1. BACKGROUND AND SCOPE

Evidence is growing that pressure on the availability of natural resources is causing a strain on the environment as well as affecting our economy. The inefficient resource-use at a time of growing demand is leading to increasing environmental pressure and resources scarcity that will affect Europe and other parts of the world over the next years and decades. Prices for global commodities like oil, raw materials and wheat have been increasing over the past five years though the current financial crisis has temporarily led to lowering demand for natural resources.

Achieving resource efficiency and a low carbon society are key challenges for the future of EU's economy, its industrial and service sector, and its citizens. Increasing energy and resource efficiency will lead to lowering material purchasing costs throughout the industry. It thus enhances competitiveness and offers opportunities to innovate. Eco-innovation – putting the EU on the path to a resource and energy efficient economy – can be seen as a key to enhancing Europe's strategic position on world markets of tomorrow. In this regard, the current bail out of the financial crisis ought to be seen as a starting point for the build up of eco-innovation and eco-industries in the EU.

The objective of this study is to support the Committee on Industry, Research and Energy in its work on the EU's industrial and energy policy and to give advice on the following issues:

- What EU policies are needed for the EU to on the one hand reduce its needs for resources and energy and on the other hand through eco-innovation create solutions, which will also drive innovation in a large range of industrial sectors?
- Are existing measures delivering the set objectives and what improvements/ new instruments should be set forward?

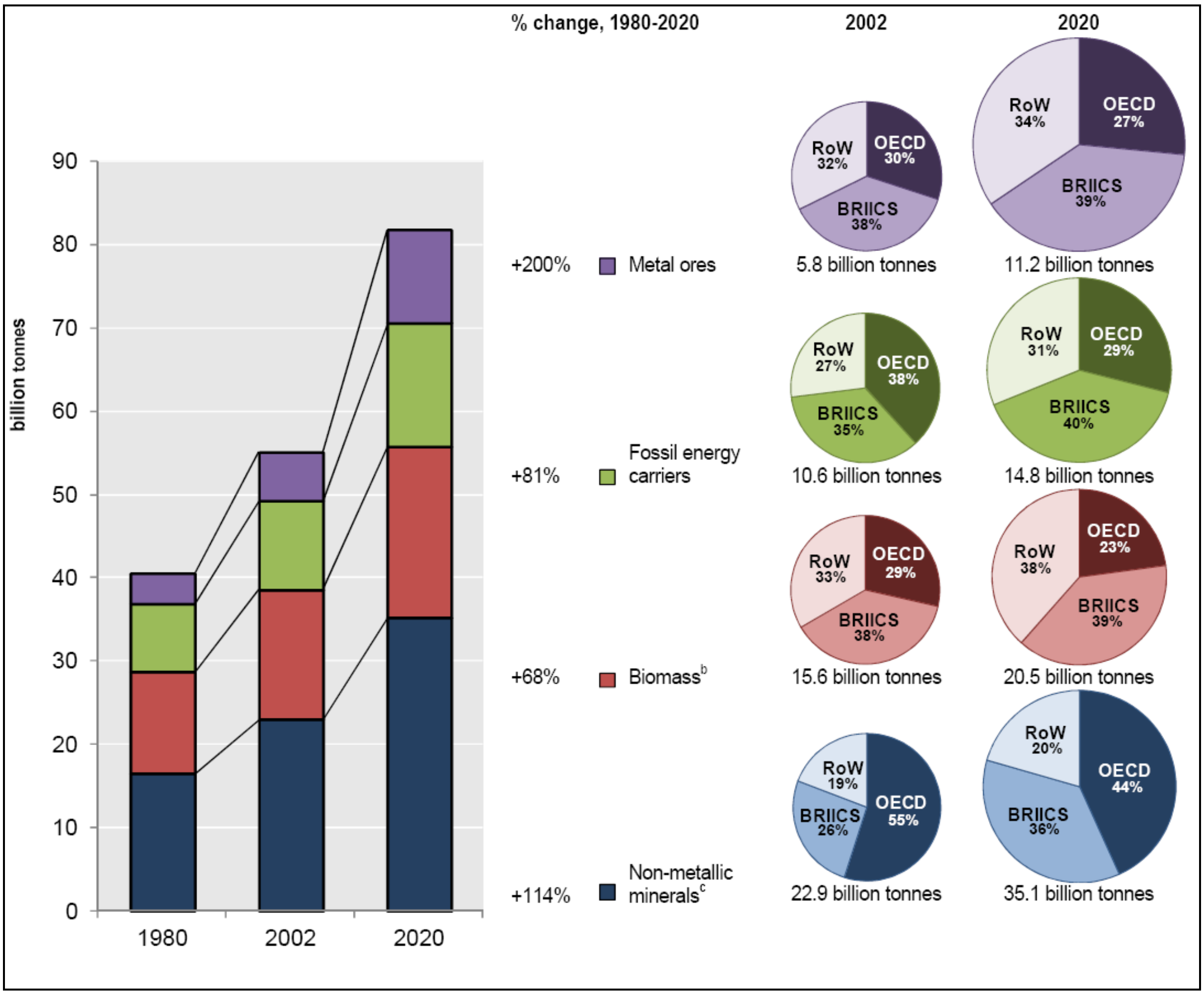
To meet these objectives, this study is structured as follows: Chapter 2 will give an overview on resource scarcities. Chapter 3 elaborates on eco-innovation, including trends, barriers and driving forces. Chapter 4 develops proposals for EU policies.

2. RESOURCES SCARCITY

2.1. Scenarios of possible resource scarcities (including energy)

Global extraction of natural resource is steadily increasing. Since 1980, global extraction of abiotic (fossil fuels, minerals) and biotic (agriculture, forestry, fishing) resources has augmented from 40 to 58 billion tonnes in 2005. Scenarios anticipate a total resource extraction of around 80 billion tonnes in 2020 (200 % of the 1980-value), necessary to sustain the worldwide economic growth (Giljum et al., 2008). Depending on the level of economic development, trade patterns and industrial structures, growth rates and extraction intensities vary between different world regions, as illustrated in Figure 2 for the three regions of OECD, the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa), and the rest of the world. Strongest growth will be observed in the BRIICS countries, while the share if the OECD countries in total global resource extraction will shrink.

