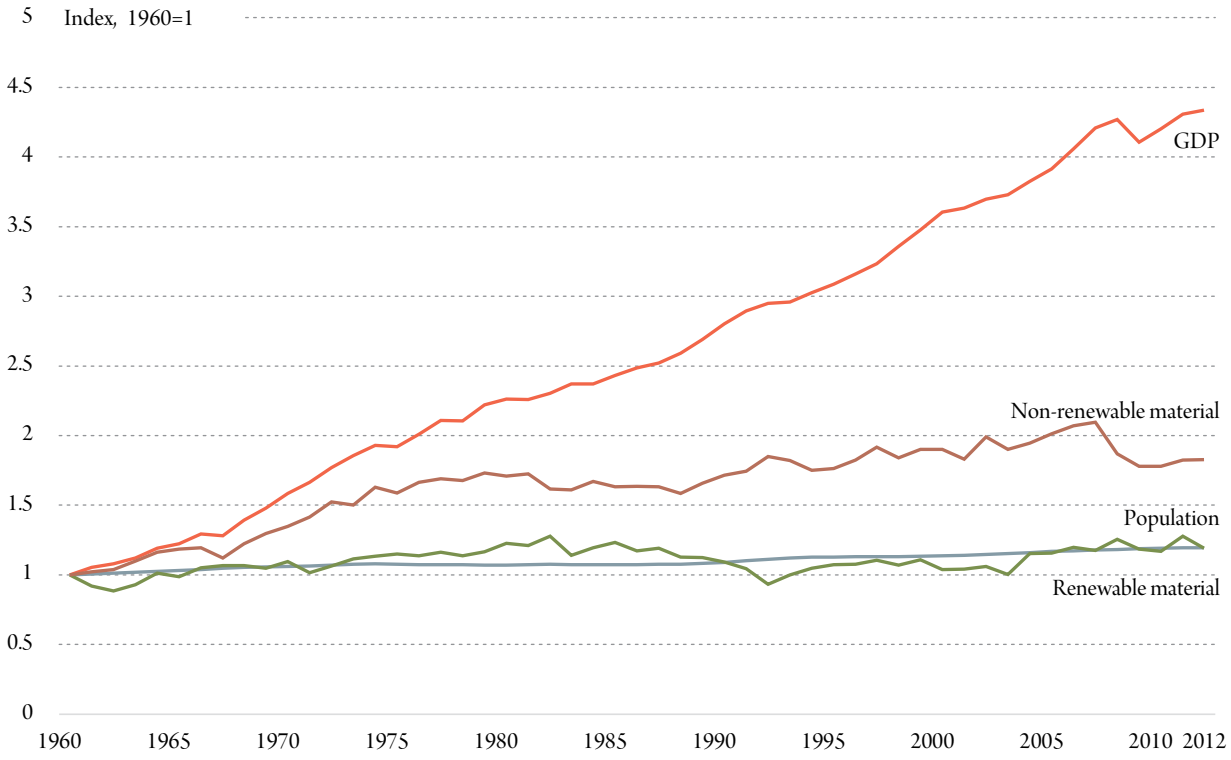
WILL WE NEED EVER MORE RESOURCES IN FUTURE?

In Austria the *great acceleration* mentioned above began in the 1960s and was particularly linked to the growth of GDP (▶ Figure 3, see below): Taking account of inflation, GDP rose between 1960 and 2012 by a factor of 4.3. Between 1960 and 1970, the use of non-renewable materials (including construction minerals, fossil energy carriers, metals, etc.) rose almost as rapidly as GDP. However, decoupling these two development paths in the 1970s meant that the use of non-renewable materials from 1960 until the end of that period only increased by a factor of 1.8. Population growth and the use of renewable materials followed a similar development path to one another and had increased by 2012 by a factor of 1.2.

Until the rate of Austrian material use flattened out in the 1970s, it had already attained a high level in international terms and amounted to 21.6 tonnes per capita and year (t/cap/a) in 2010. The global average in 2010 was 10.3 t/cap/a and was thus approximately half of the Austrian level. In the international context, material use varied in 2010 between c. 53 t/cap/a in Chile and less than 3 t/cap/a in Eritrea. The chapter on *Resource Use in Austria and the World* contains a more detailed account of the reasons for this great variation among the countries of the world. The question should be asked at this point, however, of what positive effects a higher level of resource use actually brings with it. Is a good life only possible with a certain amount of tonnes per capita in terms of resource use? These questions are extremely important at this particular time, with political debate focusing on the options for dematerialisation, because the answers to them may simultaneously provide us with insights into whether a more sustainable future need necessarily be one of greater austerity.

Figure 3: Indexed depiction of the development of GDP, population and use of renewable and non-renewable materials in Austria between 1960 and 2012

GDP rose significantly during this period. Particularly in the late 1960s and early 1970s, the use of non-renewable materials increased far more significantly than the use of renewable materials.



Data source: Statistics Austria 2014a

DEVELOPMENT IS ALSO POSSIBLE WITH FEWER RESOURCES

If we contrast figures for per capita material use with the *Human Development Index* (HDI) of the United Nations, we can obtain a first rough estimate of the degree of development that is possible at specific material use levels. The HDI is an index comprised of the indicators for economic performance, education and training, and life expectancy. An international comparison of countries with regard to their levels of material use and their HDI (▶ Figure 4, see below) shows that above a certain level, increased material use no longer corresponds to a significant improvement in HDI. Furthermore, a comparison between the distribution in 1980 and 2010 reveals that this limit is moving further to the left, i.e. in the direction of lower material use: Whereas in 1980 a DMC of 35.2 t/cap/a was required in order to achieve a very high HDI (> 0.8) according to the United Nations definition, in 2010 this figure was only 16.7 t/cap/a.

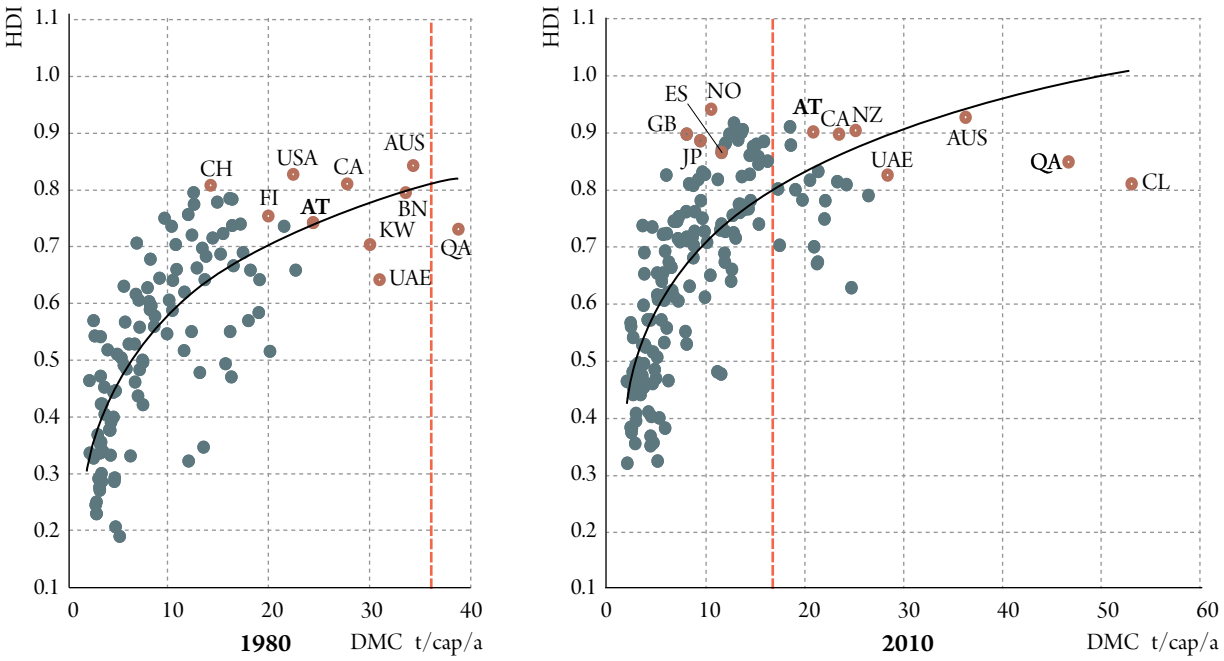
Austria shows an HDI score of almost 0.9 in 2010, yet at the same time uses a very high quantity of material resources at 21 tonnes per capita in order to achieve and maintain this level of human development. Spain, for example, has a similarly high HDI and yet requires 10 t/cap/a less. Japan achieves the same HDI with less than 10 t/cap/a material use, and Great Britain a higher HDI at less than 9 t/cap/a. These connections demonstrate that a future that conserves resources is not automatically a future of either privation or regression, but rather that a high degree of development at lower levels of resource use may also be possible.

ENVIRONMENTAL ACCOUNTS AND MATERIAL FLOW ACCOUNTING

Resource use forms the basis of our society and material use constitutes a significant proportion of this resource use. Environmental accounts were developed in order to facilitate the monitoring and analysis of societal resource

Figure 4: International comparison of Human development index (HDI) and Domestic material consumption (DMC) in 1980 (left) and 2010 (right)

Each point is representing a country. The flattening logarithmic curve created by the data points shows that HDI no longer rises with increased material use beyond a certain level. As a result, the level of material use at which a very high HDI (of over 0.8) can be achieved is falling: In 1980 this limit was c. 35 tonnes per capita and year (t/cap/a), and in 2010 it was already reduced to 17 t/cap/a (dashed vertical line in the figure).



AT – Austria, AUS – Australia, BN – Brunei Darussalam, CA – Canada, CH – Switzerland, CL – Chile, ES – Spain, FI – Finland, GB – Great Britain, JP – Japan, KW – Kuwait, NO – Norway, NZ – New Zeeland, UAE – United Arab Emirates, USA – United States of America, QA – Qatar

Data source: Schaffartzik, Mayer et al. 2014; UNDP 2014

use and its environmental impacts and to promote sustainable development. Since the mid-1990s, the various forms of environmental accounts have provided data on material use and the use of other resources. Physical accounts record total annual resource extraction, physical trade flows and resource use, together with the creation of waste products and emissions. So-called *material flow accounting* (*MFA*) is a component of environmental accounts (Eurostat 2013; OECD 2007). It records all material extracted from nature within a country, the physical imports into that country and the physical exports from the country. Stock changes within the country and other outputs into nature (emissions and waste) are also documented (▶ Figure 5, see below). The socioeconomic system being thus monitored is defined as analogous to the national accounts of that country. Materials from the natural environment obtained through *domestic extraction* (*DE*) enter the system as inputs, while emissions and waste (*domestic processed output, DPO*) flow back into nature. Imports enter from other socioeconomic systems or exports flow to them. Some part of the materials are integrated into the stocks of the socioeconomic system for a period that is longer than one year (▶ Box, page 19).

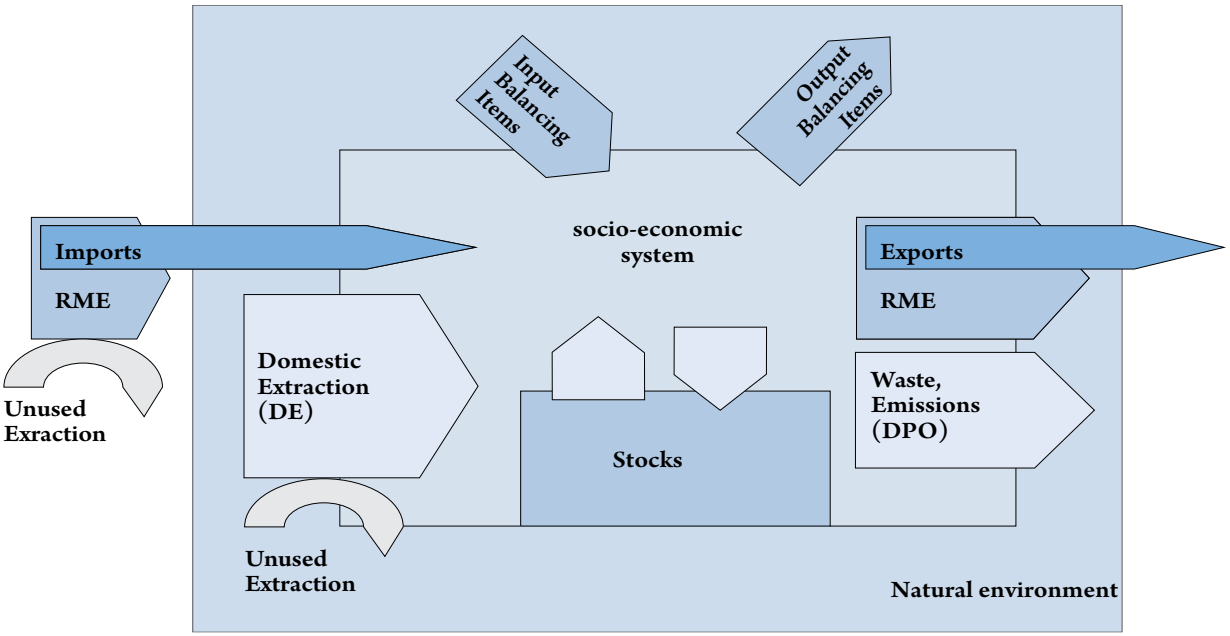
A short description of MFA methods and recommendations for further reading (methods, results, analyses) can be found both in the Annex and in the report *Resource Use in Austria* from 2011 (BMLFUW and BMWFJ 2011). Austrian MFA is available as a time series from 1960 and new data is added on an annual basis by Statistics Austria (Statistics Austria 2014a).

NOT ALL MATERIAL IS THE SAME

Although the MFA measures all materials in tonnes and aggregates these into a single indicator, not all material is the same. Fossil energy carriers, for example, have different environmental impacts to those of biomass[1], and there is a different level of demand for construction minerals to that for metals. For this reason, the report not only focuses upon the development of overall material use but also upon its composition from four major groups, i.e. biomass, fossil energy carriers, metals and non-metallic minerals. Biomass includes all materials of either plant or animal origin, which are extracted from the natural environment by either humans or livestock. This includes agricultural production as well as grass consumed by grazing animals, the products of fisheries and hunting activities, and logging in forestry. Biomass describes so-called "renewable raw materials", which play a central role in many political sustainability initiatives. A key focus of this report

1 In this report, materials are defined in accordance with the conventions of material flow accounting. The term "biomass" is, however, applied differently in the context of energy technology in particular. A definition is provided in Box (▶ page 39).

Figure 5: Schematic presentation of material flow accounting



Data source: after Eurostat 2001

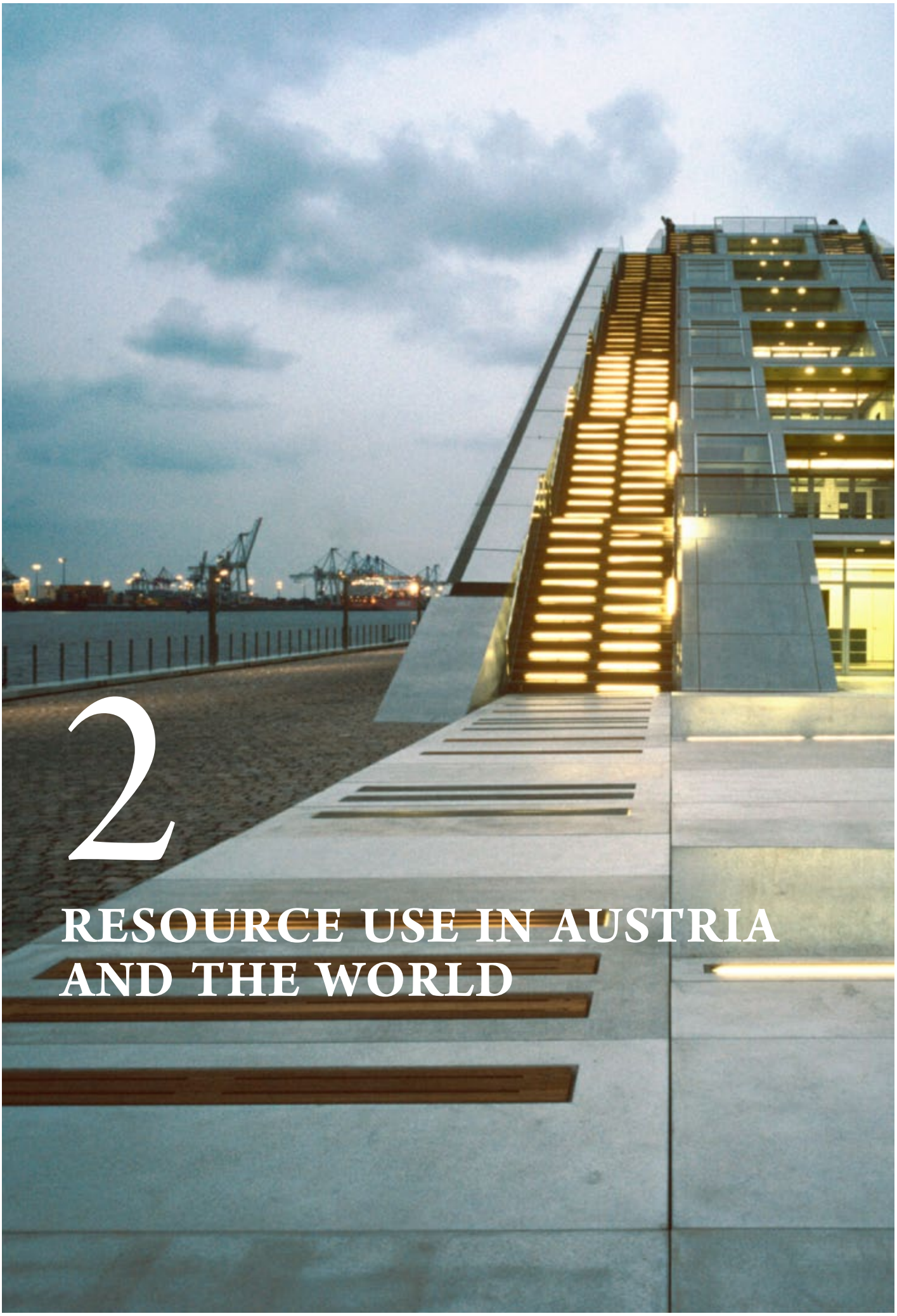
MATERIAL FLOW ACCOUNTING INDICATORS

Where material use is referred to in this report, this relates to so-called *domestic material consumption* (*DMC*). This indicator is calculated on the basis of domestic extraction including imports and excluding exports. The difference between imports and exports is referred to as the *physical trade balance* (*PTB*). For some analyses, it is interesting to know what the total input of material into Austria coming from nature or from other socioeconomic systems is. *Direct material input* (*DMI*) comprises domestic extraction and imports taken together and thus provides precisely the information needed.

All indicators are measured in tonnes per annum (t/a) and amounts are often expressed as kilo- (1 000), mega- (1 000 000) or giga- (1 000 000 000) tonnes, because they refer to large-scale material flows. Particularly in the case of comparisons between countries, or in order to make these often very large values more comprehensible, the indicators are related to populations of socioeconomic systems and are therefore expressed in tonnes per capita and per annum (t/cap/a).

is thus dedicated to these materials. Fossil energy carriers are solid, liquid and gaseous mineral materials, which are primarily used for energy through combustion processes but also used in e. g. chemical production processes.

Metals and non-metallic minerals are recorded as raw material mining. The extraction of metals is recorded as the extracted and further processed crude ore. These material groups are discussed in detail in chapter 3.



2 RESOURCE USE IN AUSTRIA AND THE WORLD

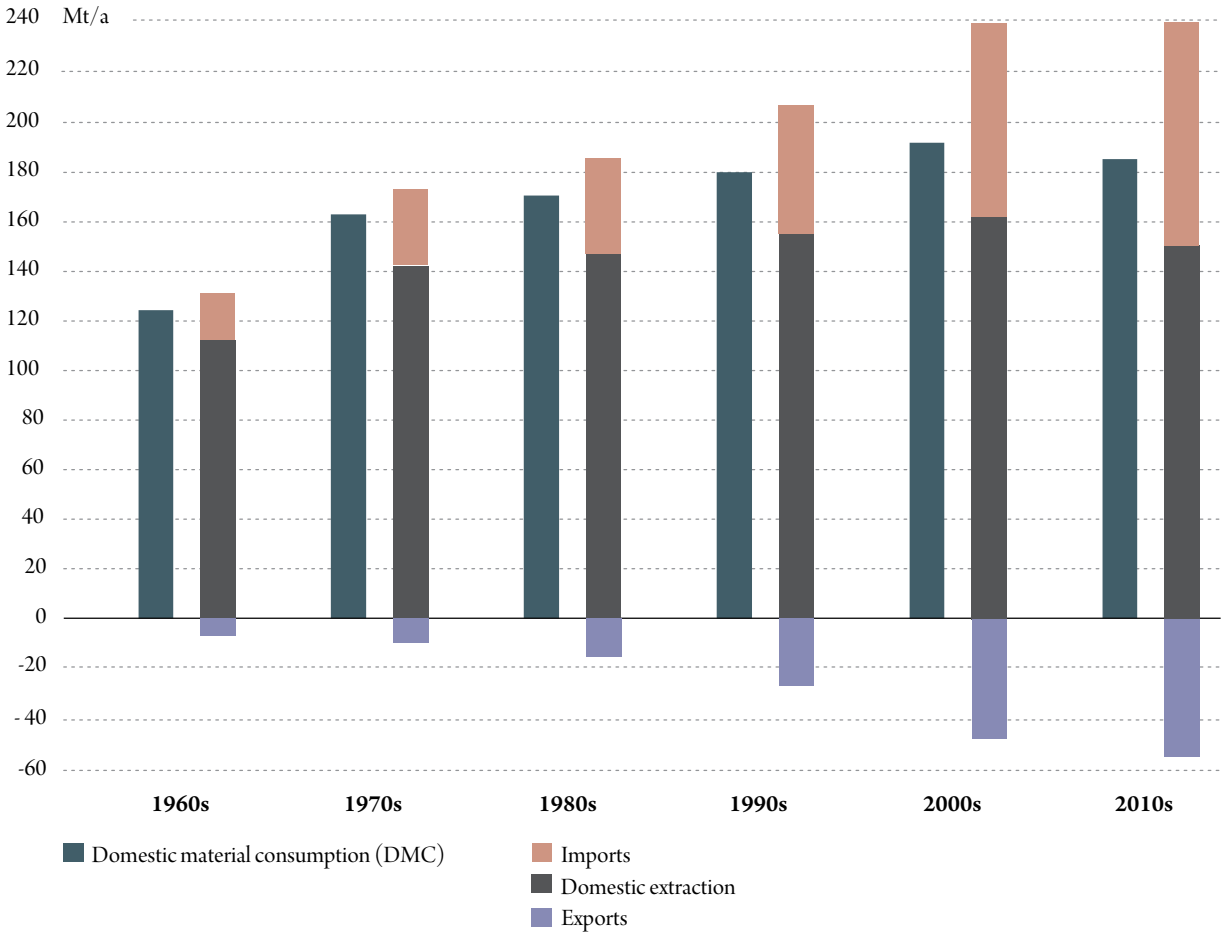
Austrian material use determines the use of domestic resources such as land and water, material and energy, as well as the emissions and wastes associated with this use. At the same time, Austria is bound into a global network of raw material use, material consumption and environmental impacts of extraction, production and use through its connections to international trade. The following chapter offers an overview of Austrian material use and the shares of domestic extraction, imports and exports. The chapter also provides a discussion about what the high and increasing relevance of international trade flows means in terms of the global impacts of Austrian material use. The insight into Austria's material use concludes with a European and international comparison. The use of individual material categories forms the subject of the chapter that follows.

AUSTRIAN MATERIAL USE IN 2012 WAS GREATER THAN 22 TONNES PER CAPITA

At 22 tonnes per capita, Austrian material use in 2012 was not only relatively high in European and international terms but also exhibits an almost continual increase since 1960. An exception to this trend is found in the years since 2010, in which Austrian material use reduced slightly for the first time since 1960. During this as yet incomplete decade, slightly less material was extracted than during the decade from 2000 to 2010 (▶ Figure 6, see below). However, since both imports and exports continued to increase beyond 2010, it has become increasingly important to consider the role of Austrian resource use not only within national boundaries but also in relation to global resource use.

Figure 6: Average material flows in million tonnes per year through the decades from 1960 to the 2010s

In the 2010s (up to and including 2012), material use and domestic extraction decreased slightly for the first time in the entire period, whereas imports and exports continued to grow.



Data source: Statistics Austria 2014a

During the first three years from 2010 onwards, an average of c. 185 million tonnes of material were used annually in Austria. At 151 million tonnes, domestic extraction represented an 82% share of this material use figure. In comparison to the average for the decade from 2000 – 2010, material use fell by c. 7 million tonnes and domestic extraction by c. 12 million tonnes. However, imports rose during the first three years of the decade from 2010 in comparison to the previous decade by 12 million tonnes and exports increased by 7 million tonnes. This means that although there was less domestic extraction and use in Austria, overall material availability (i.e. domestic extraction together with imports) actually increased slightly by c. 1 million tonnes.

DECREASING MATERIAL USE IN AUSTRIA SINCE 2008

In 2012, a total of 187 million tonnes of material was used in Austria, which represents more than 10 tonnes less than in 2008, the last year covered by the 2011 report, *Resource Use in Austria* (BMLFUW and BMWFJ 2011). In 2012, material use already comprised largely (more than 50%) non-metallic minerals, which consist primarily of construction minerals that are required for the construction and maintenance of buildings and infrastructure. Biomass constitutes the second largest share (slightly less than a quarter) of material use, followed by fossil energy carriers and metals (▶ Table 1, see below). When this amount of material is recalculated in terms of per capita use by the Austrian population over the 366 days of 2012, average material use per person and per day is a little over 60 kg, approximately 8 kg/day less per capita than in 2008.

MATERIAL AVAILABILITY FOR DIFFERENT SECTORS

In 2012, Austria's material requirement , i.e. domestic extraction plus imports, amounted to 241 million tonnes. Most of this, which is primarily fossil energy carriers, metals and non-metallic minerals, may be attributed to the chemical and petrochemical sector, construction, industrial minerals and energy industries. These four sectors processed c. 53% of all material input in 2012 (▶ Figure 7, page 23). Although they primarily use abiotic materials, biomass is used particularly in the sectors of agriculture, food and luxury foodstuffs and in the timber industry (▶ the detailed account in the chapter *Biomass,* page 40). These three sectors accounted for c. 20% of total material input and 83% of biomass input.

In the interpretation of material input by sector, it is important to take account of the fact that these sectors are also interconnected and receive supplies from one another. For this reason, the end user demand for foodstuffs, i.e. the products of a sector that directly relies primarily on biomass, is also indirectly connected with the input of fossil energy carriers, metals and non-metallic minerals. To reduce the level of Austrian resource use, attention must also be given, therefore, not only to sectors with a particularly high input of materials but also to those that supply many other sectors. Resource efficiency (▶ the chapter *Resource Use and Economic Development*, page 56) can above all be improved where the part of each sector that combines high levels of value creation with low levels of material use increases production.

Table 1: Material use by material category in Austria in 2012 in million tonnes and as a share of total material use

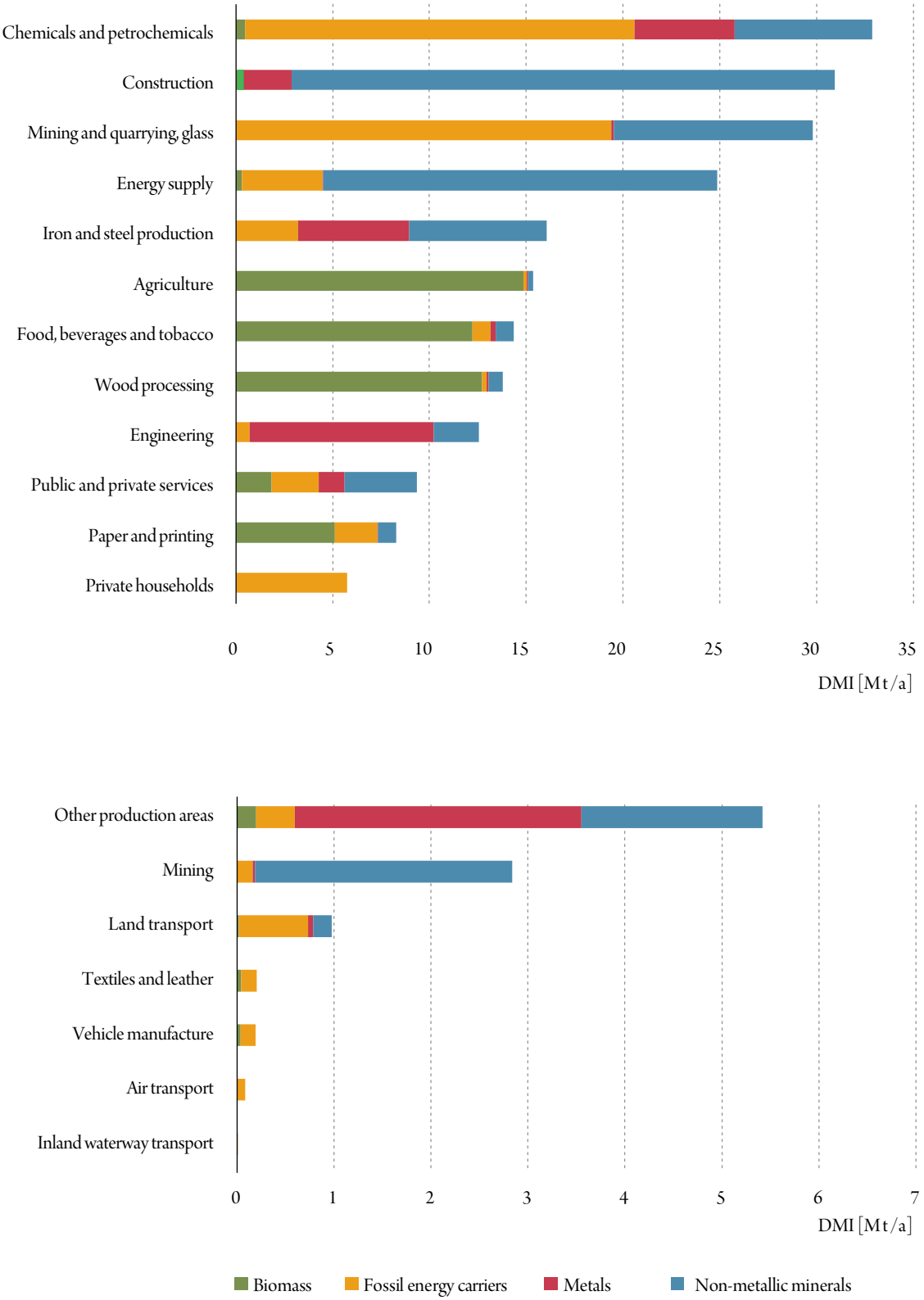
The 187 million tonnes of material that were used in 2012 represent a little over 60 kg per person and day, with more than 50% consisting of non-metallic minerals.

	Material use	
	Mt	%
Biomass	42	23%
Fossil energy carriers	28	15%
Metals	10	5%
Non-metallic minerals	107	57%
Total	187	100%

Data source: Statistics Austria 2014a

Figure 7: Austria's domestic material input (DMI) in million tonnes per year by sector and material category in 2012

Fossil energy carriers are primarily used in chemical and petrochemical industries and in the sector of non-metallic minerals and in both cases, imports are the primary source. Contrastingly, biomass input is primarily attributable to agriculture, food production and wood processing.



Data source: Statistics Austria 2014c

WHAT IS EXTRACTED IN AUSTRIA AND WHAT IS TRADED?

Since 2008 material extraction has decreased a little in Austria year on year – a slight increase was only recorded between 2010 and 2011. In 2012, a total of 150 million tonnes of biotic and abiotic materials were extracted in Austria. This so-called domestic extraction remains the primary source of materials used in Austria: Since the second half of the 20th century, domestic extraction has continually accounted for over 80% of Austria's overall material use. The more raw materials and manufactured goods are imported, however, the further this share will sink: Between 1960 and 2012, it fell from 92 % to 81% (▶ Figure 8, see below). This altogether very high share also represents a high measure of supply security in the case of some materials, whereas in the case of others there is a near total reliance on imports. A high share of material use coming from domestic extraction also means that a reduction in material use can lead directly to a reduction in the pressure on domestic resources: This has an effect not only on extraction but also after consumption, where emissions and wastes can be reduced. Conversely, rising imports in Austrian material use mean that an aliquot of environmental impacts from production of goods consumed in Austria accrues to an increased degree in other countries.

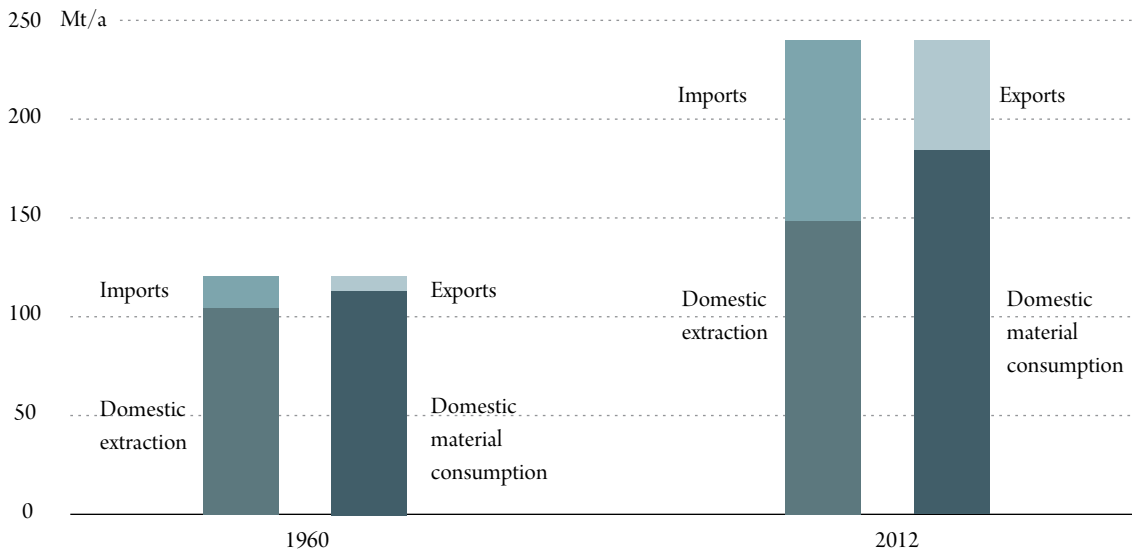
Not all the materials required in Austria are available within the country. Domestic extraction in 2012 was comprised primarily of non-metallic minerals (particularly construction minerals): These amounted to 106 million tonnes and represented over 70% of domestic extraction (▶ Table 2, page 25). In agriculture and forestry, 39 million tonnes of biomass was extracted (26% of domestic extraction). Metals und fossil energy carriers comprised only a very small share of domestic extraction (in each case, 2% of total extraction).

HIGH NET IMPORTS OF FOSSIL ENERGY CARRIERS AND METALS

In quantitative terms, the domestic extraction of biomass and non-metallic minerals represents almost the entire amount of domestic material use within these material categories. This does not mean, however, that no foreign trade in these categories takes place, but only that the import and export flows are of approximately equal size. Even in the categories in which domestic extraction is on a large scale, foreign trade accounts for a part of the demand for resources. Examples of this include coffee and

Figure 8: Austria's material flows in 1960 and 2012 in million tonnes per year

Whereas in 1960 92% of total material input (domestic extraction and imports) fed into domestic material consumption, this figure was only 81% in 2012. Furthermore, imports comprised a larger share of the overall material input in 2012 than was the case in 1960.



Data source: Statistics Austria 2014a

cocoa beans and exotic fruit, as well as wood that is imported for further processing. In the case of wood, large quantities of wood products are also exported. Domestic extraction is particularly unable to meet the demand for fossil energy carriers and metals, however – in these material categories, domestic extraction only supplied 9% and 26% of the material used (▶ Table 3, see below).

In 2012 large quantities were imported in three material categories in particular: fossil energy carriers, metals and biomass. 30 million tonnes of fossil energy carriers, primarily oil and natural gas, were imported. The imports of metallic minerals and goods produced from them amounted to 21 million tonnes. Where biomass is concerned, although Austria can make use of large domestic stocks, biomass-based goods were still imported: in 2012, 24 million tonnes were imported, comprising more than a quarter of all imported materials. Imported non-metallic minerals amounted to 10 million tonnes. In quantitative terms, Austrian imports in 2012 corresponded to over 60% of total domestic extraction. Although export flows in Austria are quantitatively smaller than imports exports amounted to 55 million tonnes in 2012), they nonetheless play an important role in economic terms. The majority of exported goods are more highly processed and obtain higher prices than less processed basic materials.

The largest share of Austrian exports are biomass-based products (almost 40% of total exports), a further 26% of exports are goods produced from metallic raw materials. In the category of fossil energy carriers, only 5 million tonnes are exported, in contrast to the large volume of imports: net imports, at 25 tonnes, are correspondingly very high. Net imports are smaller in all other material categories.

IN WHICH MATERIAL CATEGORIES DO IMPORTS PLAY A PARTICULARLY IMPORTANT ROLE?

International trade, which continues to increase despite a reduction in material use, is not of equal importance in all material categories. Through imports, Austria primarily obtains access to raw materials and primary goods, which are either not available or no longer available in sufficient quantities within the country. At the same time, global price variations (and the income variations that are reflected in these) naturally play a crucial role in the dynamics of international trade. Especially for particular materials, Austria is dependent on imports and with this on fluctuations in international prices and developments in the countries or regions from which imports originate.

Table 2: Domestic extraction of material in Austria in 2012 by material category

The comparatively high domestic extraction of biomass and non-metallic minerals accounted for almost all domestic material consumption. In contrast, a significant share of fossil energy carriers and metals had to be imported.

	Domestic extraction		Share of domestic material consumption (DMC) coming from domestic extraction
	(Mt)	(%)	(%)
Biomass	39	26%	93%
Fossil energy carriers	2	1%	9%
Metals	3	2%	26%
Non-metallic minerals	106	71%	99%
Total	150	100%	80%

Data source: Statistics Austria 2014a

Table 3: Austrian foreign trade in 2012 in million tonnes

Net imports represent the difference between imports and exports.

	Imports	Exports	Net-Import
	(Mt)		
Biomass	24	21	3
Fossil energy carriers	30	5	25
Metals	21	14	7
Non-metallic minerals	10	9	1
Other products	6	6	0
Total	91	55	36

Data source: Statistics Austria 2014a

The share of total material input (domestic extraction together with imports) comprised by imports has been rising in all material categories since 1960 (▶ Figure 9, page 27). Above all, the demand for fossil energy carriers and metals, over 40% of which was already supplied by imports in 1960, cannot be secured using domestic extraction. In 2012, 93% of the input of fossil energy carriers and 89% of the input of metals was supplied through imports. Import dependency is even increasing where biomass is concerned, despite the broad domestic resource base: from 6% in 1960 to 38% in 2012. Non-metallic minerals, which in quantitative terms consist primarily of construction minerals, are currently not widely traded, because of their relatively low cost, the high transport costs associated with the large quantities required, and their relatively wide availability. This could change in the future, as set out in detail in the chapter on non-metallic minerals and also in the 2011 report *Resource Use in Austria* (BMLFUW and BMWFJ 2011). In 1960, 7% of non-metallic mineral inputs were derived from imports. By 2012, this share had increased only slightly to 9%. Although the total input in this material category is far larger than in other material categories, – at 116 million tonnes, comprising almost 50% of the total material input – very large quantities of non-metallic minerals are imported nonetheless. In 2012 this figure stood at 10 million tonnes and thus half the amount of metal imports.

These increasing imports are however not exclusively destined for Austrian consumption –a smaller yet growing share is in turn integrated into exports (▶ Figure 8, page 24) and is ultimately consumed in other countries. The dependency on materials from other countries and on the income from goods produced domestically that are exported to other countries has continually increased over recent decades. This development can be interpreted as the consequence of the intensification of globalisation and strengthened differentiation within the international division of labour. At the European level, the challenges in the area of raw materials (such as the reduction of import dependency) are being tackled through a bundle of measures, brought together through the 2013 adoption of the *European Innovation Partnership on Raw Materials* (▶ Box, see below).

EUROPEAN INNOVATION PARTNERSHIP ON RAW MATERIALS

The *European Innovation Partnership* (*EIP*) was created to speed up the introduction to the markets of innovative solutions to major challenges. The EIP on Raw Materials is intended to reduce import dependency by securing the supply of raw materials from EU member states and third countries, through greater resource efficiency and through the use of supply alternatives. Furthermore, the EIP should ensure that Europe plays a leading role in the raw materials economy, while simultaneously mitigating ecological and social impacts related to this. In this context, a key role is played by research & development (particularly through the *Horizon 2020 Programme*) along the entire raw materials value chain (from exploration and extraction through processing/refining to recycling and substitution), concerning current knowledge, exchange of good practice, updating legal guidelines and political dialogue.

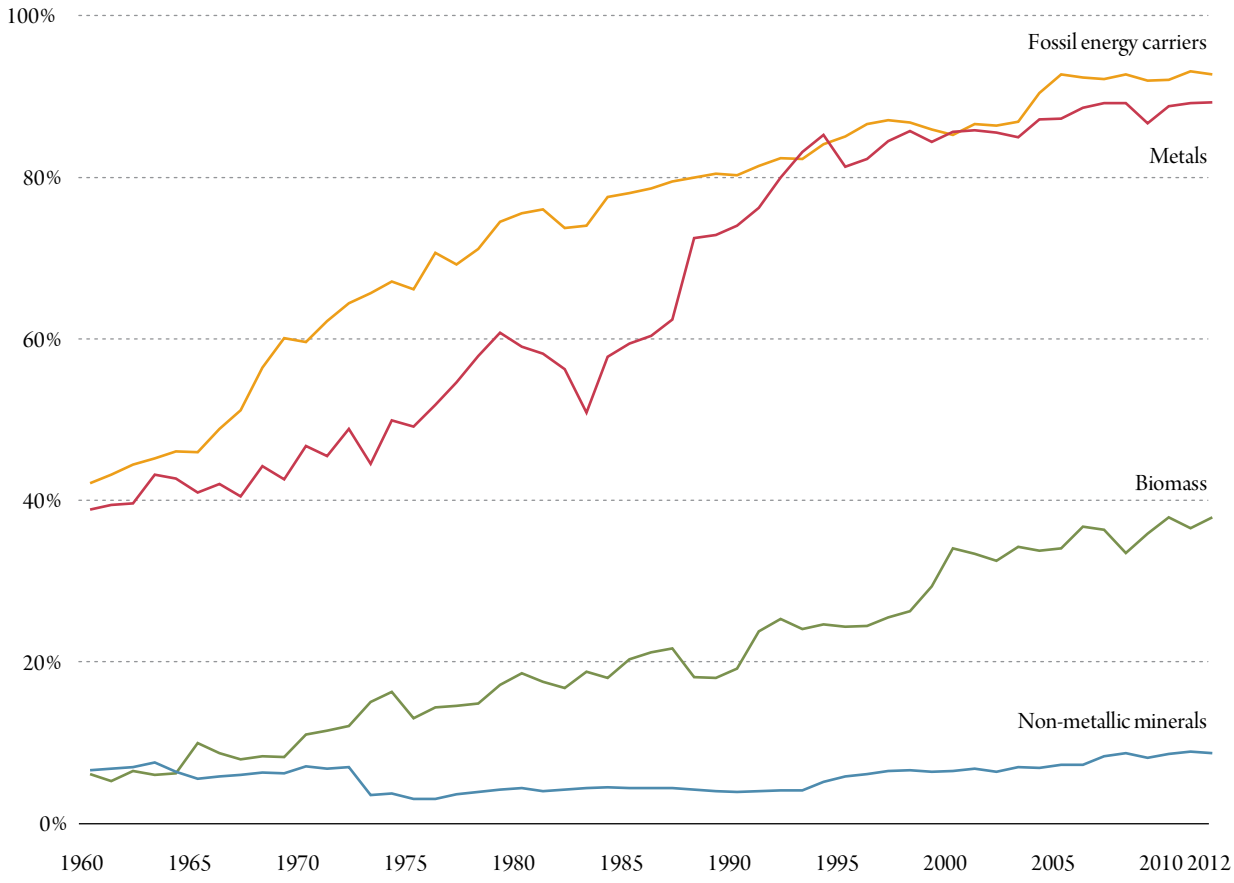
The overall goal of the EIP in Raw Materials is to support the targets of the EU's 2020 strategy for industry and together with the flagship initiatives *Innovation Union* and *Resource Efficient Europe* to achieve a sustainable supply of raw materials for the European economy.

INTERMEDIATE MATERIAL USE THROUGH IMPORTS AND EXPORTS

The growing international division of labour in material extraction and processing is leading to a situation in which in almost all countries (including Austria), a significant share of the material expenditure is related to the production of exports. This also means that imports are connected to a significant material expenditure in other countries, which cannot be recorded through the volume of traded goods crossing borders. To capture the impacts of intensified globalisation in better detail, methods are currently being developed in the context of environmental accounts in general and material flow accounts in particular, which record the intermediate material use connected to imports and exports and enable this to be integrated within the results for material input and use. For this reason, material flows are expressed as their so-called raw material equivalents, or RMEs (▶ Box, page 29). The converted flows comprise not only the weight of the traded product itself but also the material flows that are utilized to create it. By taking account of the raw material equivalents of imports and exports, so-called raw material consumption can be calculated.

Methods for calculating raw material consumption (often defined in the literature as the *material footprint*) are currently being developed. A specific calculation method has been introduced in Austria, in which the share of material input that is utilized for the production of goods for export is estimated using monetary input-output tables (MIOT). The MIOT depict the monetary structure of Austrian production and Austrian consumption. This information is expanded upon with coefficients from *life cycle analysis* (*LCA*) for all those products, which are not produced in Austria and about which production the domestic MIOT cannot therefore provide information (the method is described in more detail in Schaffartzik, Eisenmenger et al. 2014). For the countries of the European

Figure 9: Austria's import dependency, measured as the share of imports in total material inputs (domestic extraction plus imports) in per cent and by material category between 1960 and 2012



Data source: Statistics Austria 2014a

Union, a similar method has been developed and applied (Schoer et al. 2012), the results of which are now also included in Eurostat reports (Eurostat 2015a).

10 KG OF MATERIAL PER PERSON AND DAY ARE USED INDIRECTLY IN OTHER COUNTRIES

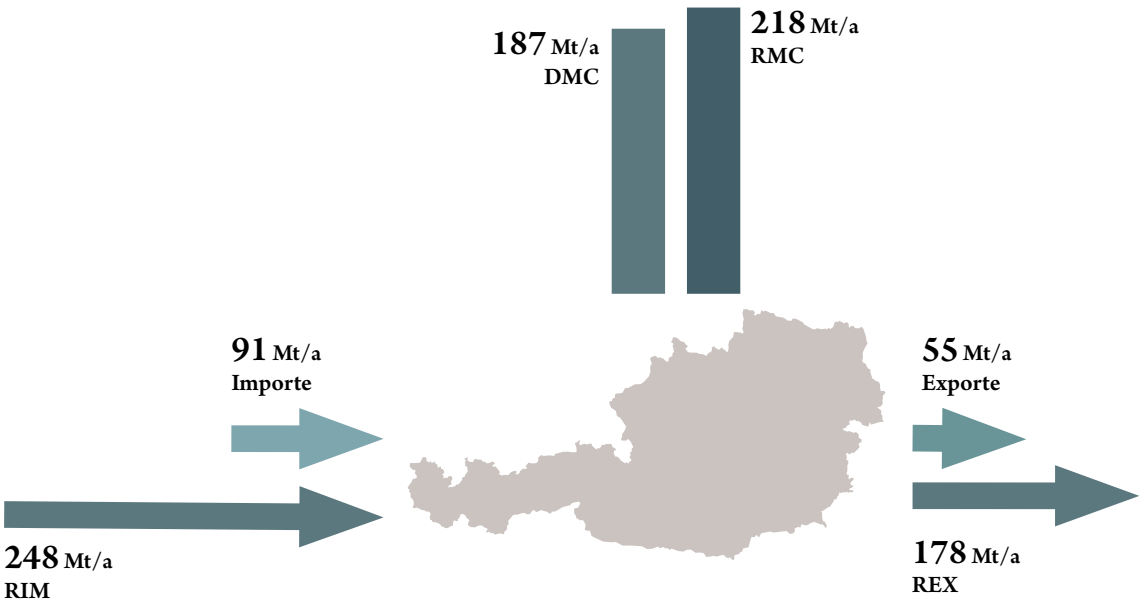
Austrian raw materials consumption exceeded material use by 31 million tonnes in 2012 (▶ Figure 10, see below). The materials used to produce goods imported into Austria exceeded the volume of imports by 156 million tonnes. The raw material equivalents of exports were c. 123 million tonnes larger than the volume of the exports themselves.

In 2012, average material use in Austria was 22.2 tonnes per capita. This represents over 60 kg per person and day. If we take account of the raw material equivalents for this material use, then average raw material consumption in 2012 comprised almost 26 tonnes per capita and year and 71 kg per person and day. Raw material consumption exceeded material use, because more material is used in the production of goods imported into Austria than is used in Austria for the production of goods for export. On the balance, per person and per day, Austria makes use of c. 10 kg more material in other countries than it supplies for the domestic production of exports.

Through imports, many countries, including Austria, outsource a large part of the material requirements (and the associated environmental problems) related to their consumption to the producer countries. At the same time, material is also brought together (and the environment put under pressure) in these countries in order to create products for consumption in other countries. The balance from these activities provides a new perspective upon the global environmental consequences that are linked to the resource consumption of a country. It is thus of crucial importance to consider the intermediate inputs related to international trade.

Figure 10: Austria's raw materials consumption (RMC), exports in raw material equivalents (REX) and imports in raw material equivalents (RIM) in comparison with domestic material consumption (DMC), imports and exports in 2012 in million tonnes per annum

Austria requires more raw material globally than it supplies. Raw material consumption therefore exceeded material use.



Data source: Eisenmenger, Schaffartzik and Wiedenhofer 2015

A COMPARISON BETWEEN AUSTRIA AND OTHER COUNTRIES

Whether measured as material use or raw material consumption, an Austrian citizen uses a large amount of material both in the European and in the wider international context. In 2012, the average European material use was 13.5 tonnes per capita. With a material use value of 22.2 t/cap/a, Austria was significantly above this average amount (▶ Figure 11, page 30). Only in five other countries (Finland, Estonia, Ireland, Sweden and Romania) was material use higher than in Austria. In a comparison between European countries, Austria's high use of non-metallic minerals stands out in particular. Both the specific nature of Austrian material use and the statistical estimation methods in this material category play a role in this case.

WHAT CAUSES AUSTRIA'S HIGH LEVELS OF RESOURCE USE?