Figure 2: Global resource extraction, by major groups of resources and regions



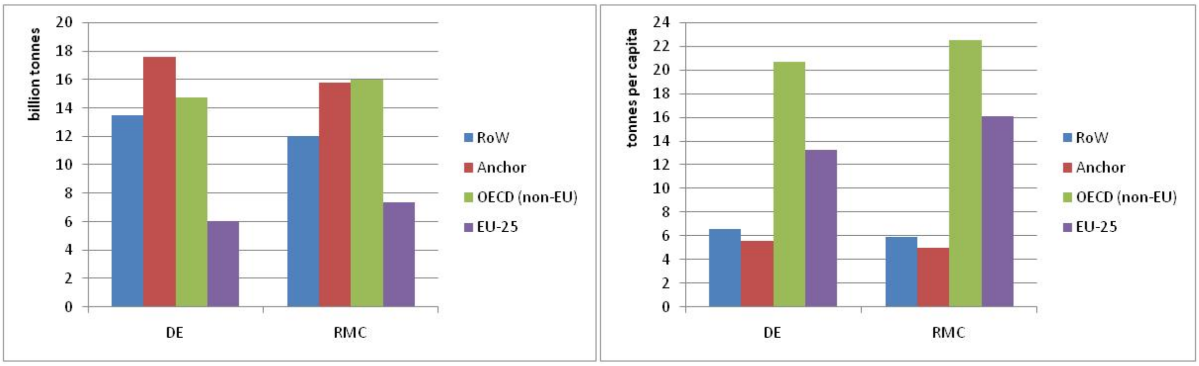
Source: OECD (2008), based on SERI MFA database at http://www.materialflows.net and Giljum, et al. (2008)

The European economy is increasingly dependent on resource imports from other world regions. In comparison to the overall global growth rate (45 % over the last 25 years), Europe's resource extraction grew only by 3 %, but studies show that these domestic raw materials are increasingly substituted by imports from other world regions.

Latin America, for instance, is specialising noticeably in the export of resource-intensive products, such as metal ores or biomass for biofuels. In 2005, Chile extracted fivefold the amount of copper of 1980, Brazil threefold the amount of sugar cane – being the raw material for ethanol fuel.

On the one hand, this development leads to a considerable dependency of Europe on the imports of other countries, which may put industry at risks of higher prices and more difficult access. On the other hand, it also leads to an "outsourcing" of the environmental burden, connected to resource extraction and processing activities to other world regions. The statement just made can be illustrated by comparing the indicators of Domestic Extraction (DE) and Raw Material Consumption (RMC) of natural resources in different world regions. While DE illustrates, where the resources are extracted, RMC shows where the products are finally consumed, which are produced based on the extracted resources.

Figure 3: Domestic Extraction (DE) and Raw Material Consumption (RMC) in different world regions (absolute numbers, left diagram and per capita, right diagram), in 2000



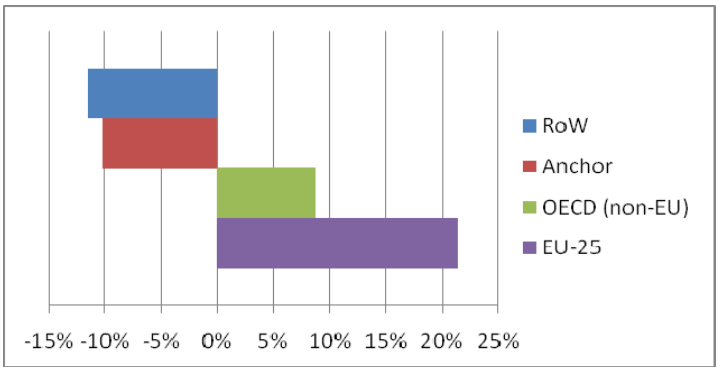
Note: "Anchor countries" is the group of emerging economies: Argentina, Brazil, China, Indonesia, India, México, Philippines, Russia, Thailand, and South Africa. Source: Giljum et al., 2008

On average a European consumes per year around three times the amount of resources of a citizen in the emerging countries while producing twice as much. In absolute numbers (left diagram) the EU's DE, as well as the RMC, is significantly lower compared to other world regions; however it is noticeable that the EU-25 consume more resources than they extract, illustrating the net-imports of natural resources. The picture changes considerably when turning to a per capita perspective (right diagram). The domestic extraction per capita in EU-25 countries is significantly higher compared to the other world regions; the Anchor countries (the group of emerging economies: Argentina, Brazil, China, Indonesia, India, México, Philippines, Russia, Thailand, and South Africa), counting almost 3.2 billion inhabitants, which lead the list of resource extracting world regions, still fall far behind all other regions when investigating per capita values.

The EU is the world region that outsources the biggest part of resource extraction. Relating net-trade flows of materials to levels of domestic extraction enables to illustrate to what extent different world regions are outsourcing material and energy-intensive production processes to other world regions. Figure 4 shows that the EU is the world region that outsources the biggest part of resource extraction required to produce goods for final demand (private and public consumption and investment), thus exceeding a potential self-sufficiency of natural resource use.

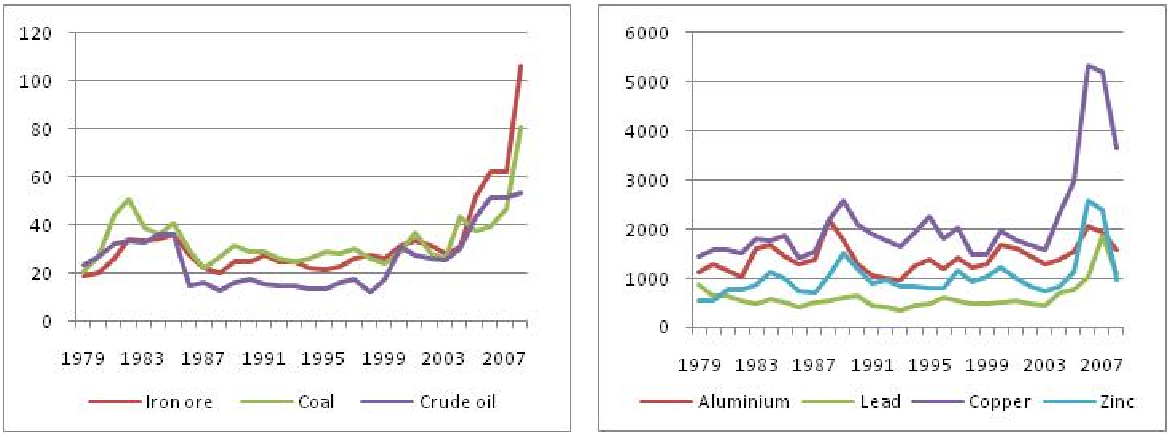
The rapidly increasing demand for resources has lead to an unprecedented boost in resource prices, especially during the last five years. While countries with large raw material deposits use these revenues to finance their public expenditures, countries or regions with relative resource scarcity, are especially affected by this development. Consequently, in the future these countries will face increasing competition for resources, for which they will have to pay high (and likely still augmenting) prices. Figure 5 illustrates the price development of the main metals and fossil fuels for the past 30 years (quite recent development has not yet been taken into account). With increasing demand, and consequently extraction, more and more material with lower concentrations is extracted as increasing prices make this extraction profitable. This leads to higher process costs, higher energy consumption, and more transportation from remote areas and higher amounts of overburden. Furthermore, to extract and process the crude ore more and more machinery is required, causing even higher pressure on resources and leading to an increase in production costs.