Austria uses more non-metallic mineral materials i. e. primarily construction minerals, than countries that are situated in warmer climatic zones and that, for example, require less material for thermal insulation of buildings and for the construction of transport infrastructure. Austria also requires on a per capita basis more non-metallic mineral materials than countries with a higher population density, which require less, calculated in per capita figures, in terms of infrastructure and buildings. Furthermore, the demand for non-metallic minerals is often higher in the alpine regions than on lower terrain, because infrastructure projects face different structural engineering challenges due to temperature variations and differences in altitude.

The data on European material use of non-metallic minerals in 2012 further reflect the country-specific impacts of the economic crisis of 2007/2008. In Spain, for example, the use of construction minerals fell so dramatically as a result of the economic crisis that per capita Spanish material use in 2012 was lowest of any EU Member State.

A further reason for the high values in Austrian use of non-metallic minerals in comparison to other European countries lies with the very high standard of the data basis in Austria. This applies particularly in the case of construction minerals, the physical quantities of which cannot usually be comprehensively recorded in statistical reporting. In Austria, the methods used to estimate these materials have been updated, so that the degree of reporting accuracy is very high in contrast to other countries. These methodological innovations can be read about in the context of non-metallic minerals in the 2011 report *Resource Use in Austria* (BMLFUW and BMWFJ 2011).

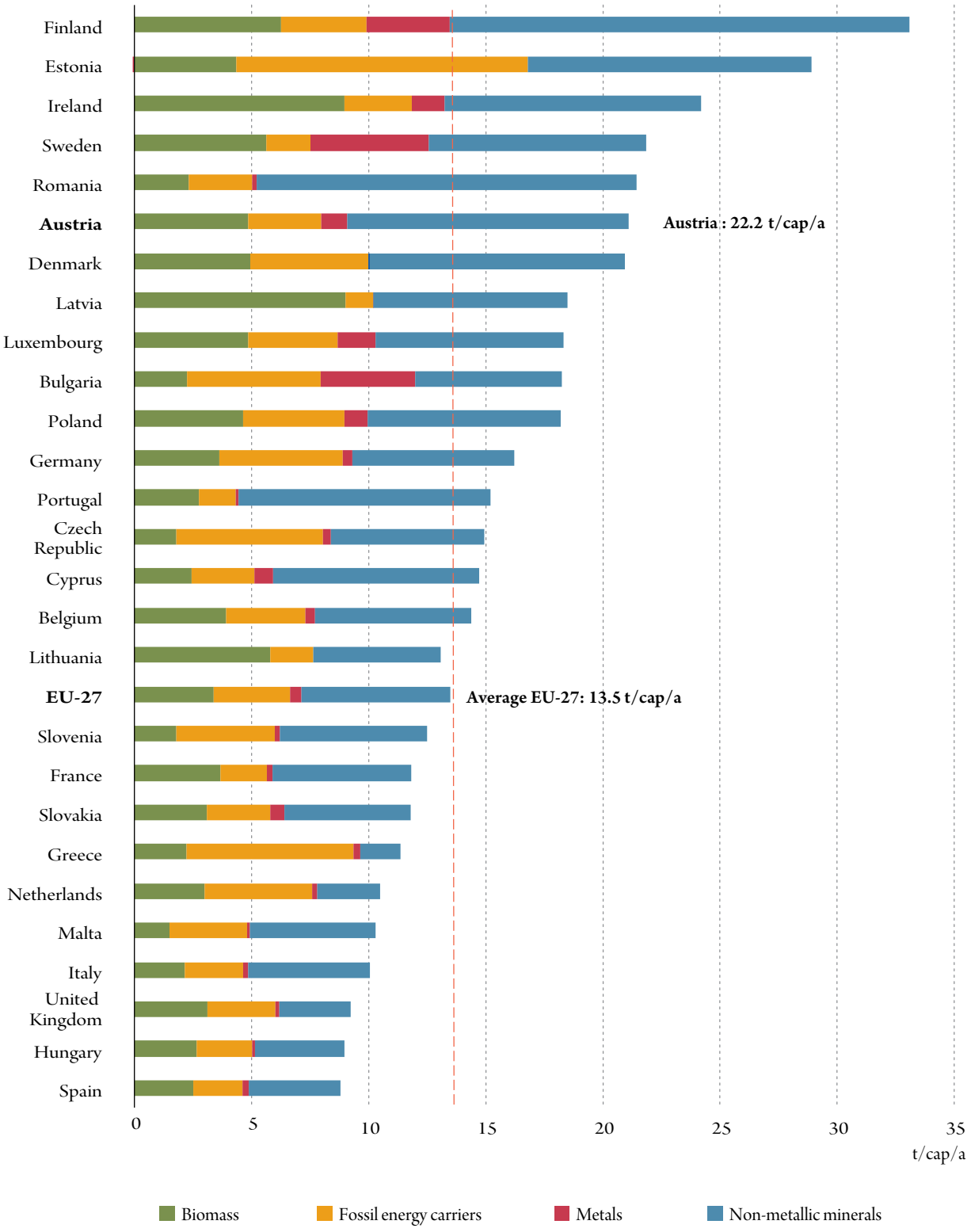
However, the differences in comparison to other European countries do not of course depend upon the different uses of non-metallic minerals or on the data basis. There is a difference of 24 tonnes per capita between the average Finnish material use (33 tonnes per capita) and the Spanish use figure (below 9 tonnes per capita) – and this difference is greater than the figure for Austrian material use. The level of material use is influenced by a range of different factors, which range from climate and topography to economic sectors and resource basis,

RAW MATERIAL EQUIVALENTS

In order to give figures for how much material – regardless of where in the world – must be utilized in total to produce the goods consumed in a particular country, indicators are calculated using so-called *raw material equivalents* (*RMEs*). The RMEs of a material import or export flow comprise the volume of the traded good itself together with the materials, which were utilized during its production. For example, in the case of an import of copper wire, the waste rock removed along with the copper ore, the fossil fuels required for mining, processing and refining, and the construction minerals removed during mining activities or at processing plants, are proportionately accounted for. The *raw material equivalents of the exports* (*REX*) and the *imports* (*RIM*) are calculated. *Domestic material consumption* (*DMC*) can also be expressed in RMEs: *Raw material consumption* (*RMC*) is calculated using domestic extraction, adding RIM and subtracting REX.

Figure 11: Domestic material consumption (DMC) by material category in tonnes per capita and year (t/cap/a) in comparison with other European countries in 2012

On average, each European citizen used 13.5 tonnes of material. Austria was significantly above this average value and recorded the sixth highest per capita figure for material use.



Data source: Eurostat 2015b

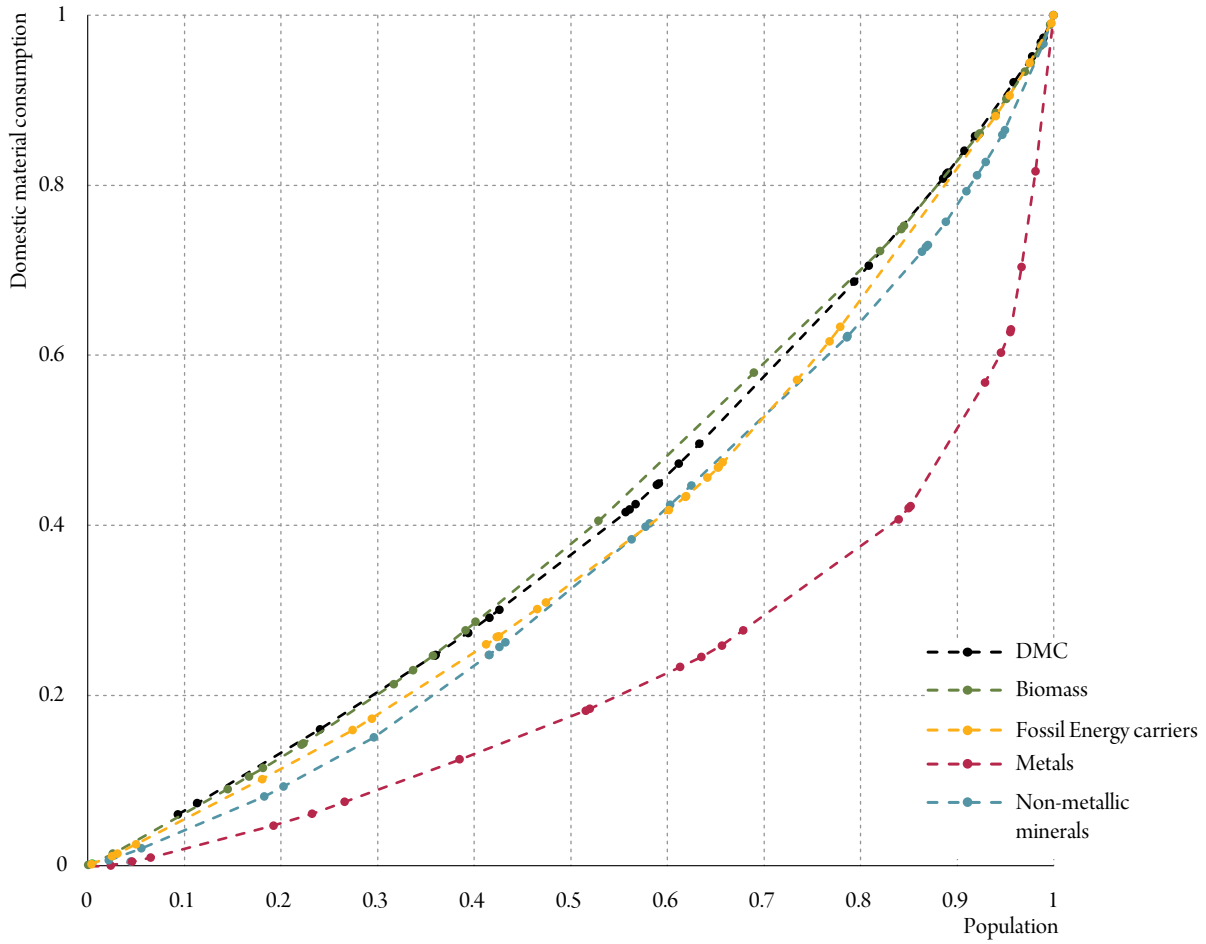
through to population density and GDP. The economic prosperity of a country alone, measured in terms of GDP, cannot explain the level of material use. By way of example, in 2012 16 European countries showed a level of per capita material use that was above the European average. Only 8 of these countries, however, showed a per capita GDP that was higher than the European average. While high resource use does not guarantee economic prosperity, only three European countries (France, the Netherlands and the United Kingdom) achieved an above-average per capita GDP while also showing below-average material use levels.

IN EUROPE, 60% OF THE POPULATION ACCOUNT FOR ONLY 20% OF THE MATERIAL USE

Overall, the multiplicity of factors that could influence material use lead to a situation in which there is a great inequality of distribution of material use among the population of the European Union (▶ Figure 12, see below). The 60% of the European population with the lowest levels of metal use, for example, only c. 20% of the materials used throughout Europe in this category. In contrast, biomass and non-metallic minerals are

Figure 12: Lorenz curves depicting material use levels in 27 European Member States in 2012 by material category

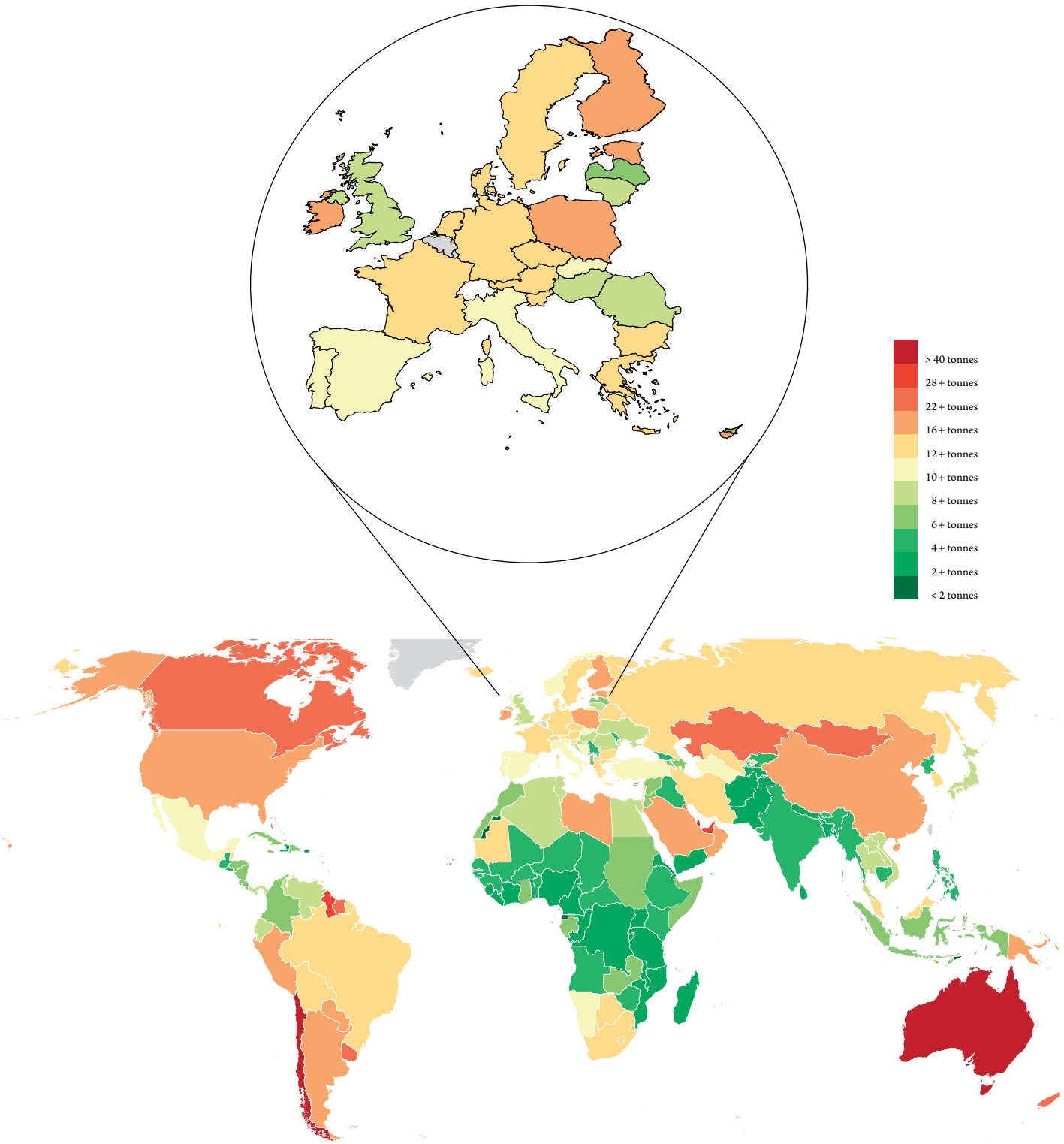
The diagonal line shows what equal distribution of material use among the European population would look like. The further the curves for each material category diverge from this diagonal line, the more unequal the distribution.



Data source: Schaffartzik, Mayer et al. 2014

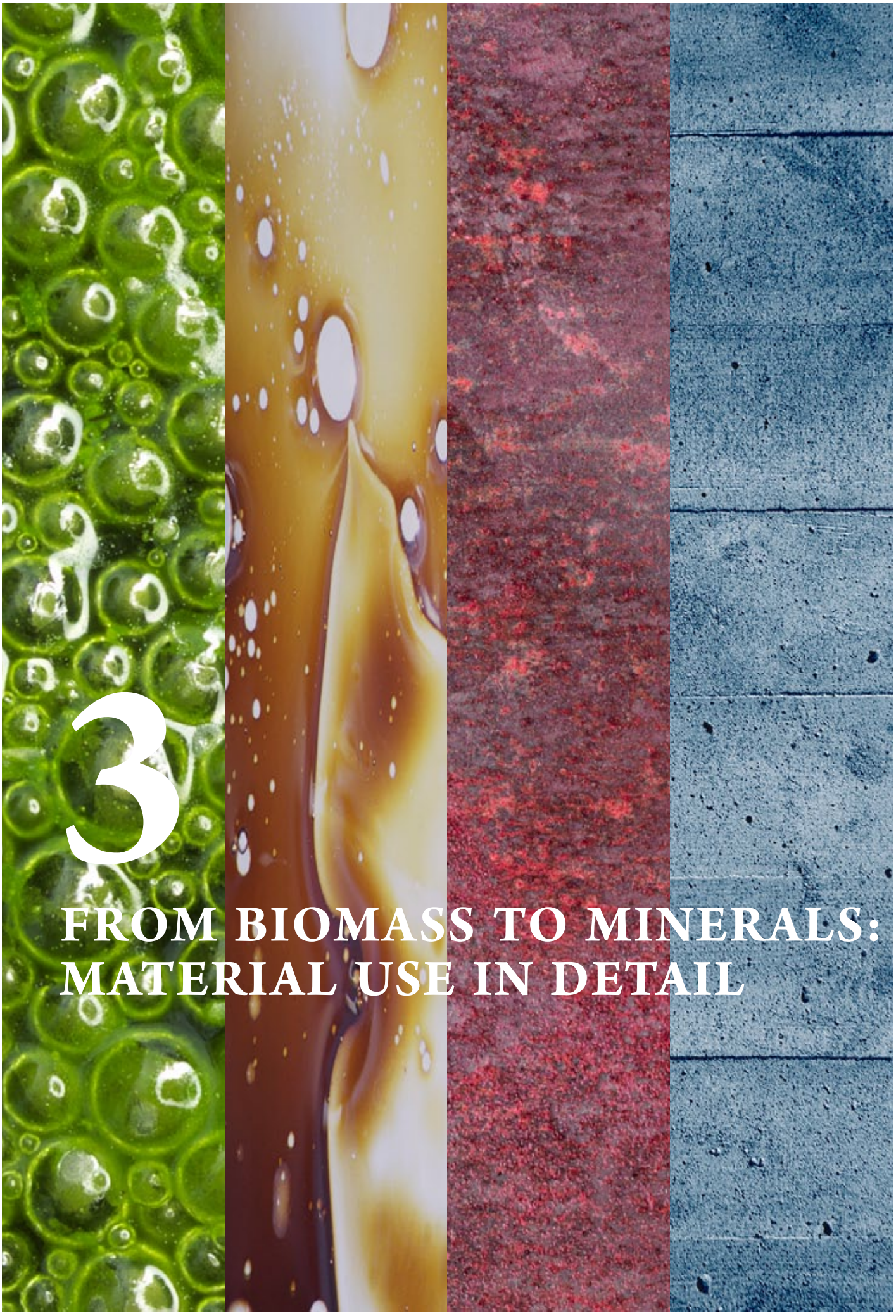
Figure 13: International material use in tonnes per capita in 2010

Countries with the highest levels of material use are coloured dark red, while those with the lowest material use levels are shown in dark green.



Data source: Schaffartzik, Mayer, et al. 2014

significantly "more equally" distributed. For these material categories, use is more closely matched by population levels than in the case of metals. While the comparison within the European Union makes clear that material use even within this community of states varies by a factor of more than three between Finland and Spain, variations are far greater at an international level. In 2010, most European countries were in the middle range regarding their per capita levels of material use in an international context (▶ Figure 13, page 32). At more than 40 tonnes per capita and year (a level that is almost double that of Austria), the 2010 material use levels especially in the raw material extracting countries of Australia and Chile and in the United Arab Emirates and Qatar were extremely high. The prominent role of raw material suppliers demonstrates the need to take account through the use of indicators in raw material equivalents (▶ Box, page 29) of how much material is consumed in the production of goods for export. The raw material use of the major raw material extractors and exporters could appear far lower than their material use, since a large part of their material use is used for the production of export goods (see e.g. Wiedmann et al. 2013).



3

FROM BIOMASS TO MINERALS: MATERIAL USE IN DETAIL

Looked at as a whole, the level and development of material use in Austria and the world contain important information on the societal utilization of natural resources. The extraction, imports and exports that constitute material use are, however, still too highly aggregated to enable e. g. measures for reducing use to be applied at this level. For this purpose, more detailed information is required about the composition of material use in terms of biomass, fossil energy carriers, metals and non-metallic minerals and also about the different trends in these material categories.

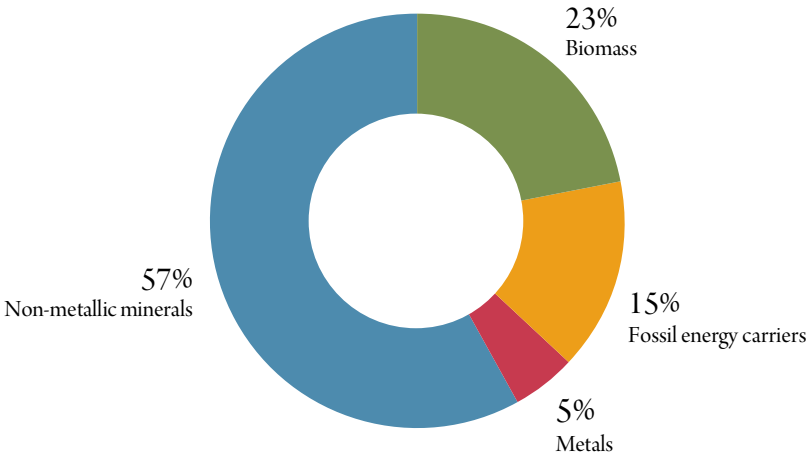
It becomes immediately clear upon first view of the composition of Austrian material use in 2012 (▶ Figure 14, see below) that the four major material groups have very different shares in the overall figure. 107 million (57%) out of a total of 187 million tonnes of material use relate to non-metallic minerals, primarily construction minerals . This report focuses on biomass, which at c. 42 million tonnes and 23% makes up the second largest category within Austrian material use. These "renewable raw materials" have particular significance within sustainability strategy. Despite their renewable characteristics, their utilization is also limited, as will be discussed below. Fossil energy carriers contribute c. 28 million tonnes (15%) and thus represent the third-largest category. They contribute through combustion to anthropogenic climate change and in view of their environmental and climate impacts are of key importance. In 2012, metals constituted 5% (under 10 million tonnes) of Austrian material use; however, they are more significant – partly through their role in rendering other materials utilizable – than this comparatively small share suggests.

ALL FOUR MATERIAL CATEGORIES ARE ENVIRONMENTALLY RELEVANT

The four material categories that together constitute Austrian material use are clearly differentiated in respect of their relevance for (environmental) policy concerns. The non-renewable abiotic materials, primarily fossil energy carriers and metals, are impacted upon over a longer period of time by the exhaustion of stocks through human utilization, raising concerns about future price increases, potential substitutes and supply security. The burning of fossil energy carriers is of particular concern with regard to their environmental impacts, such as anthropogenic climate change, but the production, use and waste disposal of metals, paints and other chemicals are also of high relevance for the environment. Although non-metallic minerals including construction minerals are rarely at the centre of discussions on environmental strategies, they are nonetheless of great importance in environmental terms, particularly because of the quantities that are extracted and utilized. This category was the key focus of the 2011 report *Resource Use in Austria* (BMLFUW and BMWFJ 2011). During the construction of buildings and infrastructure from construction minerals and during their on-

Figure 14: Shares of the four major material categories in Austrian domestic material consumption (DMC) in 2012

Non-metallic minerals, and primarily construction minerals, constitute the largest share (almost 60%) of the total of 187 million tonnes.



Data source: Statistics Austria 2014a

going utilization, other materials, primarily fossil energy carriers, are also used. In this way, the use of construction minerals has an impact upon material use that extends beyond this material category (▶ Box, see below).

DOMESTIC EXTRACTION, IMPORTS AND EXPORTS BY MATERIAL CATEGORY

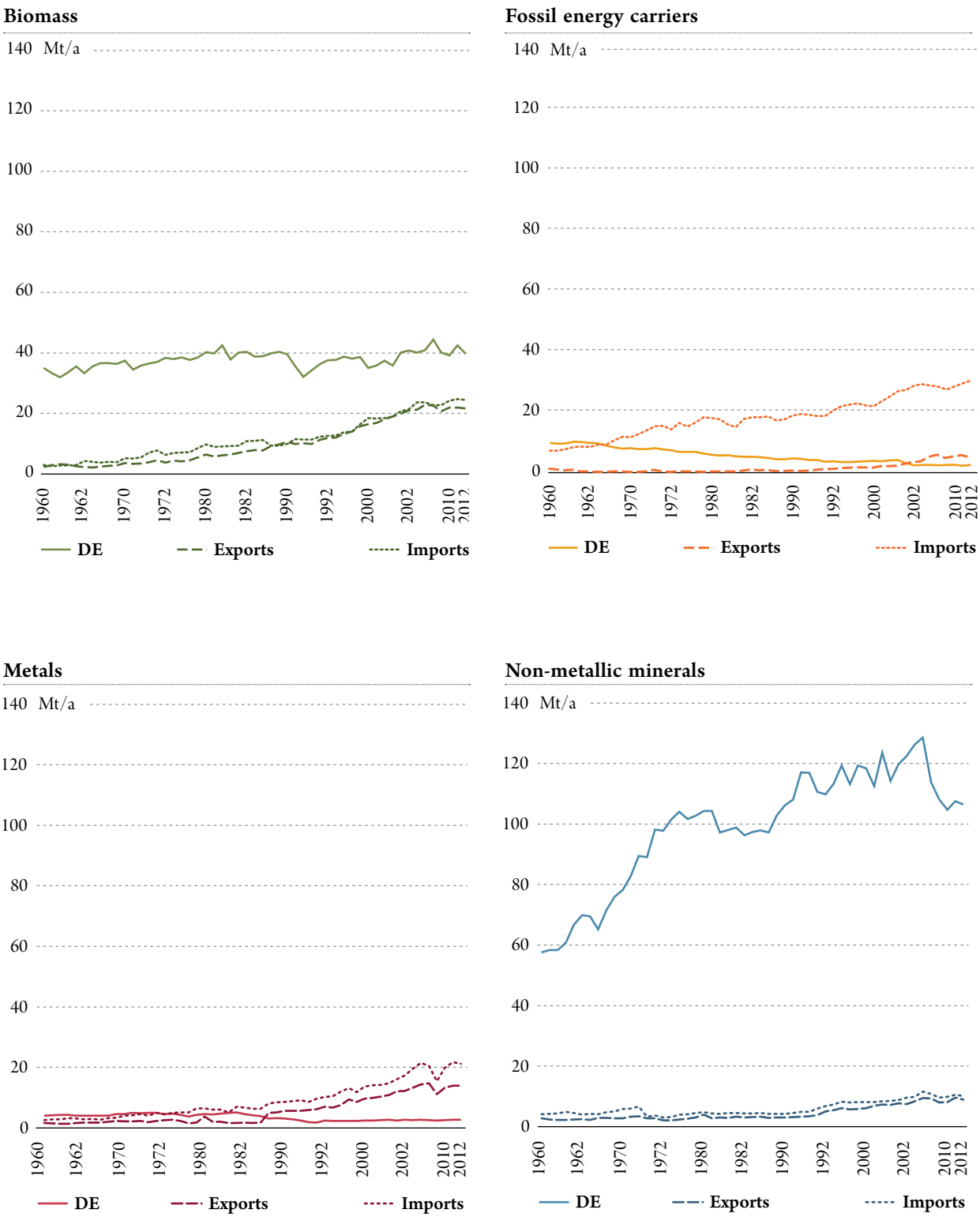
Material use in the four major material categories comprises the respective domestic extraction figures together with imports and minus exports. These three flows were in each case subject to greatly varying trends over time and were related to one another in very different ways, as Figure 15 (▶ page 37) makes clear. Domestic extraction of biomass has remained relatively stable since 1960 and rose between 1960 and 2012 from 34 to 39 million tonnes. This figure is still higher than the volumes of imports and exports, although these have increased continually since 1960. Because imports (24 Mt/a) and exports (21 Mt/a) of biomass are approximately equal in scale, biomass use in 2012 was only slightly higher, at 45 million tonnes, than domestic extraction. Fossil energy carriers show a completely different picture. At 10 million tonnes per year, their domestic extraction was already relatively low in 1960 (although slightly higher than the 7 million tonnes that were imported), falling to 2 million tonnes per year by 2012, while imports continued to rise, reaching 30 million tonnes in 2012, which was significantly higher than domestic extraction. Austria is also involved in the processing of fossil energy carriers, for which reason 5 million tonnes of fossil energy carriers were exported in 2012 (more than double the figure for domestic extraction). The relationship between imports and domestic extraction since 1960 is very similar in the case of metals to that of fossil energy carriers. In this material category too, domestic extraction is very low (3 million tonnes in 2012), however 14 million tonnes were imported. In contrast to fossil energy carriers, a still greater share of imported metals was also incorporated into exported goods, at 14 million tonnes in 2012. The non-metallic minerals, which constitute the largest category in Austrian material use, are almost exclusively extracted in Austria. Extraction increased from 1960 until the financial crisis of 2007/08 from 57 to 128 million tonnes, decreasing since then to 106 tonnes. Because of their wide availability in most countries and their comparatively low price, construction minerals, which form the major part of non-metallic minerals, are rarely traded internationally. In total, 10 million tonnes of non-metallic minerals were imported in 2012 and 9 million tonnes were exported.

THE RELATIONSHIPS BETWEEN THE MATERIAL CATEGORIES

In aiming for a reduction in material use, it is important to consider what the relationship regarding use is between the different categories. This includes the consideration that a reduction in one area might lead to an increase in another area, or in a positive scenario, to a reduction there too. The utilization of construction minerals is in some cases closely related to fossil energy carriers. Somewhat higher use of construction minerals can lead to a reduction in the demand for fossil energy carriers: Where thermal insulation is used in construction, less heating is required. The specific use of building raw materials can also be a crucial determinant: where transport infrastructure is designed for individual transport forms, the use of liquid fossil fuels increases. There is also a long-standing relationship between biomass and fossil energy carriers. In historical terms, the use of fuelwood is being replaced in many countries by oil and coal. In the move towards greater utilization of fuels from biogenic sources, it is intended that a share of fossil energy carriers should be replaced by biomass or gas of biogenic origin. This substitution is however very small and represents c. 5–7% of fuel use.

Figure 15: Trends in domestic extraction (DE), imports and exports in the four major material categories between 1960 and 2012 in million tonnes per year (Mt/a)

While for biomass (top left) and non-metallic minerals (bottom right) domestic extraction (significantly) outweighs export trade, for fossil energy carriers (top right) and metals (bottom left) the opposite is true.



Data source: Statistics Austria 2014a

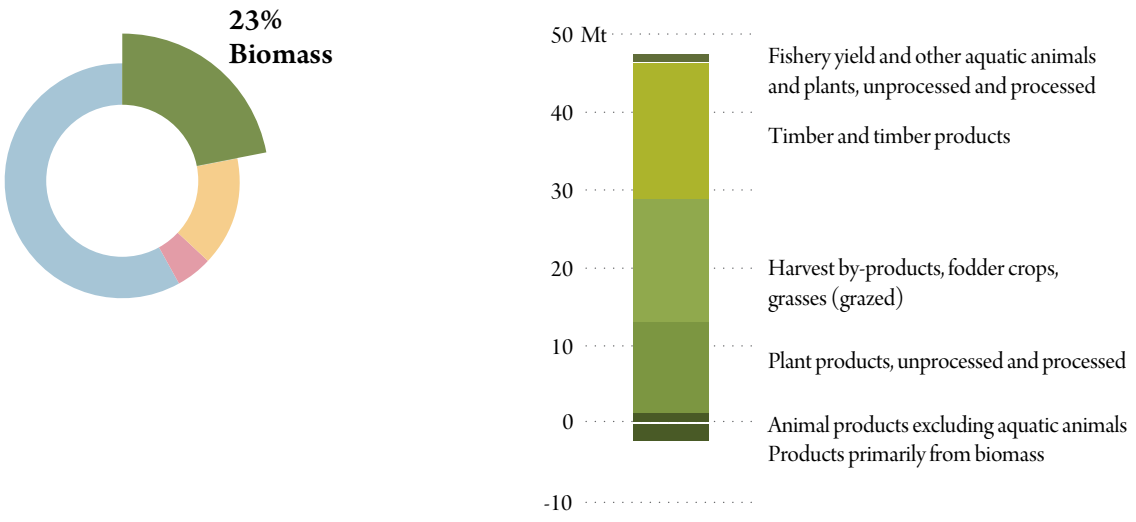
FOCUS ON BIOMASS

In the material flow accounts, biomass includes materials of plant or animal origin. In other contexts, this material group is also referred to as "biogenic materials" or "biotic resources". More detailed information on the use of these terms can be found in Box (▶ page 39). The domestic extraction of biomass includes all plant-based raw materials extracted from nature: products of arable farming, including all utilized harvest by-products or coupled products (e.g. straw), the yield from grassland, including biomass grazed by livestock, and forestry products. According to the conventions of material flow accounting, livestock belong to societal stocks – for which reason the extraction of feedstuff is included in material flow accounts, yet animals (with the exception of animals hunted in the wild, e.g. game animals, fish from marine stocks) or products from livestock farming are not accounted for as extraction. Meat from domestic production is accounted for in material use through consumption of feedstuff including grazed biomass. Contrastingly, where imports and exports are concerned, all traded goods are accounted for, including products that are not accounted for in domestic extraction. These include products of both plant and animal origin.

Since further processed products from biomass are not extracted domestically, their use constitutes the physical export trade balance (imports minus exports): Domestic material consumption is calculated as domestic extraction together with imports minus exports (▶ for material flow accounting methods, see also the chapter *Natural Resources – the Foundation of our Society* and the Annex). The material flow account shows that in 2012 Austria was a net importer of both highly processed plant products and animal products (▶ Figure 16, see below). The use of biomass is comprised predominantly of timber and timber products (over 17 million tonnes), followed by fodder crops and harvest by-products (almost 16 mil-

Figure 16: Austrian biomass use in 2012 in million tonnes per year

While Austria exports further processed biomass products of both plant and animal origin (negative values in domestic material consumption), plant products, harvest by-products and timber constitute the major components of domestic use. The share of fishery yield comprised by aquatic animals is so minute at 0.1 tonnes that this category is not discernible in the Figure.



Data source: Statistics Austria 2014a

lion), and plant products for food and industrial processing, e.g. fibre plants (almost 12 million tonnes). The domestic consumption of fish and other aquatic animals is also recorded in the material flow account as biomass. At 100 000 tonnes in 2012, the use in this category is, however, relatively tiny and is not discernible in Figure 16 (▶ page 38).

TOWARDS THE SUSTAINABLE USE OF RENEWABLE RAW MATERIALS

All material flows in the biomass category refer to so-called sustainable raw materials, i.e. raw materials that – in contrast to fossil energy carriers – renew themselves within time frames that are similar in scale to the frequency of human utilization. For this reason, biomass is accorded a key role in strategies for sustainable resource use. This is also the case in the Austrian *Bioeconomy Action Plan*, (▶ Box, page 44). The measures contained within this action plan aim to encourage the use of renewable resources by industry in Austria. A specific goal within this is to accelerate the technological utilization of biomass in new areas of application (e.g. bioplastic). Although biomass is seen as "renewable", it should not be forgotten that this is only true in circumstances of sustainable production and that the availability of biomass is not unlimited: on one hand, the available areas for cultivation are limited and becoming more scarce, and on the other hand, intensive use of these areas can lead to soil degradation, including the loss of soil fertility and/or overexploitation of groundwater and pollution of other water bodies. Where intensive farming is being practiced, fossil energy carriers together with other oil-based substances, e.g. for crop protection, are used. When agricultural production is accompanied by deforestation at $C0_2$-rich locations, the CO_2 balance of this production in particular must be assessed.

Austria, by contrast, has shown an increase in forested area for some time now. This area increase is almost exclusively due to natural reforestation processes; this means the return to forested area of land formerly used for agriculture, without human intervention to this end. Political initiatives such as the *Bioeconomy Action Plan* as part of a bioeconomic strategy (▶ Box, page 44) thus require not only information about the material use of a particular socioeconomic system but also about the specific production, conversion and utilization of these materials within the system. This knowledge is a prerequisite for the development of effective strategies for the cascading utilization of biomass (▶ Box, page 40).

TRACKING BIOMASS FLOWS IN AUSTRIA

Material flow accounting, with its focus on inputs (domestic extraction and imports) and outputs (exports, emissions and wastes), does not afford a detailed picture of the system's inner workings. A complementary function to the Austrian material flow data in this respect is fulfilled by the flow sheet developed by the *Austrian Energy Agency* (*AEA*) on biomass use in Austria in 2011 (▶ Figure 17, pages 42/43). In this material flow sheet, the biomass flows from domestic extraction or imports into the Austrian socioeconomic system are tracked through the entire system to the point at which they either reach their end-use consumption in Austria or are exported.

DEFINITION: BIOMASS

In material flow accounts, the term "biomass" refers both to living and non-living organic matter: plants, animals, deadwood, foliage, straw, etc. The fossil energy carriers of biomass origin, including peat, are not accounted for here. Only the share of biomass that is utilized by society is included in the calculations.

In the context of energy technology, the term is more narrowly defined: here biomass includes only material of plant or animal origin that can be used to produce energy (heating and electrical energy or as fuel).

Biomass in the context of material flow accounting is also often defined as renewable or sustainable raw material, as biotic resource or as biogenic material. As a rule, no conceptual difference adheres to these definitions.

The biomass derived from imports and domestic extraction and used in 2011 in Austria had a total dry matter weight of c. 48 million tonnes. Of this, 37 % came from imports, 23% from cropland and permanent crops, 10% from grassland, 22% from forestry land and 8% from other green areas.

WOOD COMPRISES ALMOST 40% OF TOTAL BIOMASS USE

According to the material flow account, in 2011 wood and wood products constituted almost 40% of all Austrian biomass use. This use, as the material flow account makes clear, was not only derived from domestic extraction but also to a significant degree from imports. The material flow account shows that in 2011 Austria imported more than 11 million tonnes of wood and wood products, the largest share of which was raw timber, i.e. wood that had not been processed further. This came primarily from Germany (34% of imports), the Czech Republic (19%), Slovenia and Slovakia (each 8%) to Austria (FAO 2014). The material flow sheet shows that the imports flowed mainly into the wood processing industry (paper and sawmill industries) and into goods manufacturing. The vast majority of products from the wood processing industry are exported. The material flow account shows that overall in 2011, Austria exported more than 7 million tonnes of wood and wood products. The export goods are almost entirely semi-finished products (e.g. sawn timber) and finished products (e.g. paper and furniture). The major destinations for these exports were Italy (34% of exports), Germany (24%), Slovenia (6%) and the Czech Republic (5%) (FAO 2014). Because of the leading position of the domestic export-oriented wood processing industry, Austria as one of Central Europe's most extensively forested countries is nonetheless a net importer of wood[2]. In Austria, wood, primarily as firewood but also large amounts of by-products and waste products from the export-oriented wood processing industry, is fed into thermal energy generation. Thus according to the energy balance, about 15% of the domestic primary energy supply comes from wood. Only a comparatively small amount of imported and domestically extracted wood is further processed as wood products that will also be used in Austria.

FOODSTUFF DETERMINES BIOMASS USE

The largest share of biomass is either directly or indirectly used for human nutrition. The role of biomass in the provision of human nutrition cannot be substituted by any other raw material. The *Bioeconomy Action Plan* responds to this in that it follows the priority sequence of food production, feed production, and bioenergy (the "table-trough-tank" principle) in terms of land-use designation.

2 The processing of imported raw timber into semifinished and finished products, which can then be exported, generates added value, work and income in Austria.

CASCADING USE OF BIOMASS

The cascading use of biomass provides for comprehensive use of both harvested biomass and biomass produced as a harvest by-product or waste product. This essentially takes two forms: 1) other parts of the plant and not only the fruit (the primary harvest product) are used, 2) the utilization chain is extended by using biomass for material purposes for as long as possible, and thereafter for energy.

Maize can be materially utilized, e.g. to produce starch, while the leaves and stems of the plant can be either used for the production of biogas or returned to the soil (or left there during harvest) as nutrient enrichment. Wood can be used initially to construct furniture, recycled where possible and only after multiple utilization as a material, used in thermal recycling to produce energy. Cascading use can lessen the pressure in terms of additional extraction of biomass by providing for a longer and more comprehensive use of the biomass already circulating in the socioeconomic system.

The largest flow of imported agricultural biomass goes either directly or via domestic animal feed suppliers to livestock farming. A smaller share of animal- and plant-based biomass flows directly via livestock farming into food production and partly into consumption. Livestock farming is also the largest beneficiary from the domestic extraction of biomass, which takes place in Austrian agriculture. Only a small share of the biomass that flows into livestock farming is eventually converted into products (meat, milk and eggs) for human nutrition. The end use for most of this biomass is assigned to animal metabolism and is returned to the environment through animal excreta and breathing. On average, 5–10 tonnes of plant biomass is required to produce one tonne of animal products. Thus, in terms of biomass use, livestock farming is extremely material-intensive. Only c. 10% of all agricultural products is directly, i.e. without flowing via livestock farming, used for the production of food. This relationship is not only applicable to Austria, but to livestock farming throughout the world. Based on the high level of material intensity of livestock production, the rapidly increasing consumption of animal products is a significant cause of the increase in global biomass demand (see Kastner et al. 2012).

In Austria too, livestock production is a significant cause of the high level of biomass use. Along with the above-average meat consumption of 106 kg per capita and year (FAO 2014), this is also linked to the geographical situation of Austria within the alpine region: The use of alpine areas by ruminants, primarily cattle, facilitates the utilization of large areas, which for climatic or topographical reasons are generally unsuitable for arable farming, with a few exceptions. Cattle-farming in alpine grasslands is thus an Austrian sector with strong productivity and, simultaneously, comparatively low greenhouse gas emissions per kg of meat or per kg of milk (Leip et al. 2010).

Given the environmental problems associated with livestock farming internationally – anthropogenic climate change, air pollution, water over-extraction and pollution, loss of species diversity – and the negative health impacts linked to the high consumption of meat and animal fats in developed countries, a reduction in the consumption of animal products is advisable (FAO 2006).

UNDERSTANDING THE MATERIAL FLOWSHEET

To produce a material flowsheet, reference must be made to a wide range of data sources, which include the data underpinning the material flow account together with supply and energy balances, data on goods production and on the production and recycling of wastes (see also Kalt and Amtmann 2014 and ▶ Box below). Since in

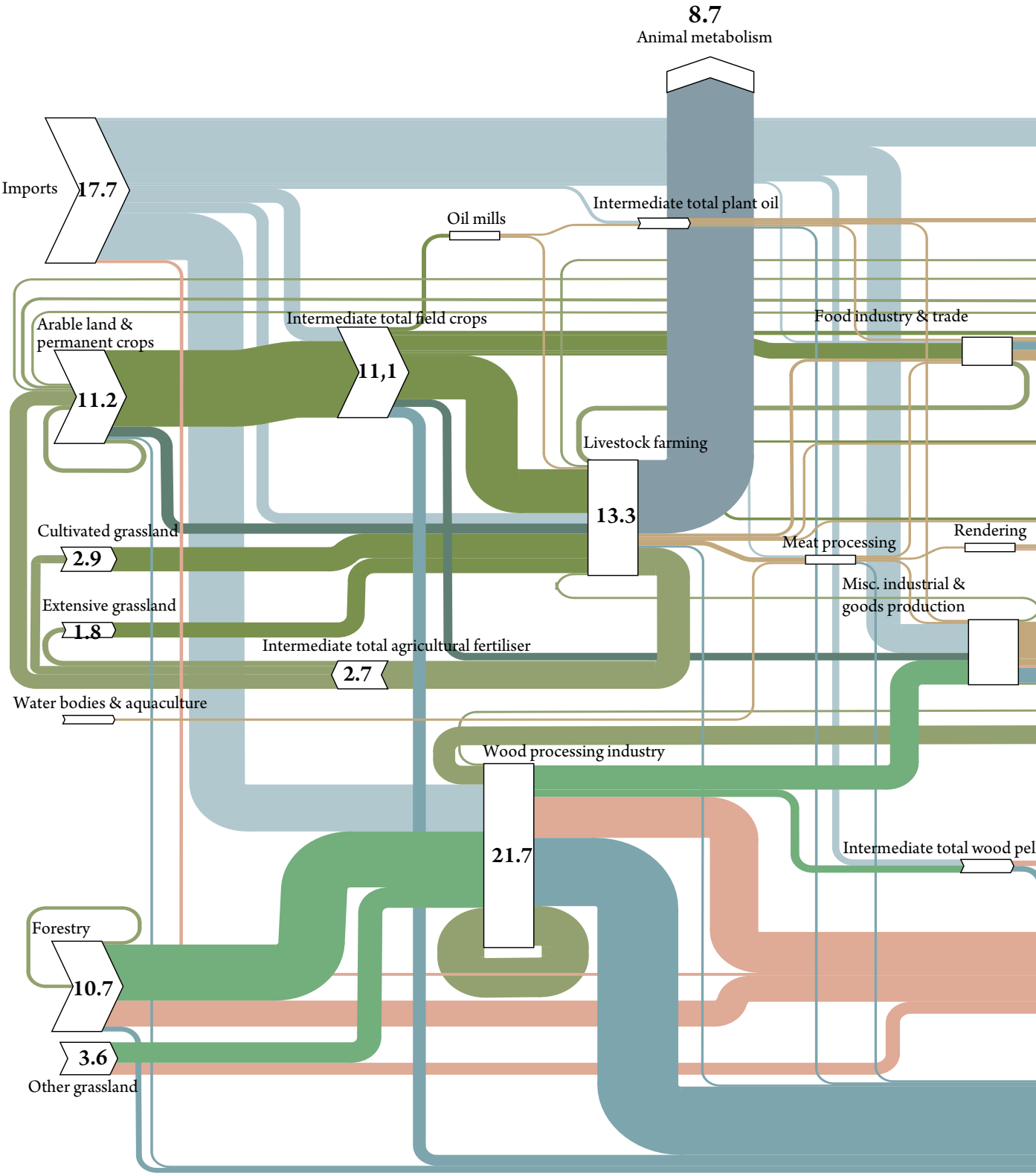
FLOWS AND NODES: WHAT DOES A MATERIAL FLOW SHEET LOOK LIKE?

The material flow sheet is a particular form of graphic representation for material flows, also known as a *Sankey diagram*, named after a 19th-century Irish ship's captain. Such diagrams comprise nodes connected by arrows. The arrows are scaled in proportion to the size of the flows (in terms of their width, rather than length). The nodes may depict sources, conversion processes or reductions in flows, and nodes may either combine different flows or mark flow divisions. At the source nodes, for example, at which biomass imports arrive in Austria, they are divided according to how those imports are used further. A large share of wood imports flow to conversion nodes for the wood processing industry and are brought together here with the flow of domestically extracted timber. Conversely, where wood is burned, this represents an end-use consumption and thus a flow reduction node.

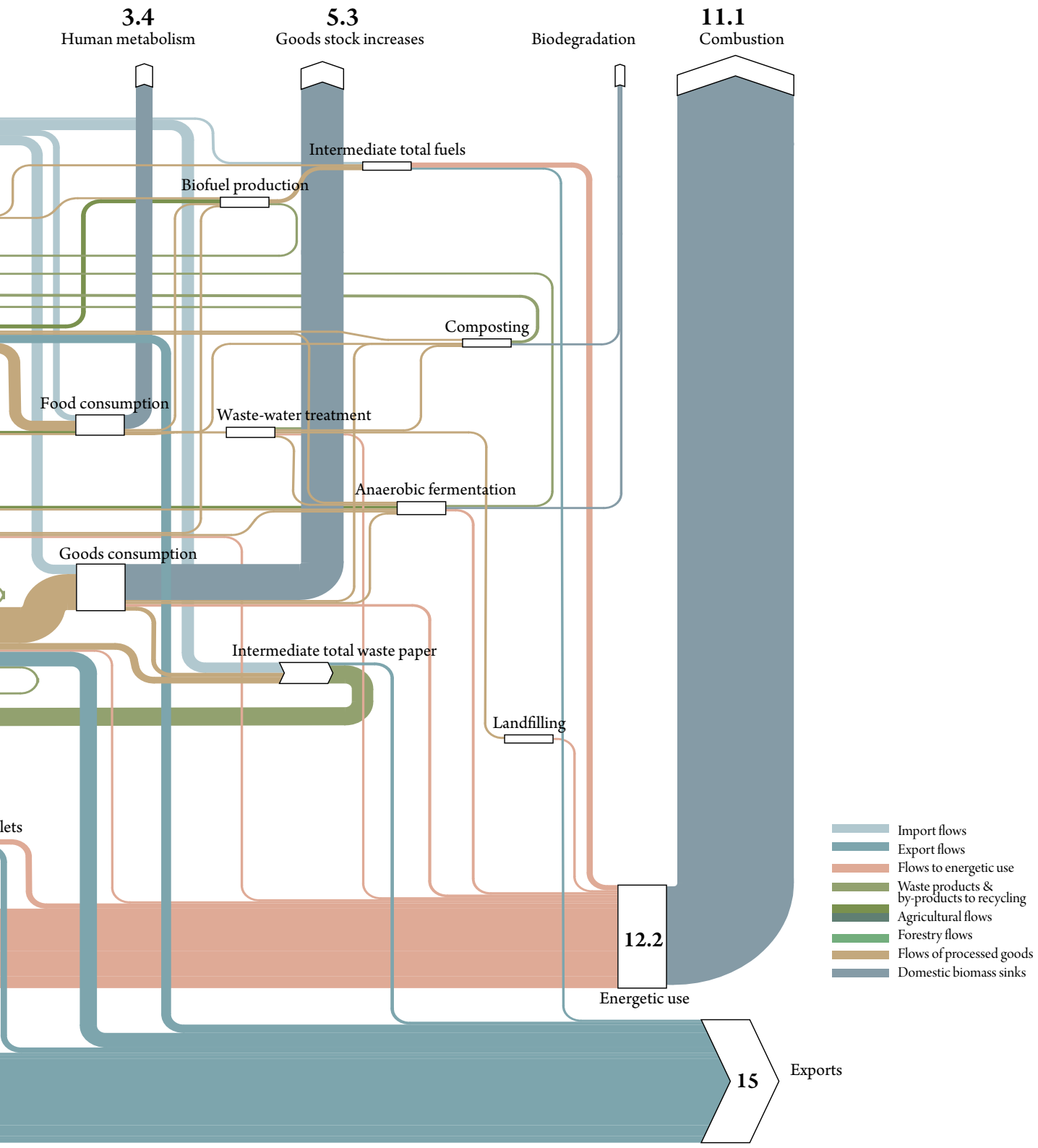
When interpreting the material flow sheet in Figure 17 (▶ pages 42/43), it is important to note that the biomass flows are either differentiated or combined according to sources and conversion processes and not according to material categories. Thus the flow of imports, for example, contains biomass from both forestry and agriculture within one and the same flow.

Figure 17: Biomass flows within Austria in 2011 in million tonnes of dry matter

The flow chart shows all components of biomass material use: The left side shows the sources of biomass from domestic extraction and imports, for which the arrows pointing to the upper edge indicate the final use (sinks) within Austria, and the arrow pointing to the lower right, the exports.