Figure 4: Net-trade flows in relation to domestic extraction



Source: Giljum et al., 2008

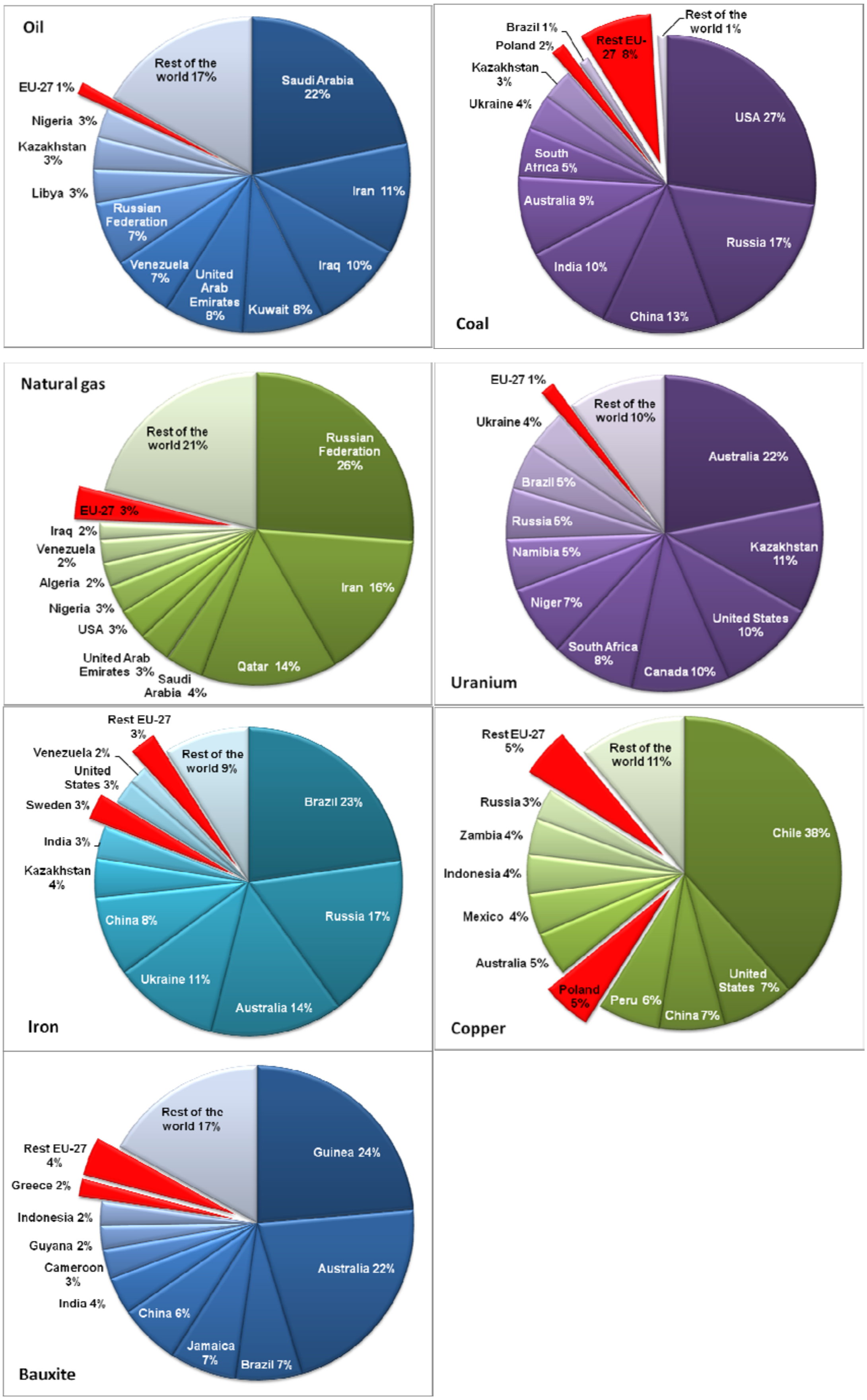
Figure 5: Commodity prices in €/t and €/barrel respectively



Note: Tin and nickel do not appear in these diagrams, as their current prices range around 11.000 €/t (tin), and 9.000€/t (nickel), respectively. While the first is steadily increasing, the latter almost tripled in the years 2003-2007 and is now again at the 2003-level. Source: HWWI Commodity Price Index.

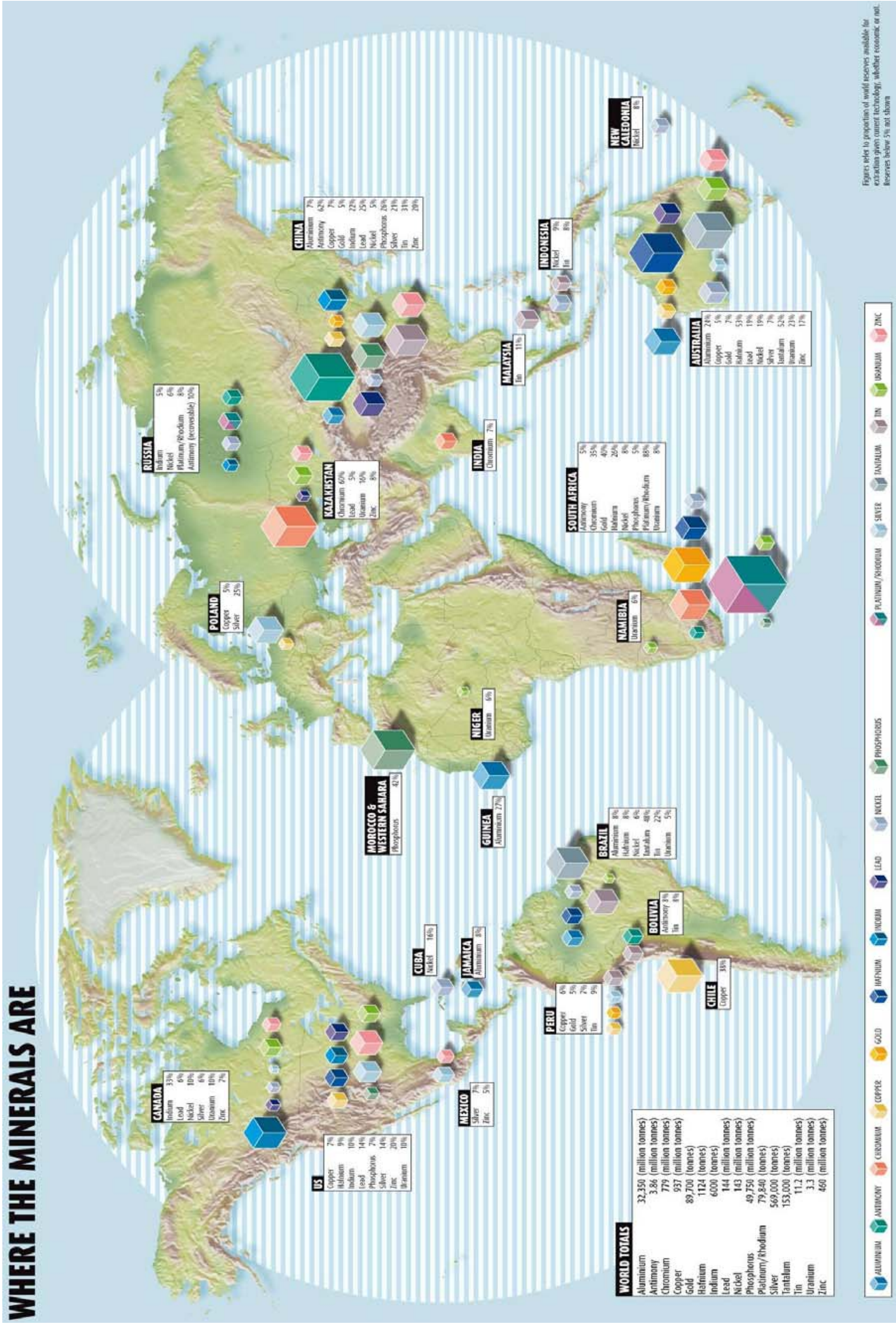
World reserves in fossil fuels and metals are unevenly distributed across the world regions. Precariously, especially countries with a highly developed economy, such as the EU or the USA, but also those with emerging economies, such as China or Brazil, which have a rapidly growing demand for resources, do not possess large domestic deposits. Figure illustrates exemplarily the worldwide distribution of the reserves of the main fossil fuels (oil, gas, coal), of uranium as well as of the three quantitatively most important metals (iron, bauxite, copper). Figure 7Figure 7 additionally reports selected precious metals as well as some minerals such as phosphorous. All such numbers however should be taken with care since high prices lead to new exploration activities and extraction activities in areas, which are known but have not been economical in previous years.

Figure 6: Worldwide distribution of reserves of the main energy carriers and metals



Sources: BP, 2006 and 2007; USGS, 2006 and 2008; NAE/IAEA, 2008

Figure 7: Worldwide distribution of reserves of selected minerals and precious metals



Source: Cohen (2007) in: New Scientist.

Only very small reserves of the main energy sources and metals are found in Europe. As Figures 4 and 5 show, Europe will rely heavily on imports from abroad in the future in order to ensure a stable access to fossil and nuclear energy as well as to metals. From this perspective, adhering to conventional energy sources like oil and gas or reviving nuclear energy would move Europe into even higher dependency of other countries with oftentimes precarious political and social circumstances.

Additionally, for various commodities, the peak of extraction has already been reached or is currently about to be reached, signifying a future decrease of extraction, and constricted availability respectively. However, data on commodity reserves and expiration dates diverge significantly. On the one hand, this is due to different assumptions and estimation methodologies; on the other hand, political and economic strategies often influence the results of such predictions. Table 1 shows an overview of prognoses concerning the anticipated peak and a possible depletion of different fuels and metals, and their main area of use. One may note however that "peak" usually refers to oil production and the supplies of minerals need to take into account criteria such as co-production, recycling, and substitutability.

Table 1: Predicted peak and depletion of different fuels and metals, and main area of usage

Commodity	Peak	Depletion	Main area of usage
Oil	2006-2026	2055-2100	Energy generation Chemical industry and pharmaceuticals Construction
Natural gas	2010-2025	2075	Energy generation
Coal	2100	2160-2210	Energy generation
Antimony	-	2020-2035	Metal alloys
Copper	-	2040-2070	Energy transport Piping Electronics
Gallium	may have passed	-	Electronics (mobile phones, solar cells)
Indium	-	2015-2020	Electronics (LCDs, solar cells)
Lead	Passed	2030	Automobile industry Chemical industry
Platinum	-	2020	Electronics (printer, etc) Industry (plug, catalyser, glass production) Medicine (pacemaker)
Silver	-	2020-2030	Electronics Pharmaceuticals
Tantalum	-	2025-2035	Electronics (mobile phone, automobiles) Pharmaceuticals Chemical industry
Uranium	-	2035-2045	Energy generation
Zinc	-	2030	Anticorrosives Energy storage (batteries)

Note that out of the variety of different results, the authors derived the time spans with the largest overlaps; the list of sources can be found in Annex 1. For some metals, no information about peak extraction could be found (marked with -).

Natural gas cannot replace oil as main energy source, once the latter is depleted. By now, "peak oil" is widely accepted as reality. Nonetheless, the assumption that worldwide huge gas reserves will help to overcome this shortage is critical, as it ignores various important aspects: first, a considerable share in the gas exploited today is associated with oil production – ceasing oil production, hence, leads to a decrease in produced gas.

Second, gas production is strongly limited by cost and time needed to build gas gathering, recovery, and transport infrastructures. Third but not least is, again, the dependency issue; apart from Russia – already at the edge of Peak Gas – the world's biggest remaining gas reserves are located in politically critical countries such as Iraq, Iran, UAE, Qatar, Turkmenistan, Nigeria and Venezuela. Generally, it is important to understand the interrelationship between oil, gas, and electricity; a change in the production of one will always affect the supply with the other (McKillop, 2006).