Data source: Kalt and Amtmann 2014


3.4
Human metabolism
5.3
Goods stock increases
Biodegradation
11.1
Combustion
Intermediate total fuels
Biofuel production
Composting
Food consumption
Waste-water treatment
Anaerobic fermentation
Goods consumption
Intermediate total waste paper
Landfilling
lets
12.2
Energetic use
15
Exports
Import flows
Export flows
Flows to energetic use
Waste products & by-products to recycling
Agricultural flows
Forestry flows
Flows of processed goods
Domestic biomass sinks

this case very different types of biomass from harvest to waste disposal are traced and included in the overall figures, all flows are, in contrast to the material flow account, calculated in tonnes of dry matter (i.e. excluding the water content therein). Moreover, for some flows estimated biomass production that is not statistically recorded is included in calculations. This applies to logging, which takes place in areas categorised as "other green areas", and to the feed production that is also included in the material flow account but is calculated there using a slightly different method. This produces marginal differences to the biomass results of the material flow account, which do not, however, reduce the usefulness of the information contained in the material flowsheet for the interpretation of the material flow data.

Each of the nodes in the material flowsheet represents to some extent an adjusting factor for Austrian biomass requirements and also, through the close interrelationship between biomass use and the other material groups, for overall Austrian material use. Where, for example, priorities for the increased utilization of renewable raw materials are to be set in order to achieve a reduction in the use of fossil materials, the material flowsheet can be used to identify to which nodes domestic extraction and imports must flow, so that these priorities can be applied to practice. The material flowsheet also shows that a more efficient use of biomass can be achieved in different ways through, for example, a reduction in conversion losses and wastes or in particularly material-intensive forms of usage[3]. An additional perspective on achievable and necessary efficiency savings is contained in the issue of land use. Even if the cultivation of renewable raw materials is to be expanded and utilized (instead of non-renewable raw materials), this should not be linked to any expansion of cultivated areas for agricultural and forestry that is problematic in terms of environmental protection.

NO BIOMASS WITHOUT LAND USE

To render the production of biomass more efficient in terms of the required land use, the intensity of land use must often be increased. By increasing the yields in agriculture and forestry, an increase in the production of biomass can be achieved using the same or even shrinking cultivated areas. This effect can be observed in the development of land use in Austria: In Austria the land area

3 Concerning wood as a raw material, it must be noted that not all components of wood stocks are suitable for cascading use. Between 25 and 30% of timber yields comprise wood types that can only be used for energy. Criteria for primarily energetic use include e.g. certain tree species, tree parts or timber qualities.

BIOECONOMY ACTION PLAN

In February 2012, the European Union adopted the strategy *Innovating for Sustainable Growth: Bioeconomy for Europe*, aimed at paving the way for a more innovative, resource-efficient and competitive society. In particular, the increased use of renewable raw materials is essential to achieve this goal.

A range of political initiatives in Austria focus in a wider sense upon the theme of biogenic resources. As part of the *klima:aktiv, biobased economy*, the *Bioeconomy Action Plan* – was created. This builds upon already existing and important initiatives to support the use of renewable raw materials and contributes to the establishment of a bioeconomy in Austria. With the help of a detailed analysis, realistic market opportunities for products from renewable raw materials were identified. Subsequently, six overlapping fields for action were defined: sustainability, standardisation, information, public procurement, research & development, the raw material base and closed circle economy.

32 concrete measures were derived from these fields for action. These recommended measures concern both the supply and processing of raw materials and the manufacturing of products and their introduction to the market.

Further Informationen: www.klimaaktiv.at/erneuerbare/nawaro_markt.html

used for agricultural purposes has been decreasing continually over several decades, even though biomass production is increasing[4]. While a significant part of former agricultural land is used for settlement and infrastructure, the majority of these areas are reforested through natural succession. Since 1960, forested land in Austria has increased by 16%. Today, significantly more agricultural goods are produced per unit of utilized agricultural area than was the case, for example, 50 years ago. Figure 18 (▶ see below) shows that cereal yields in Austria have increased by a factor of 2.3 since 1960. This means that just as much cereal can be produced today as in 1960 on less than half the area used in 1960 to cultivate cereal crops. Such increased in yields are the result of advances in efficiency in sectors upstream and downstream from agriculture, including measures in the agricultural sector itself, which may include a greater degree of mechanisation in production at favoured locations, the use of fertilizers and pesticides, irrigation and the use of higher yield seed varieties. Intensification often goes hand in hand with an increased pressure on agroecosystems (biodiversity, groundwater, soil) – however, great progress in efficiency has also been made in irrigation, fertilizer and pesticide use, which has limited the environmentally damaging effects of agricultural production: An example of one such efficiency saving is presented in Figure 18 (▶ see below): this shows that although fertilizer use in Austria rose sharply in the 1960s, it has been falling continually since the 1970s. The reduction of fertilizer use has had little impact, however, on the increasing cereal yields: although in 2013 the cereal yield was 2.3 times as great as in 1960, c. 15% less fertilizer was used. The *Austrian Agri-environmental Programme* (*ÖPUL*), undertaken in the framework of the *Austrian Rural Development Programme*, had a positive effect on the protection of resources, environmental impact and the conservation of soil fertility.

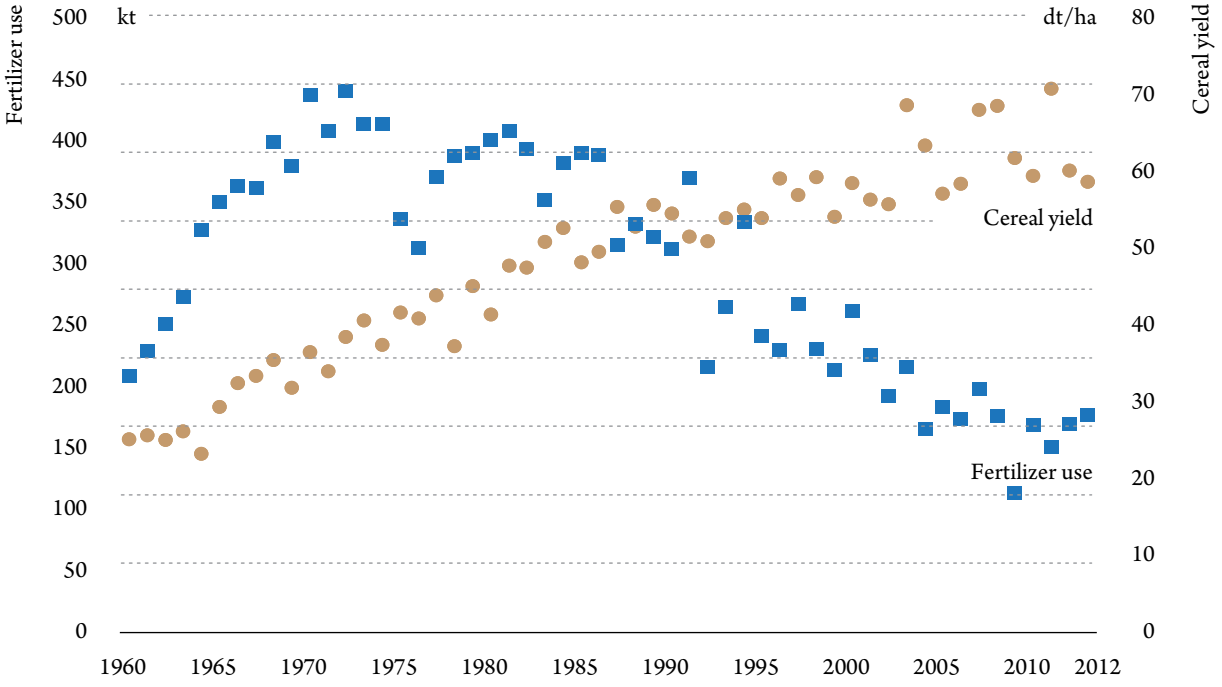
BIOMASS AS AN ENERGY SOURCE

Even where it is possible to achieve increased biomass yields in a sustainable manner, the area available for

4 This is different for the area of organic farming, which increased constantly in past years in contrast to the conventionally used agricultural areas. In 2012, already 432,896 ha were managed as organic farming, which represents 19% of the total agricultural area (excluding alpine areas).

Figure 18: Fertilizer use (nitrogen, phosphate and potassium fertilizer, in 1,000 tonnes) and cereal yield (in quintals per hectare) in Austria between 1960 and 2012

Cereal yields have increased since 1960, whereas fertilizer use has decreased during the same period.



Data source: Federal Institute of Agricultural Economics 2014; Krausmann et al. 2003

agriculture and forestry is limited. Although biomass is renewable, the production potential remains limited in scope. This means that in many cases, decisions must be taken about the amount and type of biomass that should be cultivated for the direct production of food, feedstuff for livestock or for energetic purposes. In Austria these potentially competing uses can be regulated by means of the "table-trough-tank" priority sequence mentioned above, so that only excess cereal production or lower quality cereals go into the production of fuels. Using renewable energy sources for energetic purposes should reduce the use of fossil energy carriers and thus the emission of greenhouse gases, particularly of CO_2. The *European Union's Renewable Energy Directive* (European Parliament and Council of Europe, 2009) envisages the share of renewable energy sources used by the transport sector (plant-based diesel and ethanol, biofuels and renewable electricity or hydrogen) rising to 10% by 2020. Another European Directive shortly to be concluded provides for biofuels from cereals and crop plants with a high starch content and those from sugar- or oil-producing plants to account for up to 7% in relation to the 10% target. Alongside this, a stronger focus is to be placed upon research, development and production of so-called "*advanced biofuels*" (e.g. from biogenic wastes and residues), which do not compete directly with agricultural production (European Parliament 2015). In Austria in 2013, biofuels contributed c. 5.2% to energy use (biofuels and electricity from renewable sources in the transport sector). In 2013 about 7.4% of the transport sector's energy use came from renewable sources. Production efficiency, among other factors, is a decisive factor in making optimal use of agricultural land and securing food production. This can be increased through more comprehensive utilization of cultivated plants, as well as through directly increasing yields. In this respect, the cascading use of biomass can play a central role. Cascading use provides for biomass to be utilized both in terms of using different parts of the same plant and the same parts (successively) being used as material and energy, rather than for one purpose alone[5] (▶ Box, page 40).

5 Concerning wood as a raw material, it must be noted that not all components of wood stocks are suitable for cascading use. Between 25 and 30% of timber yields comprise wood types that can only be used for energy. Criteria for primarily energetic use include e.g. certain tree species, tree parts or timber qualities.

FOSSIL ENERGY CARRIERS

Within the material flow accounts, fossil energy carriers comprise those minerals that have been created from biomass over millions of years under specific geological conditions and are used for their primary characteristic as sources of energy. Only c. 4% of the fossil energy carriers extracted worldwide are used for non-energetic purposes (e.g. for the production of synthetic materials, lubricants and fertilizers, chemicals and medicines). There is a close link between this material category and the focus of this report upon renewable raw materials, not least because of the historical origin of fossil fuels (▶ Box, page 36).

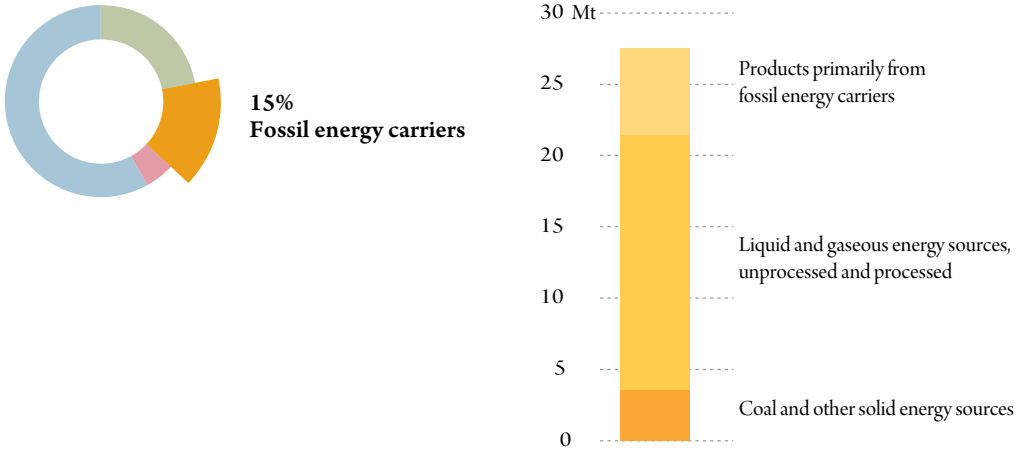
In Austria in 2012 almost 28 million tonnes of fossil energy carriers were used. Since 1960, the annual use of fossil energy carriers has increased by 12 million tonnes and from 2 to 3.3 tonnes per capita. As shown in Figure 19 (▶ see below), this use comprises largely oil and natural gas. In 2012, this subcategory made up 65% of total use in this material category. The share of coal in fossil energy use shows continual decline, comprising 13% in 2012. This decrease in the importance of coal, contrasting with the increasing importance of oil and natural gas is a classic element of the "energy transition" in industrialised countries. Whilst initially (in Austria in the second half of the 19th century) coal replaced biomass as the most important energy source, from 1900 onwards, and particularly after the Second World War, a second phase of this transition took place and coal was progressively replaced in terms of its importance by oil and natural gas (Krausmann and Haberl 2007).

AUSTRIA IS DEPENDENT UPON FOSSIL ENERGY IMPORTS

As already presented in the chapter *Resource Use in Austria and the World* (▶ Figure 9, page 27), import dependency is lower in every other material category than it is in the case of fossil energy carriers. This strategically disadvantageous situation and the high contribution made by the burning of fossil fuels to anthropogenic climate change make substitution and savings the key themes in relation to fossil energy carriers.

Figure 19: Austrian use of fossil energy carriers in 2012 in million tonnes per year

Since almost no fossil energy carriers are extracted in Austria, this use is comprised almost entirely of net imports.



Data source: Statistics Austria 2014a

In Austria there are few (remaining) profitable options for the extraction of fossil energy carriers. For geological reasons, Austria has no economically significant coal reserves and lignite mining finally ceased in 2007. Petroleum and natural gas have been extracted since 1934, albeit only in small quantities, when compared to consumption. Domestic extraction of fossil energy carriers plays only a minor role in supplying Austrian demand: In 2012 a total of only c. 2 million tonnes of fossil energy carriers was extracted in Austria, more than half of which was natural gas (c. 60%) and the rest primarily oil (c. 39%). The extracted volume represents only c. 9% of total fossil energy carriers used in 2012 (0.03% of coal and other solid energy sources, 13% of liquid and gas energy sources). Austria is thus highly dependent upon the imports of fossil energy carriers in order to cover domestic consumption and the needs of export-oriented industry sectors. In 2012, for example, 30 million tonnes of fossil energy carriers needed to be imported. Imports consisted largely of natural gas and oil (together 59%) and products from fossil energy carriers, primarily plastic, organic chemicals and coke (30%). Coal comprised only 12% of all imports of fossil energy carriers. While Austria is attempting to avoid the use of coal as an energy source (steam coal) in the interests of creating a sustainable energy economy, coal is currently irreplaceable in the blast furnace process for iron production (coking coal) and is also imported into Austria for this purpose.

Fossil energy carriers are concentrated at the sites of deposits. This means that fossil energy carriers are extracted in large quantities at specific sites before being distributed for use across the globe. Where deposits are concerned, it is clear that c. 71% of conventional world oil reserves and c. 69% of the world's natural gas reserves lie within the *Strategic Ellipse* (▶ Figure 20, page 49), i.e. from the Middle East over the Caspian Sea and into Northern Russia (BGR 2009). Supplying Austria with fossil energy carriers can only be maintained in as far as the exporting countries continue to provide oil and natural gas on the world market.

Although Austria is reliant upon imports for the provision of fossil energy carriers to answer domestic demand, fossil energy carriers are also exported. In 2012, these exports comprised slightly less than 5 million tonnes. Oil in particular, together with a very small quantity of coal, is imported in crude form into Austria, where it is processed (refined) and exported again. This processing phase produces value added: while the mean price for Austria's coal imports in 2012 was c. 220 € per tonne (€/t), the mean export price for the same material category was 313 €/t. In the case of oil and natural gas too, there is a slight difference in price: whereas for imports in 2012 an average of 580 €/t was paid, an average price of 620 €/t was achieved for exports. The example of fossil energy carriers makes clear that material and monetary flows are not necessarily directly in proportion to one another.

CAN BIOFUELS REPLACE FOSSIL ENERGY SOURCES?

Among the Member States of the European Union, Austria's energy use shows the 3rd highest share (30%) of renewable energies. At the same time, this energy use is at a very high level overall and per capita CO_2 emissions are higher than the European average. The high level of energy use is influenced by two factors in particular: energy-intensive industry and the absence of risk-laden nuclear power. In electricity production, Austria has covered a large share of its requirements from renewable sources, primarily from hydroelectricity, but increasingly also from wind power. In the case of heating and transport, where energy sources with high energy density are required, hopes are also placed on the potential offered by biomass.

In global terms, over 75% of primary energy supplies (*total primary energy supply, TPES*) come from fossil energy carriers and less than 20% from renewable sources, with fuelwood comprising the largest share by volume in the latter. Estimates suggest that by 2050, between 64 and 161 exajoules (EJ), i.e. between $64*10^{18}$ and $161*10^{18}$ joules, of primary energy could be provided by biomass (Haberl et al. 2011) – only a small share of the energy that is currently provided by fossil energy carriers. Cascading use (▶ Box, page 40) can increase this share.

Figure 20: The Strategic Energy Ellipse in the distribution of global oil reserves and global gas reserves

Source: BGR 2009

BURNING FOSSIL ENERGY CARRIERS CREATES GREENHOUSE GASES

Frequent discussions about potential alternatives to and reductions in the use of oil, gas and coal are not only related to concerns about supply security but also to those about the environmental impacts associated with the use of fossil energy carriers. The combustion of fossil energy carriers produces CO_2, among others, which is concentrated in the Earth's atmosphere and contributes together with other greenhouse gases to global warming and thus to climate change. International treaties, such as the *United Nations Framework Convention on Climate Change* (concluded in 1992) and the *Kyoto Protocol* from 1997 together with the climate protection goals formulated therein, attempt to mitigate this development. Austria has implemented these internationally agreed goals through the *Climate Strategy* of 2002, the revised *Climate Strategy* adopted in 2007, the *Law on Climate Protection* and the *Law on Energy Efficiency* adopted by the Austrian Federal Parliament in 2014. The key aspects of this strategy are reducing energy consumption, increasing energy efficiency and accelerating the use of renewable energy sources (▶ Box, page 48). To contain the environmental impacts accompanying energy use, an absolute reduction in energy use must be the primary goal. To achieve this, reduction measures must be implemented alongside those to increase efficiency.

METALS

In the material flow account, the group of metals includes both high-value, processed products from metals as well as metal concentrates and (during extraction) ores. Ores are those minerals from which economically beneficial metals can be recovered. In the material flow account, metals are initially divided between the dominant (in volume) group of iron ores and the smaller, but nonetheless very important group of non-ferrous metals.

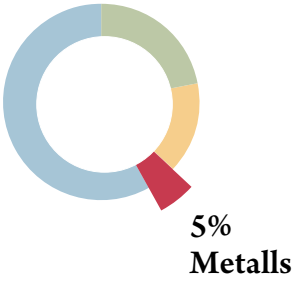
The extraction of ores takes place during the first production phase through the extraction of waste rock, which is then separated after excavation. During the next production phase – processing and refining – waste rock (in the form of spoil tips) is then conversely produced, when the ore, with its respective metal content, is processed into concentrate. The metal content of ores varies according to both the deposit sites and the metal concerned. For example, the economically profitable metal content of iron ore may be above 60%, whereas in the case of gold or platinum, this figure can be as little as c. 0.0005% (5 grammes of metal per tonne of ore).

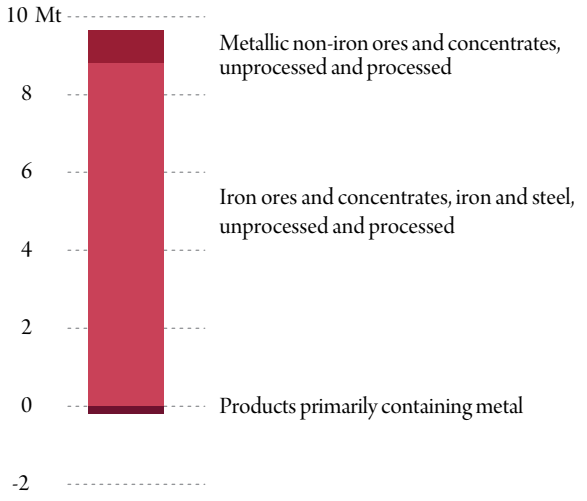
DESPITE HAVING RESERVES OF IRON AND TUNGSTEN, AUSTRIA IS DEPENDENT ON METAL IMPORTS

For geological reasons, Austria does not have large metal deposits, and the metal used in Austria is nowadays largely imported. The metal deposits that have been and are found in the country continue to play an important role in the development of the alpine region. In 2012, a total of 2.5 million tonnes of ore was mined in Austria. More than 80 % of this comprised iron ores from the Erzberg ore mountain in the province of Styria, while the rest consisted almost entirely of tungsten. At the international level, Austria is among the seven most important tungsten producers in the world. Tungsten is a particularly heavy and robust metal – no other metal has a higher melting point. For this reason, tungsten is greatly valued, particularly by steel manufacturers, for processes in which the steel may be subjected to great variations in temperature. The high density of tungsten means that it is also

Figure 21: Austrian use of metals in 2012 in million tonnes per year

In Austria, primarily iron and steel are used in larger quantities. Although other metals are of great strategic importance, the quantities used are far smaller.





Data source: Statistics Austria 2014a

used for weighting purposes, and can be found in almost every smartphone as an oscillating weight for vibration.

Thus Austria possesses iron and an important steel refiner, yet most of the country's metal use, at almost 10 million tonnes, is nonetheless supplied by imports. The trade flows show the important role of the metal refining industry in Austria. In 2012, Austria imported almost 21 million tonnes of metal (roughly double the amount that was eventually used and 10 times the amount that was extracted domestically), particularly iron and steel (86%), aluminium (5%) and products that were made from metal (5%). Among Austrian exports, which amounted to 14 million tonnes in 2012, shares of iron and steel, aluminium and metal products were all of a similar size.

ANTHROPOGENIC DEPOSITS OF METALS ARE BECOMING EVER MORE IMPORTANT

The metals used in Austria are largely integrated within societal stocks, i.e. in durable products such as machines and means of transport, buildings and infrastructure. In this respect, metals represent a counterpoint to biomass and the fossil energy carriers, which often (although not always) pass from extraction to end use within the same year (for the distinction made between flows and stocks in material flow accounting, ▶ Box (see below). During the extraction, processing and product integration of metals, natural stocks of metals (in deposits) are mined and societal stocks (defined as anthropogenic deposits) accumulate. In the course of this development, anthropogenic deposits could have acquired the same size as or even become larger than the natural deposits (Gordon, Bertram and Graedel 2006). Since the natural deposits are non-renewable and the peak extraction rates have already been surpassed in the cases of many of these deposits, societal stocks will represent an increasingly important source of metals in the future.

Metals are important basic materials for industrialisation. The demand for metals has been supplied by imports for several decades already, both in Austria and in many other industrialised countries. In industrialised countries, where they have been available at all, deposits have often already been used during the phase of industrialisation to the point at which it is barely any longer economically viable to do so. With ever more countries across the world undergoing industrialisation, the demand for metals has risen dramatically, particularly during the late 20th and early 21st centuries. This has already led to sensitive problems of supply shortages. In a study (European Commission, DG Enterprise and Industry 2014), the European Commission identified 20 raw materials the continued supply of which must be regarded as critical to the functioning of industry, and for key technologies in particular. A prominent example among these concerns rare earths. These are a group of 17 different elements, which are used primarily as permanent magnets and special alloys for application in e.g. wind turbines, cars, plasma and LCD screens or energy-saving lamps.

GLOBAL MARKET PRICES FOR METALS FLUCTUATE STRONGLY

For nearly all metals, a few countries dominate the world market on the supply side. In 2010, 76% of global metal extraction took place in four countries (Australia, China, India and Brazil). This means that changes in the global market prices can have a critical impact on almost all

FLOWS AND STOCKS

The material flow account records all flows that are required in order to build, operate and maintain the biophysical structures of a society, i.e. societal stocks. Each flow is always associated with a specific period of time; in the case of the material flow account, usually one year. For this reason, the flows are also expressed in units as tonnes per year. Stocks, however, are recorded at a particular point in time. In the material flow account, by definition the artefacts of a population in a socioeconomic system, its livestock, and the human population itself are all included in calculations. Analogous to the national accounts, artifacts include all infrastructure, buildings and means of transportation. In contrast to the national accounts, machines and consumer goods are also included as stocks.