'Critical metals' will affect the European economy more subtle, but further-reaching. The European economy is an industrial and service-oriented economy, depending highly on different raw materials, to produce high-end processed products. As the examples in Table 1 show, an uncountable number of goods of daily use and application contain small, but critical amounts of certain metals, the depletion of which would cause the cessation of a whole sector, and considerable interventions in accustomed life styles of European citizens. Apart from the main energy sources, such as coal and gas, the handling of these materials will become decisive in the future, as their increasing scarcity will lead to an even more accentuated augmentation of their prices, and consequently the costs for producing processed goods downstream.

2.2. Patterns of resource use in different sectors of the EU

Quantifying resource use on a sectoral level requires observation regarding two different aspects: direct and indirect resource use. Direct use refers to the actual weight of the products, which are traded between different sectors and countries, and thus does not take into account the life-cycle dimension of production chains. Indirect flows, however, indicate all materials that have been required for manufacturing a final product (also called up-stream resource requirements). For instance, concerning the car production sector, the indirect flows comprise all the materials already used by providers of raw materials (steel, plastics), component suppliers, etc.

The flows of goods and transactions between economic activities, both within a national economy and with the rest of the world, can be illustrated in so-called input-output tables (IOTs). These tables are used for the investigation of economic structures of national economies and the analysis of the direct and indirect effects of changes in final demand, prices, and wages on the entire economy as well as its individual components.

Detailed analyses of sectoral resource use are only scarcely available for some EU countries and so far missing for the EU. So-called "physical input-output tables (or PIOTs)" are valuable tools to analyse direct resource use of different sectors in an economy. PIOTs describe the flow of materials from nature into the economy and back to nature through the economic activities of processing and consumption. Using mass units, the principle of the conservation of matter can be applied: resources cannot be created or destroyed in any physical process.

In the following, the results of three different studies are discussed, in order to illustrate similarities or differences in the resource use of different EU member states. No reliable physical input-output table is so far available for the European Union as a whole.

1. **Direct resource use: example Germany**: The German Federal Statistical Office (2005) elaborated a PIOT for Germany in the year 1995 with 99 types of materials and 60 different producing sectors. Not surprisingly, stones and construction, coal, chemical products, metals and semi-finished metal products, glass, ceramics and food have been identified as the most material-intensive material groups.

Note that the 'Residuals'-section includes water use. However, also without accounting for the water usage during production, these groups (in slightly changed order) would be among the most resource-intensive sectors.

2. **Direct resource use: example Finland**: Several studies (Mäenpää, 2001, 2002, and 2008) exist, which elaborated and analysed a physical input-output table for Finland. Starting on a very high resolution - 190 industries and 1300 products, orientated at the monetary input-output tables available for Finland - several service industries were aggregated and the number of industries reduced to 151 due to lack of physical data. In his recent work, Mäenpää (2008) shows that in 2002 the most material intense (and hence less material productive) sector was "Mining and quarrying" with 124 kg/€, followed by "Forestry" (25 kg/€) and "Construction" (10 kg/€). Hence, in comparison with the German values, these results are far higher, indicating a more resource-intensive economy in Finland.

3. **Direct resource use: example Denmark**: Gravgård Pedersen (1999) created a PIOT for Denmark in the year 1990. Originally, the resolution of the Danish PIOTs was of about 117 industries and 2940 commodities. In order to simplify calculations, the 117 sectors were aggregated to 27 industries. The results showed that the greatest consumer of intermediate consumption materials was the construction industry with 58.7 million tonnes, followed by "mining and quarrying" (45.7 mill. tonnes), and "agriculture and horticulture" (25.5 mill. tonnes). No information was given regarding material intensities of the different sectors.

The comparison of the results of different countries is not as straightforward as it may seem. As stated before, and as demonstrated by means of the examples above, available PIOTs of specific countries often differ in terms of number of economic sectors and products. Moreover, due to the enormous amount of work associated with the compilation of PIOTs, PIOT publication periods vary significantly between different countries. Not surprisingly, sectors related to primary resource extraction (such as mining and agriculture) as well as sectors at the first stages of processing (metal industry, chemical industry) and the construction industry are the most resource intensive sectors regarding direct resource use. As regards to eco-innovation however downstream processes need to be considered as well.

Economic-environmental models and statistical analysis can quantify the indirect resource use on a sectoral level. As stated above, in addition to direct resource use, also the indirect resources necessary to produce products for final demand can be analysed. Thereby, interdependencies of different sectors are taken into account and consequently the total amount of resources required to produce final products is illustrated. These findings reflect economic activities and final demand for goods in monetary terms, which are extended by environmental data in order to calculate environmental pressures, such as material use, emissions, etc. Consequently, the material requirements along the whole production chain of a given final-demand product can be determined.