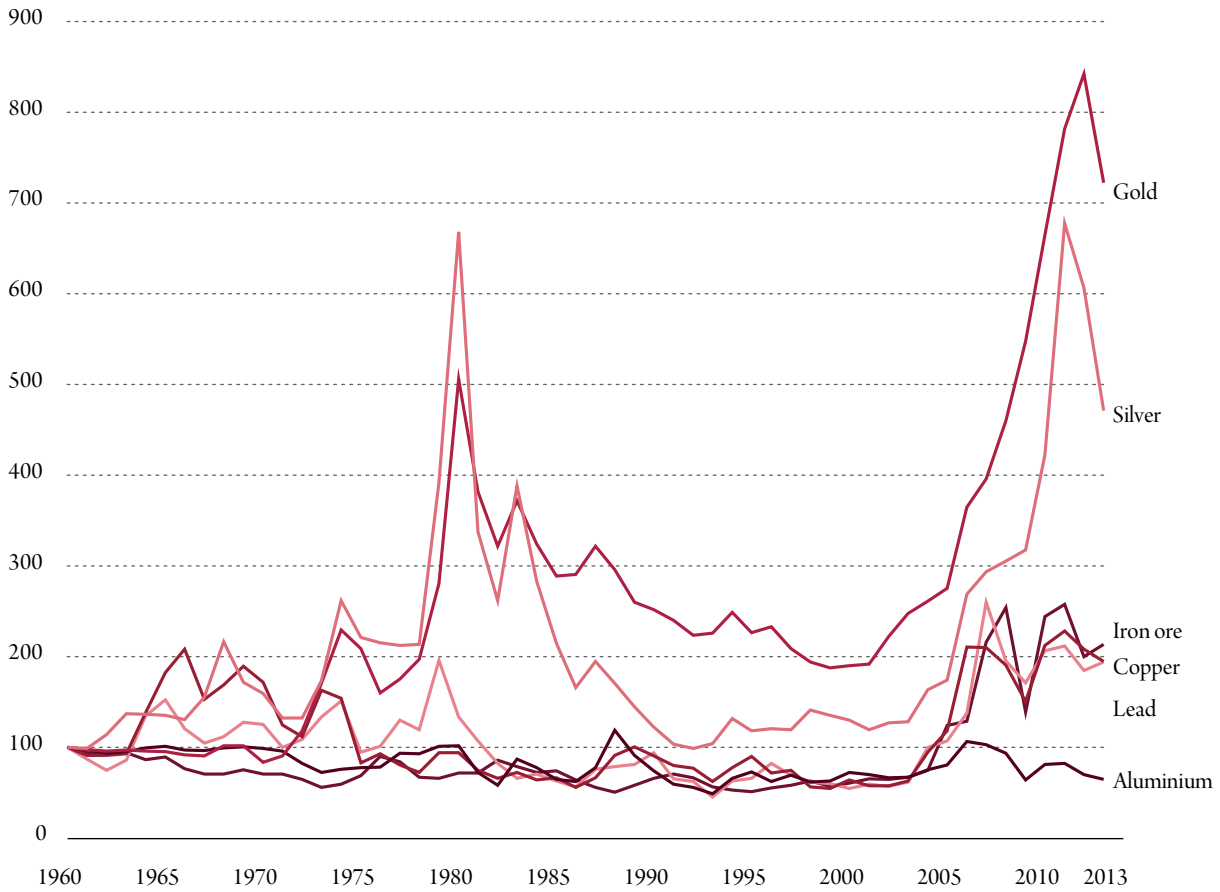
countries worldwide. Figure 22 (▶ see below) provides an example of how strongly world market prices can fluctuate in the case of a selection of metals. This is seen most clearly with gold and silver, the prices of which rose respectively between 1960 and 1980 by a factor of 5 and nearly 7, and between 1960 and 2012 by a f actor of 6 and more than 8. Yet also the prices of iron ore, lead and copper in 2012 had doubled since 1960. Of all the metals represented here, only the price of aluminium fell in the same period, to a price that was 70% of the figure for 1960.

INCREASING RESOURCE EFFICIENCY TO STRENGTHEN SUPPLY SECURITY

If natural deposits should decline and the demand for metals rise, these materials will have to be extracted in future from anthropogenic deposits, which are therefore often referred to as "urban mines". In Vienna, for example, it is estimated that c. 5 tonnes of metal per capita are contained in societal stocks (RMA, BMLFUW and BMWFW 2011). A fifth of this amount would be sufficient to supply the average annual requirement for

Figure 22: Global market prices, deflated indices (1960=100) for selected metals between 1960 and 2013

Very strong marked increases were evident in prices for silver and gold, while the prices for iron ore, lead and copper also doubled.



Data source: World Bank 2014

metals of the inhabitants of the City of Vienna. Thus recycling of metals will become a necessity in future. Currently, however, this still involves a high degree of effort and energy in a number of areas, since societal stocks often involve numerous metals in combination with one another or with other materials. For example, a computer contains 32 different metals and a mobile phone as many as 45 (Weber 2010). Although the recycling rate for iron and steel currently involves c. one-third of the metals separated from societal stocks, the metals that are used in smaller quantities are rarely recycled, if at all. For this to change, not only appropriate (energy-saving) technologies for separating metals would have to be developed, but products, buildings and infrastructure would already require a design at the planning stage that takes resource efficiency aspects, such as recycling, extended use, re-use and repair into account, for example through modular product design.

NON-METALLIC MINERALS

Non-metallic construction minerals and industrial minerals are recorded together in the material flow account as non-metallic minerals. Large quantities of construction minerals are used in all countries and include primarily sand, gravel and crushed rock, which are required e. g. for transport infrastructure or to manufacture concrete. Industrial minerals, in contrast, are used outside the construction sector and include e. g. the phosphates often used for fertilizer as well as industrial salt or table salt, diamonds and industrial sand. Construction minerals and industrial minerals cannot always be distinguished clearly from one another, however, since some raw materials are used both for construction purposes and for industrial production. Limestone plays an important role in the production of cement, for example, but is also used as a filling material in particular industrial processes (e. g. in paper production) and in agriculture as a fertilizer.

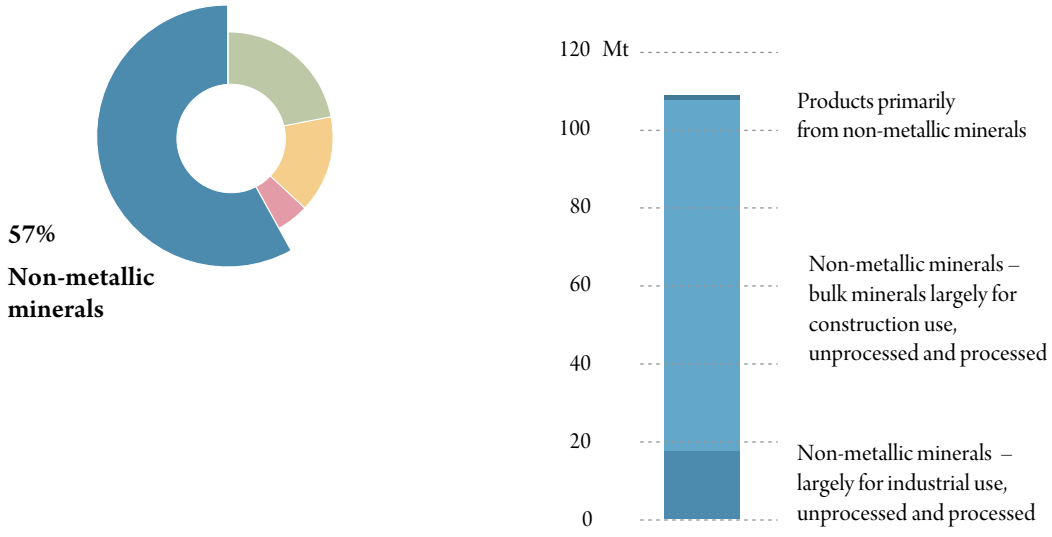
In Austria in 2010, c. 107 million tonnes of non-metallic minerals were used – this represented 57% of total domestic material consumption. Construction raw materials comprised the largest share (84%) at 90 million tonnes, followed by industrial minerals (17 million tonnes, 16%). Imported products from non-metallic minerals were negligible and therefore do not appear in Figure 23 (▶ see below).

CONSTRUCTION MINERALS ARE PRIMARILY INTEGRATED INTO SOCIETAL STOCKS

From 1960 to 2007, the use of construction minerals in Austria more than doubled, increasing from 50 to 110 million tonnes. Construction minerals are required on one hand during phases of increasing industrialisation and on the other, for the maintenance of existing infrastructure in industrialised countries. The stocks of built infrastructure in industrialised countries amount to several hundred tonnes per capita; estimates for Austria for 2006 were calculated at c. 260 t/cap (Daxbeck et al. 2009). Further investment of resources is necessary to maintain or replenish these stocks. Moreover, there is continued expansion, with the

Figure 23: Austrian use of non-metallic minerals in 2012 in million tonnes per year

In 2012, non-metallic minerals comprised 57% of Austrian material use and 84% were used for construction purposes.



Data source: Statistics Austria 2014a

construction of new stocks. In Austria, there was a particularly rapid increase in the use of construction minerals between the late 1960s and 1970s, when significant infrastructure investments were made through the expansion of the road and rail networks and in the construction of dams and wastewater systems. However, the global financial crisis of 2007/2008 saw the use of construction minerals fall significantly, to a figure of c. 90 million tonnes. This development highlights the close relationship between the use of construction minerals and the economic situation.

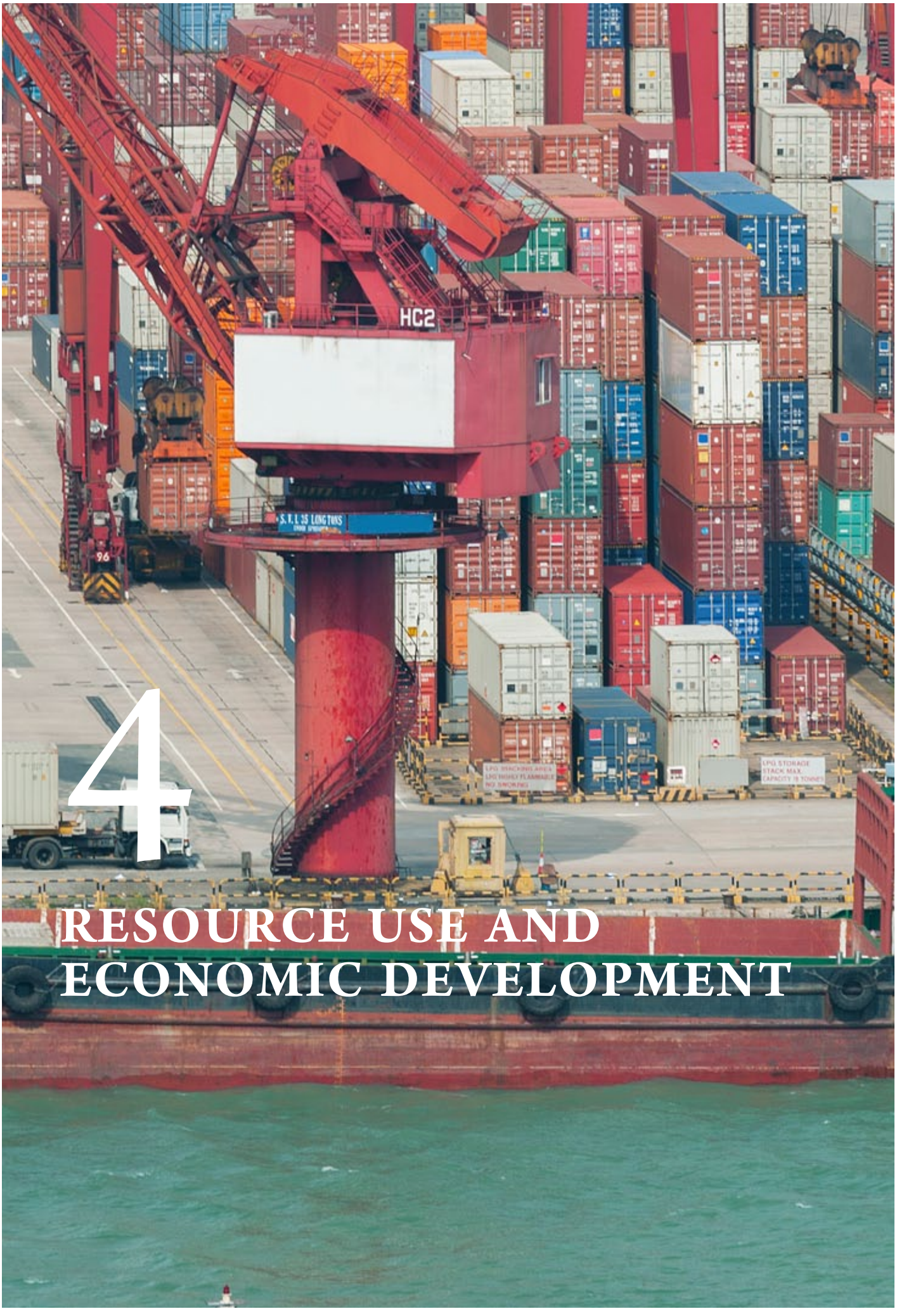
Although the extraction of construction minerals competes with other land uses (in Austria, primarily residential areas, agriculture and forestry), it is in principle possible to extract construction minerals in most European countries in sufficient quantities. An extended discussion of this issue is available in the 2011 report *Resource Use in Austria* (BMLFUW and BMWFJ 2011). The international transportation of construction minerals is often not economically viable because of the low prices of these materials and the large quantities required. In 2012, Austria only imported 3% (c. 3 million tonnes) of the total construction minerals used. In contrast, 89 million tonnes of construction minerals were extracted within Austria, consisting primarily of sand and gravel, but also limestone and gypsum.

Industrial minerals, however, which are required in smaller volumes and achieve higher prices, are more commonly traded. In 2012 Austria imported c. 6 million tonnes of industrial minerals, primarily as fertilizer. The latter also forms the most important export category among industrial minerals. On one hand fertilizer miner als such as phosphates, which cannot be extracted in Austria, are imported and on the other hand, commercial fertilizers produced from imported and/or domestically extracted minerals are exported. 17 million tonnes of industrial minerals are extracted within Austria, primarily basaltic rock, limestone and dolomite.

NON-METALLIC MINERALS DOMINATE MATERIAL USE

In most industrialised countries, non-metallic minerals (above all construction minerals) comprise a large share of domestic material consumption (DMC). Among the Member States of the European Union, this share amounts to 40–50% of DMC. On average, in the EU-27 in 2012 a little more than 6 tonnes per capita of non-metallic minerals were used. Despite a reduction since 2007/2008, use in Austria remained, at 12 tonnes per capita, double the European average. Only in Finland, Romania and Estonia was use higher than in Austria.

This largest category in Austrian material use was the focus of the 2011 report *Resource Use in Austria* (BMLFUW and BMWFJ 2011). This was connected not only with the large quantities being used but also with the direct and indirect environmental impacts related to this use (▶ see also Chapter 2 *Resource Use in Austria and the World*). Construction minerals are required and used in large quantities. They are therefore linked particularly through extraction and transportation within Austria to high greenhouse gas emissions. Furthermore, the utilization purpose of construction minerals is closely linked to the use of fossil energy. For example, whether construction minerals are used in the thermal insulation of buildings has an impact on the heating energy required. The design of the transport system– according to whether the focus is placed upon individual transport or more energy-efficient forms of transportation and mobility – has a significant impact on the use of oil-based fuels in particular. Here too, the cross-connections between the material categories must also be taken into account (▶ Box, page 36).



4

RESOURCE USE AND ECONOMIC DEVELOPMENT

As a rule, the economic development of a country is closely linked to resource use, which does not however mean that the indicators for each trend will necessarily remain in proportion to one another. The question of how closely economic development and resource use are linked to one another is extremely important in the context of sustainable resource use and policy making. If economic growth were only possible in connection with simultaneous increases in resource use, environmental protection would necessitate a reduction in economic growth. If this relationship does not exist, then greater monetary prosperity with less material use and consequently reduced environmental impacts would be possible. Strategies for sustainable development therefore rely strongly on decoupling resource use and economic growth (European Commission 2005; Fischer-Kowalski and Swilling 2011). In principle, the use of economic growth or GDP as a measure of a society's wellbeing should be the subject of debate. The key question, "What kind of growth is sustainable?" is investigated in Austria in the context of the *Growth in Transition Initiative* (▶ Box, page 61).

In the material flow account, the indicator of material efficiency (and often also resource efficiency) is used to represent the relationship between gross economic production (measured as GDP) and resource use (measured as domestic material consumption, or DMC). The resource efficiency indicator shows the value of goods and services that can be produced per unit of resource use. If one country is twice as resource efficient as another, this means that the same amount of GDP can be generated while using half as much materials. To represent actual developments in resource efficiency, it is calculated in this report on the basis of deflated GDP in so-called real term chained-linked volumes based on 2005[6].

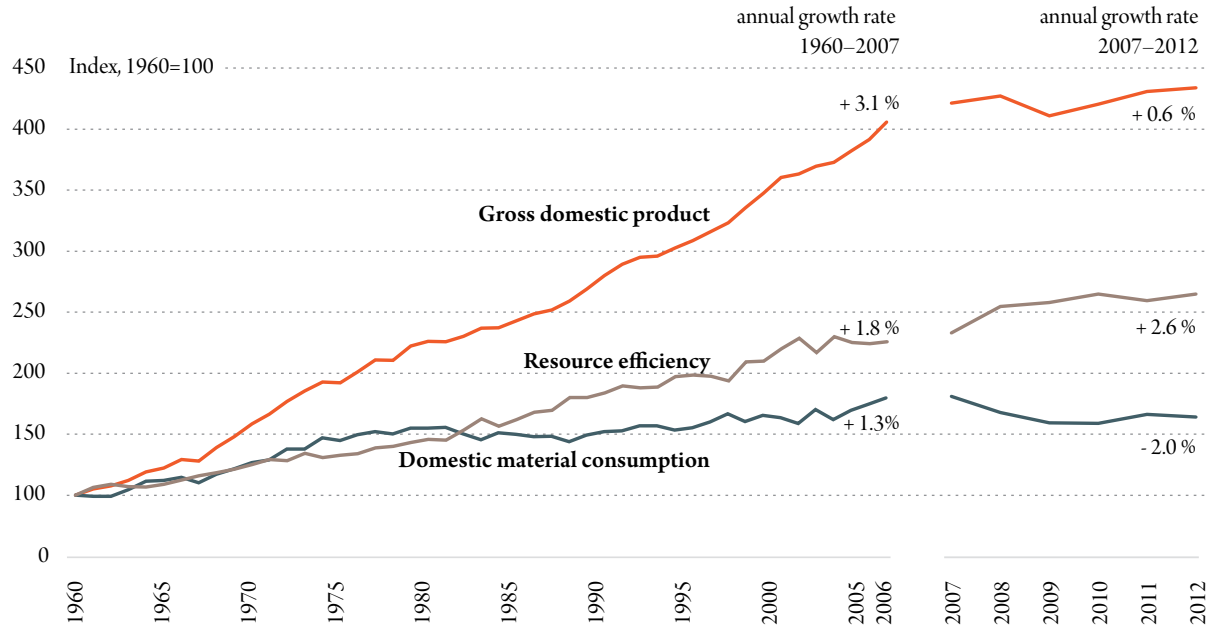
INCREASING RESOURCE EFFICIENCY IN AUSTRIA

In Austria, resource efficiency increased almost continually between 1960 and the 2007/2008 financial crisis (▶ Figure 24, see below). While in 1960 550 € GDP was achieved per tonne of material use, the 2008 figure of 1,280 € was already twice as high. In other words, to

6 Chain linking (in this case based on 2005) transforms annual GDP volumes into a comparative time series.

Figure 24: Indexed presentation of the development of Austrian gross domestic product (GDP), domestic material consumption (DMC) and resource efficiency between 1960 and 2012

The financial crisis of 2007/2008 led to a departure from the previous trend. GDP and DMC are stagnating or even decreasing slightly.



Data source: Statistics Austria 2014a

achieve the same GDP in 2007 as in 1960, Austria would have had to use less than half the amount of materials. However, this was of course not the case: GDP increased between 1960 and 2007 by more than 200 billion € (a factor of 4). Although material use also increased, it did so by a smaller factor of 1.8 (that is, by 92 million tonnes).

As is also the case in many other European countries, a break with the former trend could be observed in Austria from the financial crisis of 2007/2008. GDP, which had seen average annual growth between 1960 and 2007 of 3.1%, stagnated between 2007 and 2013, with an average annual growth rate 0.6%. DMC, which had also grown on average by 1.3% per year until 2007, albeit less rapidly than GDP, decreased by 2% per year until 2012. Since GDP increased far more rapidly than resource use until 2007, resource efficiency grew by an average of 1.8% per year. This represents approximately the development in resource efficiency depicted in the "freezing resource use" scenario as calculated in the 2011 report *Resource Use in Austria* (BMLFUW and BMWFJ 2011): This scenario showed that with an average annual increase in resource efficiency of 1.9%, economic growth of 1.9 % per year would also be possible without increasing resource use. Between 2007 and 2012, GDP grew more slowly, yet there was a simultaneous dematerialisation in absolute terms (i.e. absolute material use decreased), so that resource efficiency grew by an average of 2.6% per year.

LUXEMBOURG'S RESOURCE EFFICIENCY IS 16 TIMES AS HIGH AS THAT OF BULGARIA

In 2012 Austria was able to generate 1,454 € GDP per tonne of material use. This is slightly below the European average for resource efficiency of 1,730 €/t in the same year (▶ Figure 25, page 59) . A far higher degree of resource efficiency has been achieved by those countries exhibiting high GDP despite relatively low material use (e.g. United Kingdom, The Netherlands), and countries such as Luxembourg, which have a high material use and also a very high GDP. Very low resource efficiency is exhibited within the EU-27 by those countries whose material use is currently (and also during and beyond the financial crisis) growing rapidly, yet that (still) fail to show a very high GDP, e.g. Romania and Estonia.

Although resource efficiency provides information about the relationship between GDP and resource use, it cannot reflect a range of other factors that exert a significant influence on both indicators. As presented in the chapter *Natural Resources – the Foundation of our Society*, countries with a low population density and/or extreme climatic conditions often exhibit a higher level of resource use than densely populated countries in temperate climate zones. The countries with the highest resource efficiency are also among the most densely populated countries in Europe: Among the EU-27, Luxembourg occupies sixth place in terms of population density, the United Kingdom fourth place, and the Netherlands second place. Finland and the Baltic countries, in contrast, are the most sparsely populated countries in Europe. Industrialised countries and those currently undergoing industrialisation also have a very high requirement for materials, regardless of the economic value they generate in the current phase. For this reason, among the industrialised countries, those countries with a low level of GDP also show a low level of resource efficiency.

A high and/or increasing level of resource efficiency provides an opportunity for a more environmentally

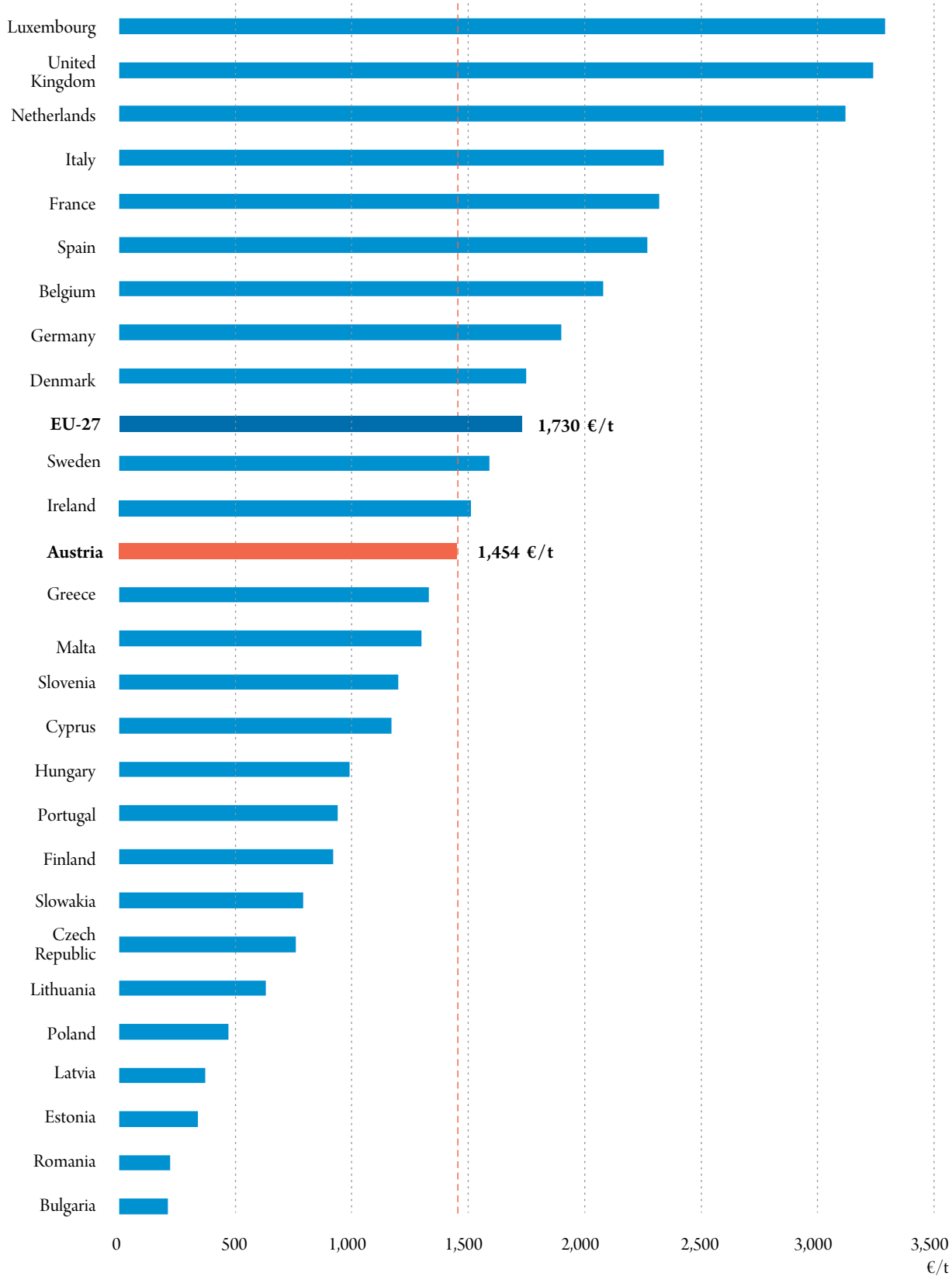
THE CIRCULAR ECONOMY

The European Commission produced a Communication in 2014 entitled *Towards a Circular Eonomy: A Zero-Waste Programme for Europe*, in which it made a commitment to developing a framework programme to establish a circular economy in Europe.