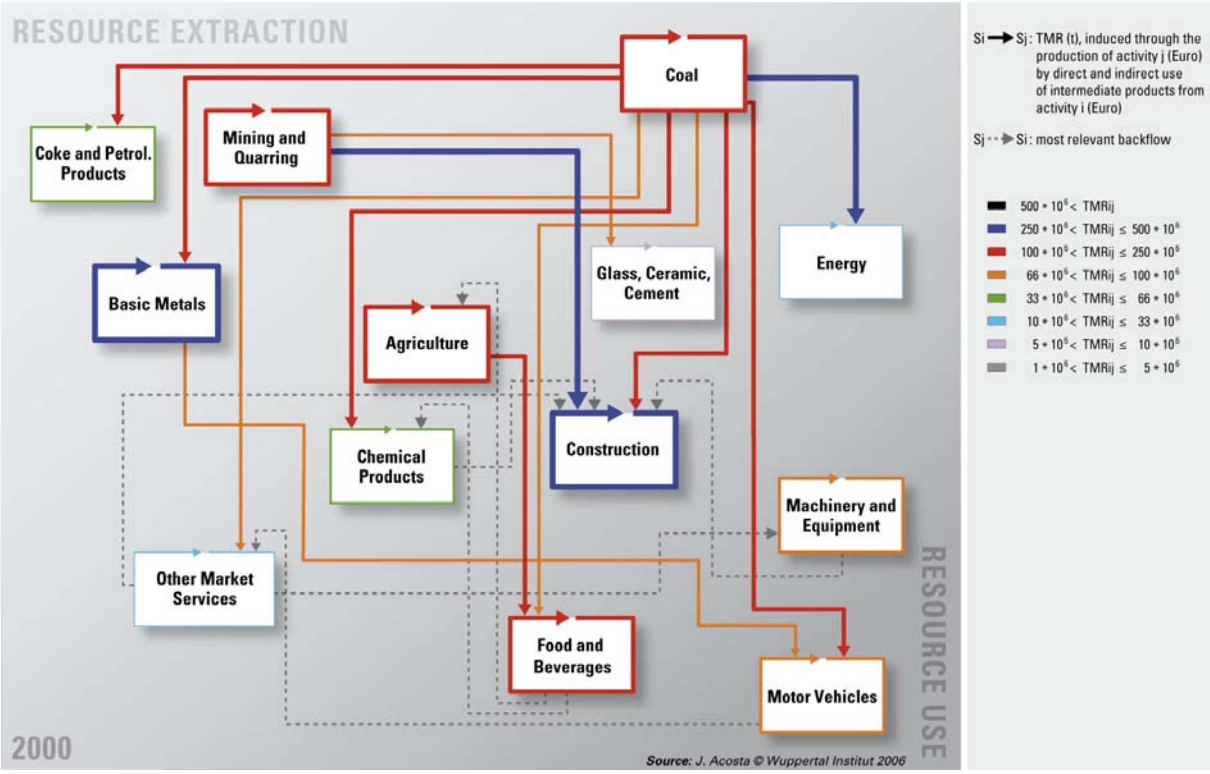
Direct plus indirect resource use: example Germany. The German Federal Statistical Office (2005) elaborated a model of 71 different economic sectors for 70 different products and analysed the development of the German abiotic resource use in the years 1995-2002. It was shown that direct resource use (domestic extraction plus net imports) decreased by 8.8 % in that time period. While the domestic use itself was reduced, another reason for the decrease was the fact that material exports increased to a higher degree than imports. Direct abiotic resource use in Germany decreased from 1448 million tonnes in 1995 to 1321 millions of tons in 2002. Based on the economic-environmental model, also the total use of abiotic products by sectors was calculated.

Research done at the Wuppertal Institute (Acosta et al. 2007) reveals that ten production sectors account for more than 50 % of German Total Material Requirements (TMR). Three areas are of strategic importance because here a huge number of technological interactions among production sectors take place:

- stones, construction, and housing (i.e.: construction)
- metals and car manufacturing (i.e.: mobility)
- agriculture, food and nutrition (i.e.: food).

The following figure illustrates the share, which each of the sectors directly and indirectly uses to produce the outputs.

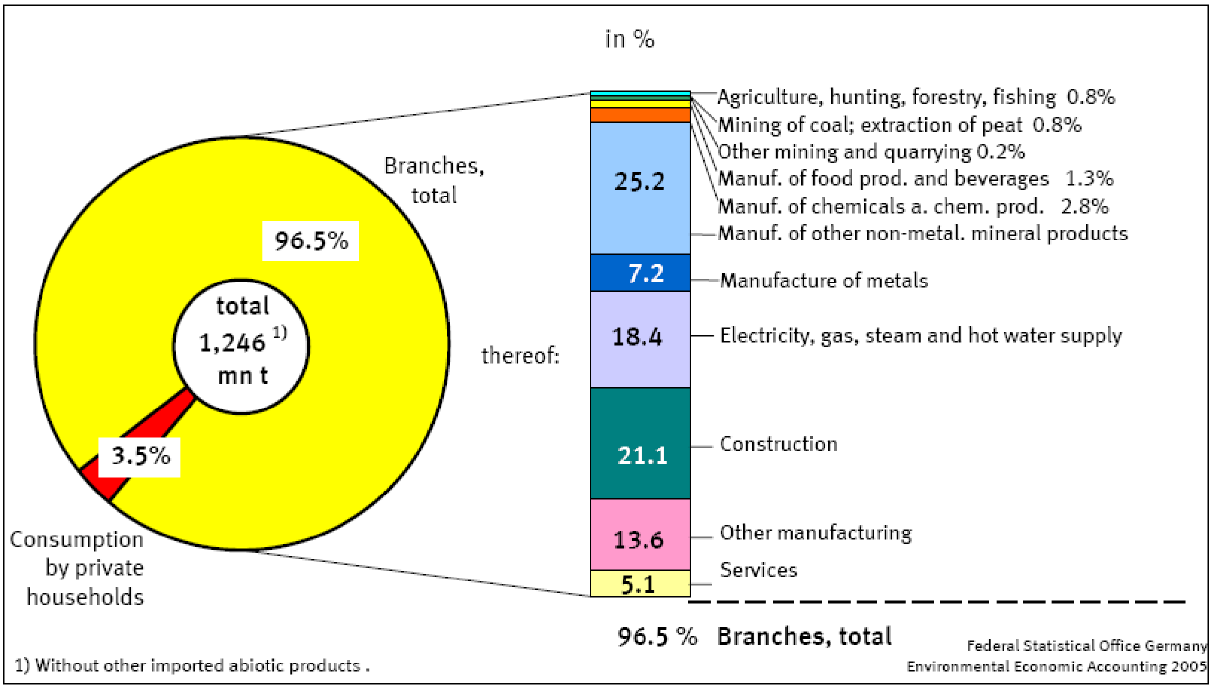
Figure 8: Direct and indirect resource use by economic activities in Germany in 2000



Source: Acosta et al. 2007.

The use of primary material in Germany is concentrated in just a few branches, which determine the overall level of resource use. Statistically, the share of the consumption of the private households is relatively small (only 3.5 %), whereas 96.5% of the abiotic resources are used in the production sectors. Compared with the analysis of direct resource use above, it can be noted that the resource extraction sectors have a much lower share, as they deliver almost all resources to other sectors, which further process primary materials. According to Destatis (2005) (Figure 9) "Manufacturing of other non-metallic products" leads the list of resource-intensive sectors with a share of 25.2%, followed by "Construction" (21.1%) and "Electricity, gas, steam and hot water supply" (18.4 %). Services, on the other hand, only use 5.1% of the total abiotic resources. According to Acosta et al. (2007), "construction" accounts for 18 %, "metals" for 9 %, "food" for 9 %, "energy for 8 %, "automotive" for 6 % of direct and indirect sectoral TMR in 2000.

Figure 9: Domestic use of abiotic primary material by economic activities in Germany in 2002



Source: Destatis, 2005

Absolute numbers of sectoral resource use and sectoral resource productivity are closely linked. In addition to the absolute numbers, the German Destatis study identified the most resource-intensive producing sectors: “Production of glass and ceramics, processing of stones and earth” with 21.5 kg/€, “Construction” (2.9 kg/€), “Production and distribution of energy” (7.6 kg/€), and “Metal production” (1.8 kg/€); which together account for around 70 % of the used materials. The strong concentration of primary materials use in a few sectors indicated that the macroeconomic development concerning absolute material consumption and resource productivity is highly marked by the development in these few sectors. One may note that other methodologies might lead to slightly differing results.

To sum up, the issue of resource scarcity deserves full political attention. In this regard, the areas of housing, mobility and food are of strategic relevance for eco-innovation.

2.3. Sectors affected by resource scarcity

Part one of this section focussed on resources, which are likely to become scarce in the short to middle term. It was shown that, apart from oil and gas – today the main energy sources worldwide – there exist various “critical materials” which are not used in big absolute quantities, but are crucial for important sectors as, for instance, electronics or chemistry and are likely to deplete in the short to medium run. From the analysis of the second part, specifying sectors with especially high resource use in absolute numbers, it can be deducted that the materials directly or indirectly used in large quantities are mainly construction materials and metals regarding abiotic resources and agricultural harvest for the food processing industries regarding biotic resources. In this final section, we present the conclusions, which can be drawn from the previous analysis.

Literature dealing with the impacts of resource scarcity on different economic sectors is hardly available. Studies dealing with reserves and the likely production peak of different resources are available as are studies analysing patterns of (direct and indirect) resource use on the sectoral level.

However, studies trying to quantify the vulnerability of different sectors due to expected resource scarcities in the future do not seem to exist yet and should be subject for further research. Available studies provide their analysis on a very general level; see for example an analysis done for the ITC industry (German EPA 2007). Therefore, also this study will only derive some tentative general conclusions.

Oil plays a crucial role for all sectors, both in its energetic and non-energetic use. "Peak oil" is expected within the next years and oil depletion will occur somewhere around the middle of this century. Further shortage of oil as the main energy source for many manufacturing sectors, the construction sector, and in particular also the transport sector, will cause negative economic impacts in the form of further rise of prices of final goods, if no alternatives are developed in time and transition towards a non-oil based economy can be governed in a structured way. Also other sectors, which use oil as a primary raw material for production, such as the chemical and the pharmaceutical sector, would be heavily affected by a further shortage of oil.

Further shrinking of the primary extraction sectors in Europe is likely but exceptions may be possible. The past 30 years saw a continuous shrinking of the European extraction sectors, in particular in the mining of fossil fuels and metal ores. As the reserves of these raw materials are mainly located outside Europe, it can be expected that these primary extraction sectors will further decline in the next decades and that Europe will face growing dependence on resource imports from other world regions. One may note however that, firstly, Scandinavian States and others have started to conduct feasibility studies on renewing extraction activities at certain sites and, secondly, the extractive sector in Europe is likely to remain strong in the area of industrial (non-metal) minerals.

High-tech industries, in particular the electronic industry, will be affected by declining availability of precious metals. Some particular industries, which have boomed in the past few years, such as the information and communication industry or the entertainment electronics industry are highly dependent on the availability of precious metals (such as Antimony, Indium or Tantalum) necessary for producing processors, screens or other electronic parts. It can be expected that worldwide competition for these resources will significantly increase in the near future, as several of these precious metals have already reached its extraction peak.

Also the development of new technologies, such as photovoltaic electricity generation, could be slowed down by resource scarcity. One example are solar cells, for which gallium and indium is yet required to produce indium gallium arsenide, the semiconducting material which is at the heart of a new generation of solar cells. A second case for a critical material might be platinum. Given the critical supply of some raw metals, more in-depth research on the nexus between materials and renewable energies is needed to clarify possible limitations.

2.4. Summary

While, on the one hand, Europe is one of the world regions with the highest per-capita resource consumption, on the other hand, the catching-up of other world regions and emerging economies, respectively, is leading to enormous rapidly growing demand on energy, metals, construction minerals, etc. Precariously, the reserves of the most important resources are located outside of Europe, causing a critical dependency relationship of Europe with other countries and regions.

So far, the world's economy has been strongly dependent on oil as main energy source and as important raw material for industrial sectors, such as the chemical and the pharmaceutical industry. Consequently, as peak oil is expected for the very near future, a further shortage will cause negative economic impacts in the form of further rise of prices of final goods, if no alternatives are developed in time and transition towards a non-oil based economy can be governed in a structured way. Additionally, the expected decline in the availability of precious metals will strongly influence high-tech industries. It can be expected that worldwide competition for these resources will significantly increase in the near future, potentially leading to serious conflicts related to the access to resource reserves.

Hence, in order to deal with this increased scarcity of natural resources, a significant reduction of the worldwide resource use will be necessary.

3. ECO-INNOVATION: CURRENT STATUS AND OPPORTUNITIES

3.1. Definition and Scope

A demand for eco-innovation has arisen because of the need to address today’s pressing environmental challenges. A comprehensive definition of eco-innovation was recently given by Reid and Miedzinski (2008) in the ‚Sectoral Innovation Watch in Europe: Eco-Innovation’ report, and this definition will also be used for the purpose of this report. The definition states that eco-innovation is “the creation of novel and competitively priced goods, processes, systems, services, and procedures designed to satisfy human needs and provide a better quality of life for everyone with a whole-life-cycle minimal use of natural resources (materials including energy and surface area) per unit output, and a minimal release of toxic substances”.

Important to note is that eco-innovation is not simply an end of the pipeline ‚curative’ technology. Eco-innovation can be considered at any stage of a product or service lifecycle. However, when considering the impact eco-innovation can have on resource or energy efficiency, the most gains are to be made when tackling the "upstream" or production part of the supply chain, for example, improving the efficiency of manufacturing and using materials.

It is nevertheless important to emphasise that eco-innovations, which reduce energy and resource consumption at any stage of the life-cycle are important, and applying a holistic and multifaceted approach to furthering eco-innovation is necessary. This means not simply focusing on technological innovations but also on the ‚human’ element of eco-innovation such as those innovations involving behavioural and lifestyle change.

3.1.1. Different types and levels of Eco-Innovation

The different types of eco-innovations can generally be grouped into three main categories; *process, product* and *system* innovations.