In contrast to a "linear" economy, which extracts, consumes and disposes of resources, the circular economy concept pursues the goal of retaining the resources used for as long as possible within the cycle and then, for example, to recycle them as raw materials for production and consumption. This involves not only encouraging their material use but also their use as energy sources: in many industrial processes, waste heat is generated that has not been used until now. In the interests of sustainable resource use, this cycle must also be closed as effectively as possible.

Figure 25: Resource efficiency in Austria and the EU-27 countries in 2012 in Euros per tonne

Austria is with 1,454 €/t a little less resource efficient than the European average (1,730 €/t).



Data source: Statistics Austria 2014a , Eurostat 2015c

friendly economy, because it enables a higher degree of economic performance to be achieved without a corresponding rise in resource use. However, it nonetheless cannot guarantee an actual reduction of environmental burdens. A high degree of resource efficiency can also be achieved by countries that, despite having a very high (and continually growing) level of resource use, still have a far higher (and more rapidly growing) level of GDP. As soon as GDP grows more rapidly than resource use, resource efficiency improves, even where resource use is continuing to grow. Such a development is often referred to as decoupling with increasing resource use, or as "relative" decoupling. This contrasts with decoupling accompanied by decreasing resource use, so-called "absolute" decoupling, where resource efficiency and GDP increase and resource use simultaneously decreases.

MEASURES TO IMPROVE RESOURCE EFFICIENCY IN AUSTRIA

The efficient and sustainable use of resources is a necessity and steps are being taken towards a sustainable development in the interests of the environment, economy and society.

The Austrian federal government has put measures in place to increase resource efficiency, particularly through the *The Austrian Strategies for Sustainable Development* (*NSTRAT, ÖSTRAT*), the *Resource Efficiency Action Plan* (*REAP*), the *Strategy for Research, Technology and Innovation* (*FTI*), the *National Action Plan on Sustainable Public Procurement* (*NaBe*), *Austrian Environmental Funding Scheme* (*UFI*), and through the *RESET 2020 – Resources.Efficiency.Technologies Initiative* (▶Box, see below).

Achieving a greater level of resource efficiency is an important indicator for an equally important goal. However, it is not a political end in itself but instead something that should bring about an actual reduction in resource use through structural changes. It is thus also a concrete issue of developing measures leading to greater resource efficiency, which can enable a "good" life with more efficient and lower levels of both material input and environmental impact.

GROWTH MUST TRANSFORM ITSELF

Austrian economic growth and the increase in material use in the 20th and 21st centuries have made our current high level of material prosperity possible. This development has however had negative consequences, such as the use of natural resources reaching to the very limits of natural availability and the destruction of ecosystems. Furthermore, the increases in quality of life, which were made possible by this growth, have not proven possible to

RESET 2020 – RESOURCES, EFFICIENCY AND TECHNOLOGIES

In Austria, the BMLFUW is currently developing the initiative *RESET 2020* linking resource efficiency in the area of environmental technologies, sustainable production methods and sustainable consumption.

This will be strategically implemented through a programme of measures in the Ministry's different fields of responsibility. As a point of connection for cooperation, networking and knowledge exchange with stakeholders from the economy, public administration, society and science, the initiative provides an overview of the key issues and challenges identified with potentially increasing resource efficiency. At the heart of the initiative lie the frugal use and optimized input of material resources from the perspective of the circular economy and cascading use.

Existing European and national initiatives and strategies, such as the *Resource Efficiency Action Plan* (*REAP*) are implemented through *RESET 2020 – Resources.Efficiency.Technologies* and updated to include emerging areas as these are identified.

For further information, see: www.bmlfuw.gv.at/umwelt/nachhaltigkeit/ressourceneffizienz.html

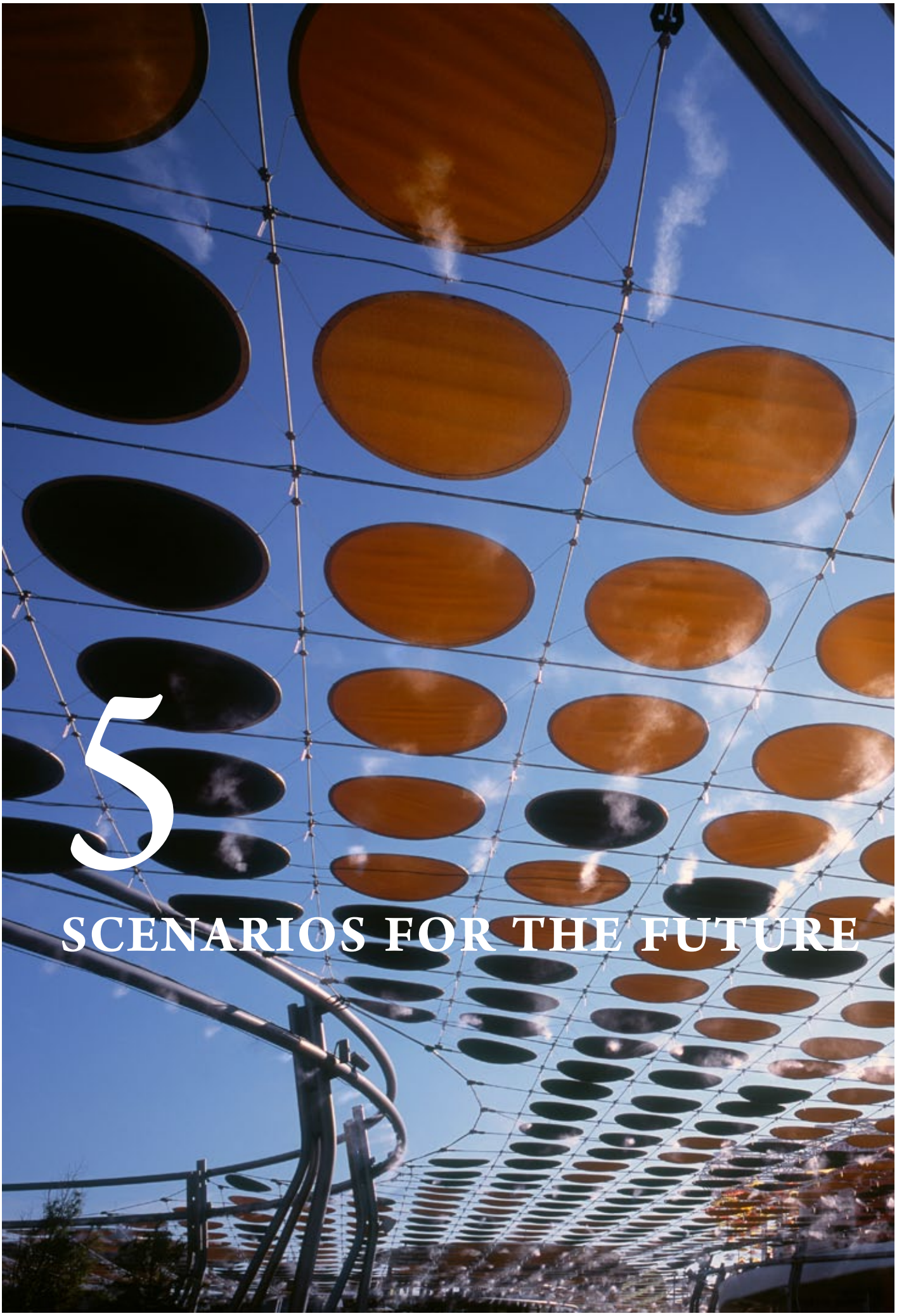
THE "GROWTH IN TRANSITION" INITIATIVE

The *Growth in Transition Initiative* was founded in Austria in 2008 by the Austrian Federal Ministry for Agriculture and Forestry, Environment and Water Management. The initiative brings together more than 20 partner institutions, including ministries, provincial governments, interest groups, companies, universities and civil society organisations.

The network promotes discussion about sustainable economic growth and a focus upon the theme of a different, resource efficient economic strategy. What constitutes a good life, and is this only possible given a particular level of resource use? Is more always better? What does an economic system capable of ensuring a high degree of wellbeing with the lowest possible level of resource use look like? Growth should not be a goal in itself, but only a possible consequence of sustainable economic management. The aim is to manage a transition to a sustainable economy

Events and publications in the framework of *Growth in Transition* can be found on the website: www.growthintransition.eu

distribute equally, either in Austria or globally. Economic gowth per se has changed little in terms of the unequal distribution of assets and income both within most societies and between individual world regions. Many international studies show that material prosperity (including income) plays an important role in personal happiness, yet that it ceases to grow in importance above a certain level of prosperity (Steinberger and Roberts 2010). More consumption does not mean more happiness. Meanwhile, the importance of strong social cohesion, health and an intact environment is growing and these aspects are also becoming important factors for quality of life. As the Austrian *Growth in Transition* Initiative (▶Box, see above) also shows, the reconceptualization of growth has become a political reality. Growth cannot be an end in itself but must be evaluated in terms of the losses and gains associated with it. This argument is also presented in international initiatives that support social development *beyond growth* or even in the absence of growth (*degrowth* and the *steady state economy*).



5

SCENARIOS FOR THE FUTURE

On the basis of the material flow account and its indicators, as presented in the previous chapters of this report, much is revealed about the development of Austrian resource use up to the present time. Since, however, the environmental impacts of the past cannot be rescinded, the primary aim is to see in what way these environmental impacts can be influenced. To gain insights into how the future of Austria might look with respect to material use, scenarios for material use until 2030 and 2050 have been calculated. Together with information about trends and the composition of material use in Austria until 2012, developments regarding both population and GDP in Austria are taken into account. For the population forecasts, the main scenario of Statistics Austria with average fertility, life expectancy and immigration was applied. According to this scenario, the Austrian population will grow to c. 8.8 million by 2020 and to 9.5 million by 2050. For GDP forecasts, two different growth rates have been assumed: In the first case, a constant average GDP growth rate of 2% per year and in the second case the GDP growth rate in Austria since the financial crisis of 2007/2008 of 0.6% per year.

The indicators, which characterise the Austrian economy in 2012 and its material use are presented in Table 4 (▶ see below). The growth rates included here serve as a comparison with the scenarios presented thereafter.

REDUCING CONSUMPTION THROUGH GREATER EFFICIENCY

A total of seven different scenarios were calculated (▶ Table 5, page 64):

- **1 trend continuation scenario**, in which material use in the next 40 years (2010 – 2050) continues to develop as it has done in the previous 40 years (1970 – 2010)
- **1 stabilisation scenario**, in which DMC can be maintained at 2012 levels up to 2050
- **5 resource efficiency scenarios**, which are based on assumptions about the development of resource efficiency and GDP

The trend continuation and two variants of increased resource efficiency (EFF-EU and EFF2+) produce an increase in DMC by 2050. Contrastingly, a clear reduction in material consumption is achieved through a (very) marked increase in resource efficiency in scenarios EFF3+ and EFF7+ or through a slight increase in resource efficiency accompanied by stagnating GDP (EFF2~).

Table 4: Domestic material consumption (DMC), gross domestic product (GDP) and resource efficiency (RE) in 2012 and growth of these indicators between 1960 and 2012 in absolute terms and in annual averages

DMC 2012		BIP 2012		RE	Growth 1960–2012					
Mt	t/cap	Bil. €	€/cap	€/t	DMC total	DMC annual	BIP total	BIP annual	RE total	RE annual
187	22.2	272	32,226	1,454	64%	1%	334%	2.9%	165%	1.9%

Data source: Statistics Austria 2014a

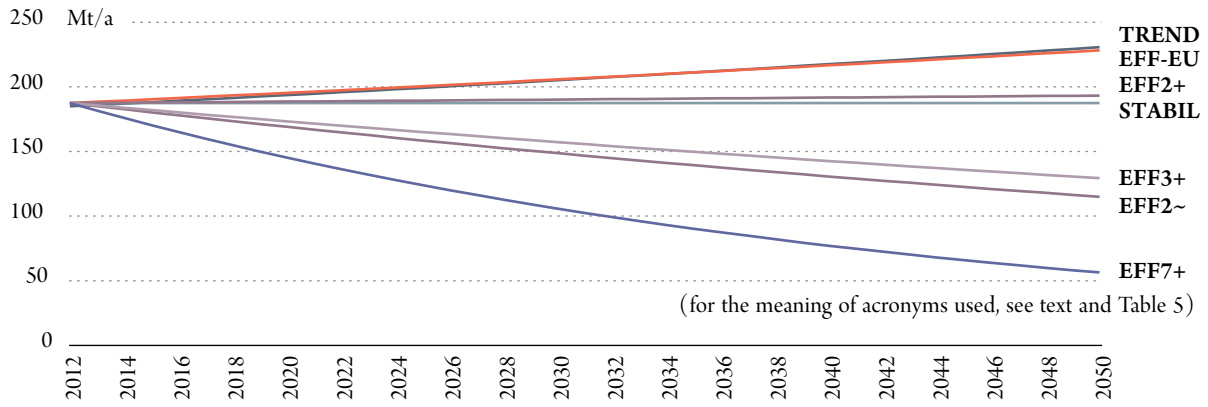
Table 5: Overview of scenarios for domestic material use (DMC) to 2030 and 2050

The first two scenarios (TREND and STABLE) are based solely on an assumption for the development of DMC and not upon an assumption for GDP development.

	DMC		Growth to 2050			Annual growth (average)		
	2030	2050	DMC	BIP	Efficiency	DMC	BIP	Efficiency
1	**TREND CONTINUES (TREND):** annual growth rates of DMC from 1970 and 2010 by material category are applied to the period from 2010 to 2050							
	204 Mt/a 22.2 t/cap	230 Mt/a 24.1 t/cap	26%	---	---	0.6%	---	---
2	**STABILISATION (STABIL):** DMC stays at the 2012 level until 2050							
	187 Mt/a 20.3 t/cap	187 Mt/a 19.5 t/cap	0%	---	---	0%	---	---
3	**ACHIEVEMENT OF EU-EFFICIENCY-GOAL (EEF-EU):** Resource efficiency increases by 30% by 2030 and continues this trend until 2050							
	205 Mt/a 22.3 t/cap	227 Mt/a 23.8 t/cap	22%	112%	74%	0.5%	2%	1.5%
4	**RESOURCE EFFICIENCY X2, HIGH GDP (EFF2+):** Resource efficiency c. doubled by 2050, 2% annual growth in GDP							
	189 Mt/a 20.6 t/cap	192 Mt/a 20.2 t/cap	3%	112%	106%	0.1%	2%	1.9%
5	**RESOURCE EFFICIENCY X2, STABLE GDP (EFF2~):** Resource efficiency c. doubled by 2050, 0.6% annual growth in GDP							
	147 Mt/a 16.1 t/cap	114 Mt/a 11.9 t/cap	-39%	26%	106%	-1.3%	0.6%	1.9%
6	**RESOURCE EFFICIENCY X3, HIGH GDP(EFF3+):** Resource efficiency c. tripled by 2050, 2% annual growth in GDP							
	156 Mt/a 17 t/cap	128 Mt/a 13.4 t/cap	-31%	112%	209%	-1%	2%	3%
7	**RESOURCE EFFICIENCY X7, HIGH GDP (EFF7+):** Resource efficiency increased by a factor of 7 by 2050, 2% annual growth in GDP							
	104 Mt/a 11.4 t/cap	55 Mt/a 5.8 t/cap	-71%	112%	620%	-3.2%	2%	5.3%

Data source: Own calculations based on Statistics Austria 2014a Eurostat, 2015c

Figure 26: Overview of development of material use in million tonnes per year to 2050 in seven scenarios



Data source: Own calculations based on Statistics Austria 2014a Eurostat, 2015c

1 – TREND CONTINUATION (TREND)

Annual growth rates of DMC from 1970 and 2010 by material category are applied to the period from 2010 to 2050

Resource Use in Austria		
to 2030	204 Mt/a	22.2 t/cap
to 2050	230 Mt/a	24.1 t/cap

Growth to 2050	Total	Ø p. a.
DMC	26%	0.6%
BIP	---	---
Efficiency	---	---

A simple trend continuation shows how material use would develop between 2010 and 2050, if past trends (from 1970 to 2010) were to continue unchanged. The trend scenario can be taken as a comparative scenario for the other scenarios in order to see how material use would develop if conditions were to change. In the 40 years until 2010, biomass use increased at an annual rate of 0.16%, the use of fossil energy carriers at a rate of 0.71%, metal use at a rate of 0.91% and the use of non-metallic minerals at a rate of 0.68%. These growth rates were applied to the material categories from 2010 onwards, to provide a forecast for material use by 2050. According to this scenario, 230 million tonnes of material would be used in Austria in 2050, which at slightly more than 24 tonnes per capita represents a significant increase in both absolute and per capita terms in relation to the 2010 figure. This trend continuation would also change little in the composition of use according to material categories: non-metallic minerals would constitute the largest share at 61%, followed by biomass (19%), fossil energy carriers (15%) and metals (6%) (▶ Figure 27, page 66). The high level of material use, which would be produced by a continuation of current trends, would not be sustainable either for Austria or in global terms.

2 – STABILISATION OF DMC (STABLE)

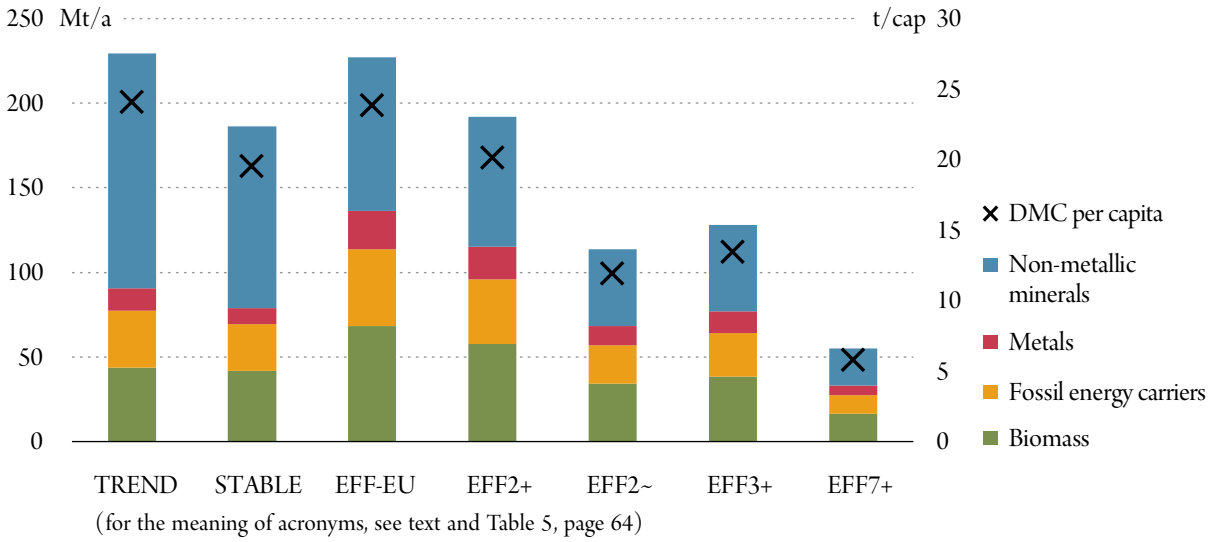
DMC stays at the 2012 level until 2050

Resource Use in Austria		
to 2030	187 Mt/a	20.3 t/cap
to 2050	187 Mt/a	19.5 t/cap

Growth to 2050	Total	Ø p. a.
DMC	0%	0%
BIP	---	---
Efficiency	---	---

The stabilisation scenario is based on the assumption that DMC could be maintained at 2012 levels through to 2050, i.e. that in 2050, 187 million tonnes of material would be used, as was the case in 2012. Since the Austrian population, in contrast to material use, would continue to grow according to the main scenario of Statistics Austria, per capita material use would have to be 19.5 tonnes by 2050 and thus somewhat less than current levels. The shares of the different material categories in DMC would also remain as they were in 2012 (▶ Figure 27, page 66). Since material use in Austria is already unsustainable at current levels, this scenario too cannot be regarded as sustainable. From a global perspective above all, it clearly fails to fulfil the criteria for sustainable resource use: if the entire world population were to reach 9 billion people by 2050 and this level of material use were to be applied to all the world's inhabitants, almost 180 billion tonnes of material per year would be used each year, which would be more than twice the current figure.

Figure 27: Scenario outcomes for domestic material consumption (DMC) in 2050 by material category and DMC per capita



Data sources: Eurostat 2015c

IMPROVING RESOURCE EFFICIENCY

In what ways could improvements in resource efficiency contribute to a more sustainable future? To answer this question, five scenarios containing efficiency improvements were developed. These scenarios show which combinations of efficiency and GDP would be necessary and possible in order to achieve a reduction in material use. For all efficiency scenarios, it was assumed that Austrian material use until 2050 would be composed of 30% biomass, 20% fossil energy carriers, 10% metals and 40% non-metallic minerals.

3 – EFF EU

Resource efficiency increases by 30% by 2030 and continues this trend until 2050

Resource Use in Austria		
to 2030	205 Mt/a	22.3 t/cap
to 2050	227 Mt/a	23.8 t/cap

Growth to 2050	Total	Ø p. a.
DMC	22%	0.5%
BIP	112%	2%
Efficiency	74%	1.5%

At the European level, the target has been set to increase resource efficiency by 2030. In the **EFF-EU scenario**, it was assumed that this had been achieved and that the requisite improvement in resource efficiency would also be maintained up to 2050. For resource efficiency to increase by 30% by 2030, it would have to increase each year by 1.5% (▶ Table 5, page 64). The result of this scenario is close to that of the trend continuation scenario (TREND, Figure 26, page 64). At 227 million tonnes or 23.8 tonnes per capita, material use would be slightly higher in 2050 than the current level. This level of resource uses significantly higher than the European and especially the global average. An increase in resource efficiency of 30% would not be sufficient as a single measure to improve sustainability in Austria and globally.

4 – EFF 2+

Resource efficiency c. doubled by 2050, 2% annual growth in GDP

Resource Use in Austria		
to 2030	189 Mt/a	20.6 t/cap
to 2050	192 Mt/a	20.2 t/cap

Growth to 2050	Total	Ø p. a.
DMC	3%	0.1%
BIP	112%	2%
Efficiency	106%	1.9%

If Austria were to approximately double its resource efficiency by 2050 – and achieve a GDP of 3,000 € per tonne of material used – and GDP were to exhibit a high rate for Austria of 2% per year, material use would rise slightly by 2050 to reach 192 million tonnes per year (**EFF2+ scenario**). Since the population would grow more quickly, per capita use would be reduced to 20.2 tonnes.

To achieve this increase in resource efficiency, there would have to be an annual increase in resource efficiency of 1.9%. This is already higher than the annual improvement in the EFF-EU scenario, yet because material use would remain at the same high level, it would not be sustainable and could also not be implemented on a global scale.

5 – EFF 2~

Resource efficiency c. doubled by 2050, 0.6% annual growth in GDP

Resource Use in Austria		
to 2030	147 Mt/a	16.1 t/cap
to 2050	114 Mt/a	11.9 t/cap

Growth to 2050	Total	Ø p. a.
DMC	-39%	-1.3%
BIP	26%	0.6%
Efficiency	106%	1.9%

A greater reduction in material use would be made possible by doubling resource efficiency and achieving a relatively low growth rate for GDP of 0.6% per year (**EFF2~ scenario**). For this, however, as in the EFF2+ scenario, resource efficiency would have to improve at an average annual rate of 1.9%. The average GDP growth rate since the financial crisis would be maintained until 2050. This would reduce material use to 114 million tonnes per year and 11.9 tonnes per capita. Despite significant reductions, material use would thus still be above the current global average. The low GDP growth rate linked to this scenario would require a reassessment of the current political approach, which is based on achieving stronger growth.

6 – EFF 3+

Resource efficiency c. tripled by 2050, 2% annual growth in GDP

Resource Use in Austria		
to 2030	156 Mt/a	17 t/cap
to 2050	128 Mt/a	13.4 t/cap

Growth to 2050	Total	Ø p. a.
DMC	-31%	-1%
BIP	112%	2%
Efficiency	209%	3%

If a GDP growth of 2% per year were to be achieved whilst still reducing material use, resource efficiency would have to be very significantly increased. If it were possible to triple resource efficiency by 2050 (**EFF3 + scenario**), i.e. to increase resource efficiency by 3% per year, material use could be reduced by 2050 to 128 million tonnes per year and to 13.4 tonnes per capita.

Austria's resource use levels would thus represent the current European average. If this level of resource use were extended to the global population, however, this would result in a huge increase in material extraction and the environmental impacts associated with this, and it cannot therefore be described as sustainable.

7 – EFF7+

Resource efficiency increased by a factor of 7 by 2050, 2% annual growth in GDP

Resource Use in Austria		
to 2030	104 Mt/a	11.4 t/cap
to 2050	55 Mt/a	5.8 t/cap

Growth to 2050	Total	Ø p. a.
DMC	-71%	-3.2%
BIP	112%	2%
Efficiency	620%	5.3%

Only if resource efficiency were to be increased by a factor of 7 (and an average annual growth rate in efficiency of more than 5%) could a very significant reduction in material use to c. 5.8 tonnes per capita be achieved, while simultaneously maintaining a high GDP growth rate (**EFF7+ scenario**). This scenario comes within the parameters of the targets set out in the *Austrian Resource Efficiency Action Plan* (REAP).[7] If resource efficiency were equally to be raised to this level, it would have to be doubled by 2025 in relation to 2012, and quadrupled by 2040. This would require not only the political prioritisation of this goal but also close cooperation between politics, the economy, science and society. The *great acceleration* in the use of natural resources by humans and consequently also in environmental pollution and material use has primarily taken place since 1950 (Steffen et al. 2015). For this reason, setting the level that existed before this acceleration as the goal for future resource use is currently a matter of debate within the sustainability sciences. This would mean setting a goal for DMC of 5 tonnes per capita and year for all countries worldwide. For Austria, achieving this goal by 2050 would have to be accompanied by a reduction in material use to 48 million tonnes per year – in other words, a still greater reduction than is calculated in the scenario discussed here. Improvements in sustainability would be expected through this measure both in Austria and on a global level. However, whether setting a 5-tonne per capita goal could guarantee global sustainability,cannot be conclusively stated.