Process Innovations: a process innovation is the implementation of a new or significantly improved production or delivery method. Production-integrated environmental management (PIUS) captures manifold approaches of process innovation. ‘Organisational’ innovation (which can also fall into the category of process innovation) can describe the implementation of a new organisational method in the firm’s business practices, workplace organisation or external relations. Such innovation is closely linked to learning and education (see Bleischwitz 2003; Davenport, Bruce, 2002; Easterby-Smith, Araujo, Burgoyne 1999; Lane, Bachmann 2002). An organisation’s innovativeness and advanced learning processes are widely based on identical elements. A final aspect of process innovation includes ‚marketing’ innovations (product design, packaging, product placement, promotion) such as eco-labelling. Key words in this area include cleaner production, zero emissions, zero waste, and material efficiency.

Product Innovations: product eco-innovations include any novel and significantly improved product or service, produced in a way that means its overall impact on the environment is minimised. This, however, usually implies risks for the company since customers need to be convinced to purchase the new product. Adding services to selling a product also can be categorised here. Keywords in this area include the concepts of eco-design (Brezet, van Hemel 1997), technological sustainability innovations, environmental technology, and the dematerialisation of products.

System innovations: this type of innovation does not only refer to technological systems, but also to radical and disruptive technologies that alter the market conditions (such as hydrogen and fuel cells) as well as all types of system changes such as industrial, societal or behavioural changes. Key words in this area include the concepts of life-cycle analysis, cradle-to-cradle, material flow analysis, integrated environmental assessment, integrated sustainability assessment, closed-loop-material-cycles, decoupling, factor 4 and factor ten, sustainable production and consumption, eco-sufficiency and immaterialisation, user-oriented systems and sustainable lifestyles.

3.1.2. Measuring eco-innovation and material flows

There is currently little research into methodological approaches to measuring eco-innovation. A number of methods for measuring eco-innovation such as survey analysis, patent analysis and digital and documentary source analysis, are highlighted by Kemp and Pearson (2008). There has also been some reference to adapting innovation systems theory and indicators to the measurement of eco-innovation (Foxton, Pearson and Spears, 2008). However, the former study confirms that the general knowledge base for eco-innovation is poor. Reid and Miedzinski (2008) argue that the primary objective of eco-innovation should be to reduce material flows. There are a number of approaches to deal with analysing material flows, resource productivity and decoupling (highlighted in box 1). Excessive man-made material flows increase welfare, but also have detrimental effects on the environment. Therefore eco-innovation should be concerned with reducing these material flows and furthering sustainability objectives (Reid & Miedzinski, 2008).

Box 1: Decoupling Indicators

Since it is impossible to manage a system without metrics, appropriate decoupling indicators with proper accounting for resources must be used. The OECD (2008) has now released a handbook on material flows and resource productivity. This includes an overview of the main material flow indicators grouped according to the purpose of their description. The main categories include: ‚input indicators’ such as Domestic Extraction Used (DEU), Direct Material Input (DMI) and Total Material Requirement (TMR); ‚consumption indicators’ for example, Domestic Material Consumption (DMC) and Total Material Consumption (TMR); ‚balance indicators’ including Net Addition to Stock (NAS) and Physical Trade Balance (PTB); ‚output indicators’ which are Domestic Processed Output (DPO) and Total Domestic Output (TDO); finally efficiency indicators which refer to GDP per DMI, GDP per DMC and GDP per TMR. As to the ecological dimensions of sustainability, calculations of material input – from cradle to cradle - per unit of service (MIPS), and ecological rucksack measurements have also been developed.

Source: OECD 2008

3.1.3. Eco-innovation and resource-efficiency

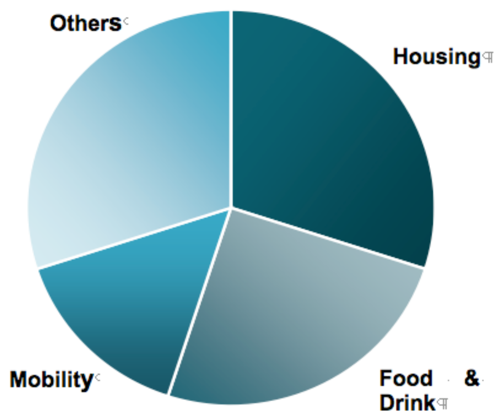
Resource-efficiency can be considered a key strategy of eco-efficiency because of its huge potentials for cost savings and innovation. German Federal Statistical Agency estimates that roughly 40 % of Gross Production Costs in manufacturing industry stems from purchasing materials. Surprisingly however, little research has been done on the potential resource savings through eco-innovations.

According to a study by the consultancy Arthur D'Little, The Wuppertal Institute and the Fraunhofer ISI (2005), there is a robust potential for resource efficiency in branches such as manufacturing of metal products, of systems for electricity generation/distribution and similar, chemical industry (excluding primary industry), manufacturing of synthetic goods, and construction industry.

This is estimated in the order of 10 – 20 % of current material use, amounting to total between 5.3 and 11.1 billion Euro per year in Germany alone. Eco innovation opens up a new field of innovation activities, and there are huge opportunities available, not just in terms of saving on material costs but also by finding alternative options for scarce resources.

3.2. Examples of eco-innovations in key areas

Figure 10: The three areas with the highest environmental impact



*Source: EIPRO Study 2006, NAMEA Study 2006, WI 1998

The areas of housing, mobility, and food and drink have been identified by the European Commission and the EEA as having the highest environmental impact throughout their full life cycle (EIPRO Study 2006, forthcoming NAMEA Study, see also chapter 2). This means that altogether, these fields of demand account for approximately 70-80% of environmental impacts arising from all products over their life cycles. The environmental impacts within these areas are multifaceted, ranging from planetary problems as divergent as global warming, acidification, and photochemical ozone formation, to localised pollution leading to eutrophication or species loss (EEA, CSCP, 2008). The figure illustrates the relative proportion of environmental impact from each of the three impact areas and these areas are discussed in more detail below. Furthering eco-innovation in each of the three areas is of particular interest, since eco-innovation has great potential to help reduce the use of resources and lower environmental impacts.

Housing: refers to environmental impacts from aspects relating to extraction and production of aggregates and construction materials, use of chemicals, maintenance services, finance services, design of buildings, use of renewable energy sources, energy efficiency in buildings (public and commercial as well private), household appliances, water use, construction, reuse of demolition and household waste, etc.

Food and Drink: refers to environmental impacts from aspects relating to agricultural production, food processing, use of chemicals, energy use, packaging, logistics, retailers, consumer choices, waste, food services such catering and restaurants, etc.

Mobility: refers to environmental impacts from aspects relating to extraction and production of metals and other materials, public and private transportation, freight transportation, railway service, aviation, disposal of vehicles, alternative vehicles and fuels, resource use and emission etc.