7 The REAP target is to increase resource efficiency by at least 50% by 2020 in comparison to 2008. This would reduce absolute resource use by c. 20%. The EFF7+ scenario would (compared with the 2012 baseline) achieve a reduction of 21% in resource use and an increase of 53% in resource efficiency by 2020. In the long term (by 2050), REAP aims at increasing resource efficiency by a factor of 4 – 10. In the EFF7+ scenario, resource efficiency would increase by 2050 by a factor of 7.

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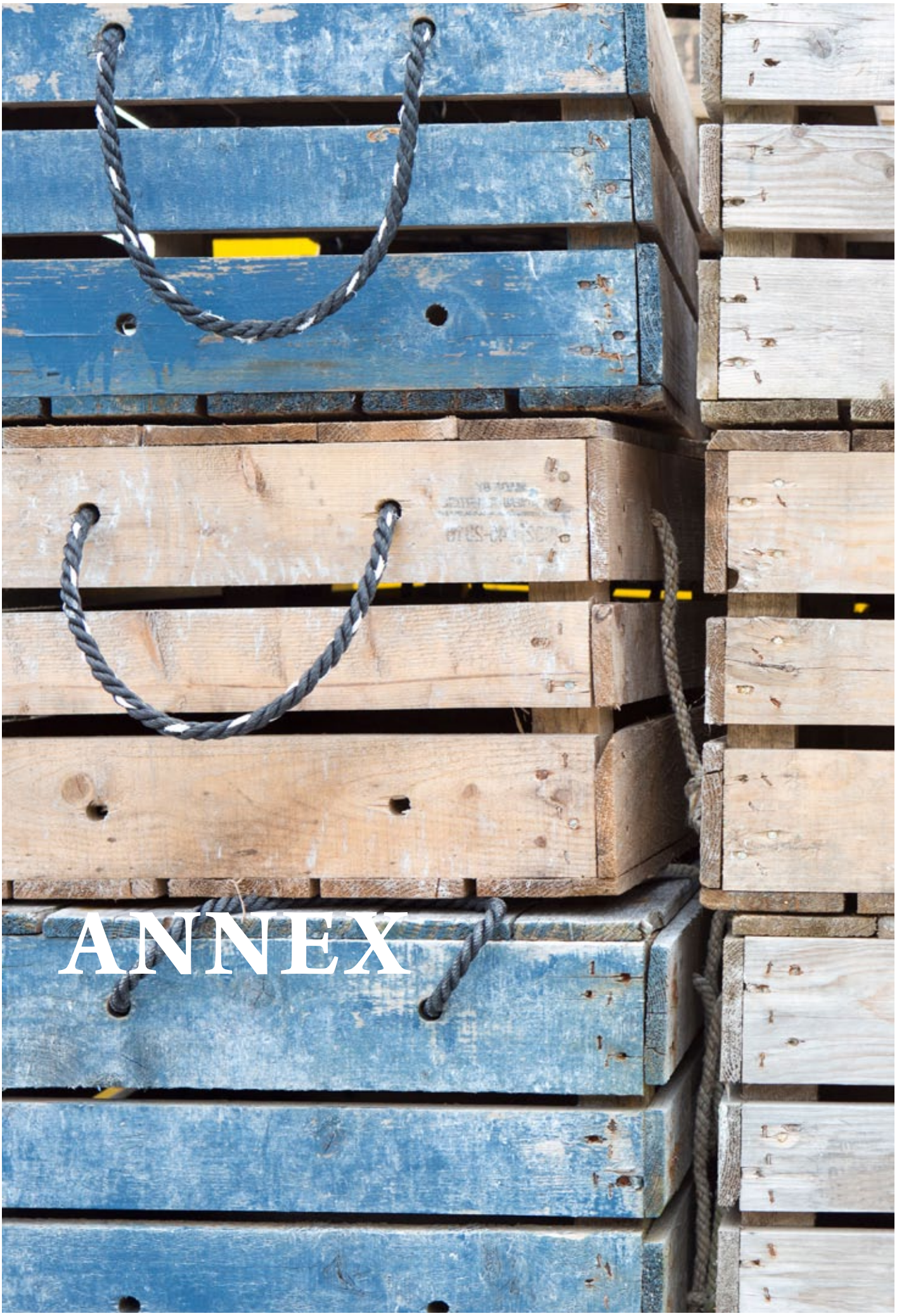


ANNEX

MATERIAL FLOW ACCOUNTING – CONCEPT, DATA SOURCES AND METHODS

Material flow accounting and analysis is an EU-wide accounting tool for the material inputs, stocks and outputs of a social system. This accounts for solid, gaseous and liquid materials, excluding water and air, recorded in physical units (usually measured in tonnes). The material flow account is a component of the environmental accounts.

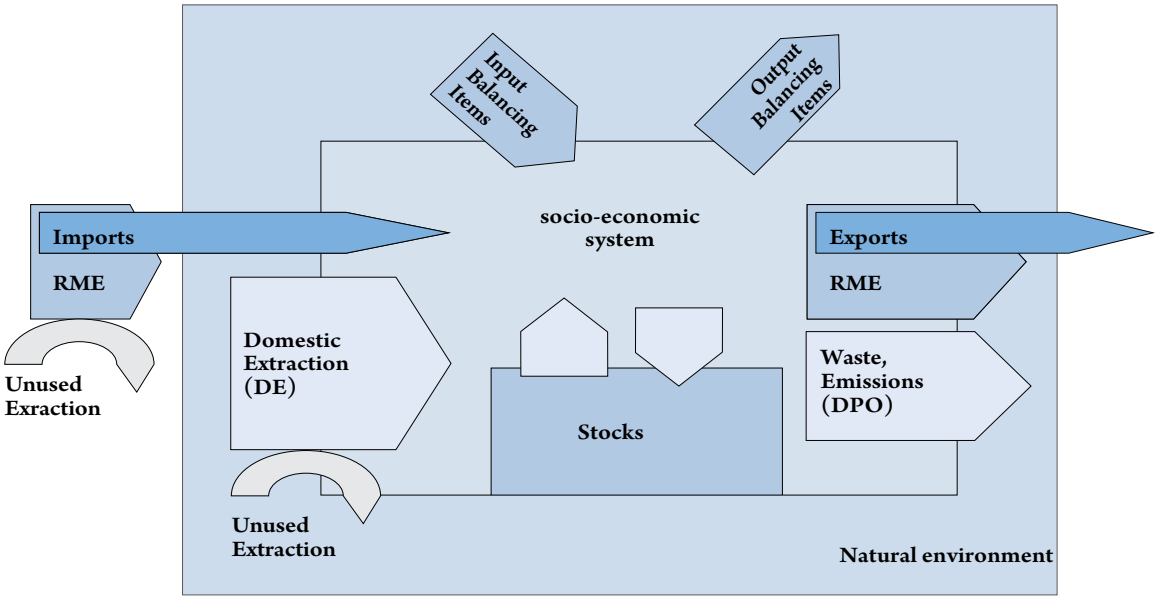
CONCEPT

Material flow accounting (*MFA*) measures all material flows that are required for the development, operation and maintenance of a society's biophysical structures. These biophysical structures (or "stocks") are calculated according to a definition including all persons, artefacts and livestock (including livestock farming and aquaculture). In line with the *System of National Accounts* (SNA), artefacts comprise all infrastructure, buildings, vehicles, machinery and, in contrast to the national accounts, also durable goods. To be able to record the material exchange relations of a societal system (a national economy), two system boundaries must be defined in the framework of the MFA: 1. The boundary between the societal system and its natural environment, from which material is extracted and to which emissions and wastes are outsourced; 2. The boundary between the societal system and other societal systems (national economies), from which goods are imported and/or to which goods are exported (▶ Figure 28, see below).

Water and air are not included in the material flow account as material extracted from the environment, unless they are contained in raw materials or goods. This concerns e.g. harvested cereal crops, fruit, vegetables and various goods included in export trade. In the case of grazed biomass, harvest by-products and wood, the water content is conventionally calculated at 15 %.

Inputs into the socioeconomic system are in the first instance raw materials that are extracted within the country (domestic extraction) and imported raw materials and processed goods (imports). Domestic extraction includes all raw materials that are extracted from nature. This includes raw materials from agriculture and forestry (e.g. field crops, grass cuttings, wood) and from mining (e.g. coal, iron ore, limestone, salt). In contrast, imports include products at very different processing stages, from

Figure 28: Schematic presentation of material flow accounting



Source: after Eurostat 2001

iron ore to mobile telephones. Outputs of the socioeconomic system include wastes and emissions (*domestic processed output DPO*) on one hand and exports on the other. Intermediate material use in the case of both imports and exports can be presented in *raw material equivalents* (*RMEs*). RMEs comprise the mass of the traded goods themselves, together with all those material inputs used during upstream production processes. These are calculated in order to render visible the impacts of outsourcing through the foreign trade. During extraction, additional materials are also moved, which do not flow into the societal system as utilized extraction, i.e. which are not assigned to any societal use. These flows are recorded in the MFA as unused extraction and include, for example, overburden in mining, excavated soil material from the construction of infrastructure, or crop residues. Other environmental impacts (e.g. soil erosion), which result from the societal utilization of resources, for which there are other measurement and observation tools are not included in the MFA.

Applying the conservation of mass principle is decisive for ensuring the consistency of an MFA. This states that materials and energy within a closed system cannot be either created or destroyed. The following equation must therefore be fulfilled:

Inputs = Outputs +/- stocks changes

So that the material balance can be closed, balancing items must be introduced into the MFA on both the input and the output sides (water vapour, air as input into combustion processes, etc.). Those wishing to read more on the subject can find a detailed description of the treatment of such balancing items in the methodological guides published by Eurostat (see reference list).

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, and therefore also includes grazed biomass. This category further 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 recorded in terms of their mass at the point of leaving the mine, meaning that figures are inclusive of waste rock. Fossil energy carriers (also energy raw materials) encompass non-metallic mineral raw materials, which developed from biomass in geolog-ical prehistory. Conventional energy sources include brown coal, hard coal, petroleum and natural gas.

The basic MFA module accounts for all direct movements that pass beyond the above-mentioned system boundaries (domestic extraction, imports, exports). The data on domestic extraction, imports and exports collected in the MFA framework allow for 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. This comprises domestic material extraction plus imports and minus exports. Domestic material consumption includes all materials that were used in the societal system, whether in economic production processes or in final consumption. In other words, 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*).

RMC thus describes all raw materials used in the production of goods for domestic consumption.

DATA BASIS AND METHODS

The MFA is compiled using existing 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, Statistics of Agriculture und Timber Felling
Fossil energy carriers	Energy Balances
Non-metallic minerals	Mining Data, Short Term Statistics, and Supply and Use Tables
Metals	Mining Data

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 the common unit form of metric tonnes. 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 either poorly represented in or completely absent from the statistics. 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.

Where harvesting cultivated crops in Austria leaves crop residues, there are harvest indices available with ratios between harvest yield and total plant mass. 75% of available residues (straw) are extracted (primarily for use as bedding material) while 25% remain on the field as unused extraction and are therefore not included in the MFA. Apart from straw, beet leaves are extracted as a harvest by-product and used as livestock feed. Here too, factors for the ratio of crop yield to leaf residue and to the utilized share of the leaf residue are available. Furthermore, biomass directly grazed by livestock (mainly grass) is excluded from the statistics. This flow is estimated for Austria by using a feed balance approach. This involves calculating the feed requirements for animals using roughage (ruminants and horses) and relating this to the supply of marketable feed (concentrates) and fodder crops. The fact that part of the existing feed supply will be used to cover the feed requirements of chickens and pigs.

The extraction of construction minerals is incompletely recorded in official statistics. In Austria, a three-step procedure has been implemented, which extrapolates the non-reported extraction on the basis of Short Term Statistics and Material Input Statistics. 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 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, 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. These tables report the production of construction minerals in the non-producing sector in monetary values. Based upon the supply tables, 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, corresponding 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 EU15, 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. Since 2011, the reporting of material flow data within the European Union has been governed by a regulation (European Parliament and Council of the European Union 2011).

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 that – in many cases with the support of the BMLFUW – deal with various aspects of the material flow analysis include the Institute of Social Ecology of Alpen-Adria University, Klagenfurt-Vienna-Graz (http://www.aau.at/socec/), the Institute for Ecological Economics at Vienna University of Economy (http://www.wu.ac.at/ecolecon/) and Business and the Institute for Water Quality, Resource Management and Waste Management of the Vienna University of Technology.

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 accessed via different institutions: Current data on material use in Austria are available at Statistics Austria. Material flow

accounts for the EU Member States can be obtained via the data server of EUROSTAT, the Statistical Office of the European Union (http://ec.europa.eu/eurostat/web/environment/material-flows-and-resource-productivity/database). The Institute of Social Ecology provides 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 BMLFUW, the (Institute for Ecological Economics (Research Group Sustainable Resource Use) at Vienna University of Economy maintains the website www.materialflows.net, which provides data on global material extraction by countries since 1980.

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 the use of raw materials, energy, water and land, waste and waste water disposal and atmospheric emissions are set against economic data, including gross domestic product, income, consumption, investments, etc. Environmental accounts are structured according to the EU guidelines on environmental indicators and a green national accounting system.

The **System of National Accounts** (**SNA**) is in principle a closed system of accounts in which key macroeconomic factors are reported as transactions or balances (e.g. gross domestic product (GDP), gross national income, available household income, net lending/borrowing by the state, private consumption, investments), based on the notion of an economic cycle. National accounts are harmonised internationally in line with the *System of National Accounts*, and the *European System of National Accounts* (ESNA) is a variant of this, which is tailored specifically to European conditions. Whereas the SNA has the character of 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 that 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, and by definition, productive livestock. Society must reproduce itself both in respect of culture and communication and also biophysically. Resources are used for biophysical reproduction, that is, the development and maintenance of the physical structures of society.

The concept of **social metabolism** assumes that in analogy to a biological organism, society also operates in "metabolism" (or 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 into its environment in the form of wastes or emissions. This metabolic exchange can be recorded in the form of physical accounts.

Material Flow Accounting (**MFA**) is an accounting tool for recording the material inputs and outputs of a societal 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 with the natural environment and with other economies are set accordingly. Resources extracted from the natural environment within the country (domestic extraction, DE) enter the system as inputs, while emissions and wastes flow back into the environment as outputs. 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, which are intentionally extracted or transformed in the natural environment and utilized by society. The physical resources per se are not lost but rather transformed through utilization. The specific quality that makes them useful for society is usually used and lost in this process. The empirical analysis presented in the current publication focuses on material resources such as 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 dead organic matter (dead wood, leaves, straw, etc.). Biomass is frequently referred to as renewable or sustainable raw material. Fossil energy carriers are not included, although they have their origin in biomass.

Fossil energy carriers are non-metallic minerals, which have been created over millions of years from the decomposition of plant or animal remains in the Earth's crust

and which are primarily used for the production of energy.

Metals include mineral materials ranging from ores to processed metals. In raw materials science, ores are defined as mineral materials from which metals with economic value can be extracted. In material flow analysis, metals are subdivided into ferrous ores and non-ferrous ores.

The group of the **non-metallic minerals** comprises construction mineralsand industrial minerals. Construction raw materials are non-metallic mineral raw materials, such as sand and gravel, which are required in great quantities 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, together with metallic and non-metallic minerals, 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 concentrated 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, felled timber and mining products.

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

Domestic material consumption (**DMC**) describes the share of materials that remains within a national economy. The DMC therefore equals domestic material extraction plus imports and minus exports. In this report, DMC is often referred to in abbreviated form as material use.

Physical trade balance (**PTB**) is calculated by subtracting the exports from the imports. It is defined as the converse of the monetary trade balance (which equals exports minus imports). This reflects the fact 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 (in which 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 that offer materials on the global market for use in other countries.

Raw material equivalents (**RMEs**) of the imports and exports are composed of all the material inputs that were required in the production of the traded goods (intermediate material use), plus the mass of the imports and exports themselves. RMEs 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 consumed in the course of production.

Raw material consumption (**RMC**) is the domestic material consumption expressed in raw material equiv alents. It therefore consists of domestic extraction plus the imports expressed in RMEs and minus the exports expressed in RMEs. The RMC thus describes the total demand for raw materials, which a country consumes in terms of final use, both nationally and globally.

Resource efficiency (when viewing 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. Resource efficiency is also expressed as resource productivity.

Decoupling of economic output and resource use occurs in cases where the economic growth exceeds the growth of resource use (i.e. resource efficiency increases). A distinction is made between two types 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.

ABBREVIATIONS AND UNITS OF MEASUREMENT

ABBREVIATIONS

AEA	Austrian Energy Agency (Österreichische Energiegentur)
GDP	gross domestic product
DE	domestic extraction
DMC	domestic material consumption
DMI	direct material input
DPO	domestic processed output
EU-27	the 27 Member States of the European Union (as of 2013)
HDI	human development index
LCA	life cycle analysis
MFA	material flow accounting
MIOT	monetary input-output table
PTB	physical trade balance
REAP	Resource Efficiency Action Plan
REX	raw material equivalents of exports
RIM	raw material equivalents of imports
RMC	raw material consumption
RME	raw material equivalents
TPES	total primary energy supply
SNA	system of national accounts

MEASUREMENT UNITS

cap	capita
dt	quintal (hundred tonnes)
EJ	exajoule (trillion joules)
GJ	gigajoule (billion joules)
Gt	gigatonne (billion tonnes)
ha	hectare
kg	kilogram
kt	kilotonne (thousand tonnes)
MJ	megajoule (million joules)
Mt	megatonne (million tonnes)
t	tonne

DATA TABLES

Table A-1: Austrian material flows in 1960 and 2012 in million tonnes, increases in flows between 1960 and 2012 and composition of flows by material categories
All figures rounded, rounding differences have not been cleared.

	MATERIAL FLOWS (Mt)		GROWTH (factor)	SHARE OF TOTAL FLOW	
	1960	2012	1960 – 2012	1960	2012
DOMESTIC EXTRACTION	105.37	150.02	1.4		
Biomass	34.40	38.97	1.1	33%	26%
Fossil energy carriers	9.67	2.37	0.2	9%	2%
Metals	3.92	2.52	0.6	4%	2%
Non-metalic minerals	57.38	106.16	1.9	54%	71%
IMPORTS	15.81	91.39	5.8		
Biomass	2.22	23.78	10.7	14%	26%
Fossil energy carriers	7.03	30.06	4.3	44%	33%
Metals	2.50	20.95	8.4	16%	23%
Non-metalic minerals	4.07	10.09	2.5	26%	11%
Other products	---	6.31	---	---	7%
EXPORTS	7.24	55.22	7.56		
Biomass	1.63	21.03	12.9	22%	38%
Fossil energy carriers	1.15	4.89	4.3	16%	9%
Metals	1.50	13.83	9.2	21%	25%
Non-metalic minerals	2.78	8.90	3.2	38%	16%
Other products	0.19	5.83	31.1	3%	11%
DOMESTIC MATERIAL CONSUMPTION	113.94	186.72	1.6		
Biomass	34.99	41.72	1.2	31%	23%
Fossil energy carriers	15.55	27.53	1.8	14%	15%
Metals	4.92	9.64	2.0	4%	5%
Non-metalic minerals	58.67	107.35	1.8	51%	57%
Other products	-0.19	0.48	-2.6	0%	0%

Data sources: Statistics Austria 2014a

Table A-2: Austrian domestic material consumption in 1960 and 2012 in tonnes per capita by material categories and increases in flows between 1960 and 2012
All figures rounded, rounding differences have not been cleared.

	DOMESTIC MATERIAL CONSUMPTION (tonnes per capita)		GROWTH (factor)
	1960	2012	1960 – 2012
Total	16.17	22.16	1.4
Biomass	4.97	4.95	1.0
Fossil energy carriers	2.21	3.27	1.5
Metals	0.70	1.14	1.6
Non-metalic minerals	8.33	12.74	1.5

Data sources: Statistics Austria 2014a

Table A-3: Austrian resource efficiency in Euro per kilogramm (€/kg) and components Domestic material consumption (in million tonnes per year) and GDP (in billion Euros) in 1960 and 2012 and increase in flows between 1960 and 2012
All figures rounded, rounding differences have not been cleared.

	RESOURCE EFFICIENCY AND COMPONENTS		GROWTH (factor)
	1960	2012	1960–2012
Resource efficiency (€/kg)	0.55	1.45	27
Resource efficiency (€/t)	550	1,454	2.7
Domestic material consumption (Mt/a)	113.94	186.72	1.6
GDP (Billion €)	62.63	271.55	4.3

Data sources: Statistics Austria 2014a

Table A-4: Austrian material flows by material categories from 1995 to 2012 in million tonnes per year
All figures rounded, rounding differences have not been cleared.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DOMESTIC EXTRACTION	152	156	163	156	163	158	153	166	156	164	167	170	173	162	152	148	154	150
Biomass	37	37	38	37	38	34	35	37	35	39	40	39	40	44	39	39	42	39
Fossil energy carriers	4	3	3	3	4	4	4	4	4	3	2	2	2	2	2	2	2	2
Metals	2	2	2	2	2	2	2	2	3	2	3	2	3	2	2	2	3	3
Non-metalic minerals	110	113	119	113	119	118	112	123	114	119	122	126	128	114	108	104	107	106
IMPORTS	53	55	59	61	61	65	68	70	73	77	81	87	91	88	80	88	92	91
Biomass	12	12	13	13	16	18	18	18	18	20	21	23	23	22	22	24	24	24
Fossil energy carriers	20	22	22	23	22	22	23	25	27	27	28	29	28	28	27	28	29	30
Metals	10	10	12	13	12	14	14	14	15	16	17	19	21	20	15	20	22	21
Non-metalic minerals	7	7	8	8	8	8	8	8	9	9	10	10	12	11	10	10	10	10
Other products	4	4	4	4	4	4	4	5	5	5	5	6	6	6	5	6	6	6
EXPORTS	28	29	32	35	36	38	40	43	44	48	50	53	58	59	50	55	57	55
Biomass	11	11	13	13	15	16	16	17	18	19	20	21	22	22	20	21	21	21
Fossil energy carriers	1	1	1	2	2	2	2	2	2	3	3	4	5	6	5	5	6	5
Metals	7	7	7	9	8	9	10	10	11	12	12	13	14	15	11	13	14	14
Non-metalic minerals	5	5	6	6	6	6	7	7	7	8	7	8	10	9	8	8	10	9
Other products	4	4	4	4	4	4	5	5	5	6	6	6	7	7	6	7	6	6
DOMESTIC MATERIAL CON-SUMPTION	177	182	190	183	189	186	181	194	185	193	199	205	206	191	181	181	189	187
Biomass	38	38	39	37	39	36	36	37	35	40	40	42	41	44	41	41	45	42
Fossil energy carriers	23	24	24	24	24	24	25	27	29	27	27	28	26	25	25	26	26	28
Metals	5	6	7	6	5	6	6	6	6	6	8	9	10	8	7	9	10	10
Non-metalic minerals	111	115	121	115	121	120	113	124	115	120	124	127	130	115	110	106	108	107
Other products	0	0	0	0	-1	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	0	0

Data sources: Statistics Austria 2014a

Table A-5: Austrian domestic material consumption by material categories from 1995 to 2012 in tonnes per capita and year

All figures rounded, rounding differences have not been cleared.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total	22.3	22.9	23.9	22.9	23.6	23.3	22.5	24	22.8	23.7	24.2	24.8	24.8	22.9	21.7	21.6	22.5	22.2
Biomass	4.7	4.7	4.8	4.7	4.8	4.5	4.5	4.6	4.3	4.9	4.9	5.1	5	5.3	5	4.9	5.3	5
Fossil energy sources	2.9	3	3	3.1	3	3	3.1	3.3	3.5	3.3	3.3	3.3	3.1	2.9	3	3.0	3.1	3.3
Metals	0.7	0.7	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9	1.1	1.2	1	0.8	1.1	1.2	1.1
Non-metalic minerals	14	14.4	15.2	14.4	15.2	15	14.1	15.4	14.2	14.7	15.1	15.4	15.7	13.8	13.1	12.7	12.8	12.7
Other products	0	0	0	0	-0.1	0	0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0	0.1

Data sources: Statistik Austria 2014a

Table A-6: Austrian resource efficiency in Euro per kilogrammes (€/kg) and components
Domestic material consumption (in million tonnes per year) and GDP (in billion Euros) 1995 bis 2012

All figures rounded, rounding differences have not been cleared.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ressource efficiency (€/kg)	1.09	1.09	1.07	1.15	1.15	1.21	1.26	1.19	1.26	1.24	1.23	1.24	1.28	1.40	1.42	1.46	1.42	1.45
Resource efficiency (€/t)	1,091	1,085	1,065	1,151	1,153	1,211	1,258	1,193	1,264	1,238	1,233	1,241	1,279	1,399	1,417	1,455	1,425	1,454
Domestic Material consumption (Mt/a)	177	182	190	183	189	186	181	194	185	193	199	205	206	191	181	181	189	187
GDP (Billion €)	193	198	203	210	218	226	228	231	233	239	245	254	264	267	257	263	270	272

Data sources: Statistics Austria 2014a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