Green Industry

for a Low-Carbon Future

Resource Use and Resource Efficiency in Asia

A pilot study on trends over the past 25 years

Sustainable Europe Research Institute (SERI)
Vienna, Austria

Stefan Giljum, Stephan Lutter, Christine Polzin

Wuppertal Institute for Climate, Environment, Energy
Wuppertal, Germany

Monika Dittrich, Stefan Bringezu

Resource use and resource efficiency in Asia

A pilot study on trends over the past 25 years

Commissioned by UNIDO under the "Green Industry" Programme

Final version

26.4.2010

Executive summary

UNIDO has recently started a programme on “Green Industry for a Low-Carbon Future” in order to support green industrial growth in the developing world. In September 2009, ministers from 22 Asian countries adopted the “Manila Declaration on Green Industry in Asia”, expressing their support to implement policies, regulatory and institutional frameworks conducive of making industries more resource-efficient and less carbon intensive. Monitoring the implementation of such programmes requires robust data and indicators, which can be used in cross-country comparisons or in-depth country reports.

This pilot study provides the first comparative and quantitative assessment of resource consumption and resource efficiency in Asia. It illustrates the potential of resource flow-based data and indicators by presenting and analysing a large number of indicators on resource consumption and resource efficiency (in this report illustrated in terms of material consumption and material productivity) as well as on the links between resource consumption and energy-related CO_2 emissions. For the first time, this study addresses questions such as: How has resource consumption in Asia developed over time? To what extent are Asian economies dependent on imports of different types of resources to maintain national production and consumption? How has the resource efficiency of different Asian economies developed over the past 20 years? Are energy-related CO_2 emissions closely linked with material consumption in Asian countries?

19 Asian countries were selected for the analysis, together representing more than 90% of GDP in Asia. The 19 countries cover all types of development profiles: industrialised countries, such as Japan; small commodity exporting countries, such as Bahrain and Qatar; big and fast-growing economies that are experiencing a rapid industrialisation, such as China, India and Indonesia; and developing countries, such as Bangladesh, Sri Lanka and Pakistan.

The study is based on the methodological framework of material flow accounting and analysis (MFA), as established by the OECD and EUROSTAT. All indicators are calculated based on available international statistics, such as the UN Statistics Division or the International Energy Agency (IEA). Calculations were performed for the years 1985, 1995 and 2005.

Asia is not only the growth centre of the world economy in terms of monetary production and consumption, it is also the world region with the highest growth rates in material and energy consumption. On the aggregated level, current patterns and trends of resource consumption in Asia are clearly not environmentally sustainable. With almost 100% between 1985 and 2005, growth in resource extraction in Asia was much faster than global average growth, increasing Asia’s share in global resource extraction from 22% in 1985 to 31% in 2005. The group of 19 Asian countries thus today extracts around one third of the natural resources consumed in the world economy. Asia is also a huge and rapidly growing net-importer of natural resources from other world regions. The imports of the 19 countries nearly tripled between 1985 and 2005 up to 3.3 billion tonnes. Fossil fuels are the main import product group, followed by metal ores, to the largest extent imported by China. Asian exports grew even stronger than imports, although on a smaller absolute level.

With a difference of a factor 40 between countries with the highest and lowest per capita resource consumption, high inequalities in material consumption are found within Asia. While a Bangladeshi consumes only around 1.2 tonnes per year, which hardly suffices for the fulfilment of even the basic needs, resource consumption is as high as 45 tonnes per year in small and rich oil-exporting countries, such as Bahrain. Distribution issues thus need to be addressed in the design of resource use policies in Asia. The populous countries China and Indonesia started with low per capita consumption levels around 3 tonnes in 1985 and doubled them to around 6.5 tonnes in 2005. In many medium and high-income Asian countries (Rep. of Korea, Japan, Israel or Saudi Arabia), per capita consumption is around 15 tonnes per year, only slightly lower than the current OECD average.

On an aggregated level, resource efficiency has not significantly improved in Asia over the past 25 years. While GDP in the 19 countries increased by 114% between 1985 and 2005, resource consumption grew by 101%. Thus the majority of Asian countries is currently in a situation in which economic development is very closely linked with increased resource consumption. In many countries, per capita resource consumption is even increasing faster than GDP per capita, thus not even relative de-coupling between growth and resource use is taking place. Political efforts to increase resource efficiency therefore need to be intensified, in order to make future economic growth in Asia "greener" and achieve de-coupling.

Huge differences can also be observed regarding resource efficiency of different Asian countries. With 2,400 US$ of value generated per tonne of resource consumption, the Japanese economy was by far the most resource efficient of all investigated Asian countries. Japan thus was almost a factor 20 more resource efficient than the country with the lowest resource efficiency, Indonesia (with only 140 US$ per tonne). The big emerging economies China and India are among the countries with the lowest resource efficiency, with 250 US$ and 200 US$ per tonne, respectively.

Material consumption and energy-related CO_2 emissions are strongly correlated, despite very different levels of GDP per capita. In some countries, such as China and the Rep. of Korea, a linearly proportional increase in CO_2 emissions per capita can be observed with growing resource consumption per capita. Resource extracting economies (such as Indonesia or Malaysia) increased their resource consumption faster than CO_2 emissions, while countries with larger service sectors (such as IT sectors in the case of India) increased energy consumption (and thus related CO_2 emissions) faster than material consumption.

Asian countries need to alter current development trends and help avoiding a situation of severe global resource scarcities and (potentially armed) conflicts about the access to limited natural resources. Today's global responsibility for reducing resource consumption primarily lies with industrialised countries with high per capita consumption levels. However, extrapolating a level of per capita consumption as currently observed in Japan or Europe (around 15 tonnes per person) to the population of around 3.5 billion in the 19 Asian countries, resource consumption would reach nearly 52 billion tonnes a year. This would almost equal the level of today's world-wide used annual resource extraction and would imply serious environmental, social and economic challenges.

Increasing resource efficiency, erasing poverty in the developing countries and reducing resource consumption in the high-consuming countries should be the policy priorities in different groups of Asian countries in a joint policy agenda towards "Green Industries". For countries with high and medium levels of resource consumption, targeted policies to drastically increase resource efficiency need to be implemented, clearly targeted at limiting (or for some countries reducing) absolute amounts of resource use. For the dynamic emerging economies, priorities are resource efficiency in building up their infrastructure, i.e. fostering energy and material efficiency in buildings, transport systems, etc. and improving efficiency in their basic industries, such as metals, chemicals and pulp/paper. Poor, developing countries with very low consumption levels will require support of other (Asian as well as non-Asian) countries to increase material affluence to a humane level and erase poverty. This group of countries may particularly benefit from the transfer of green technologies from abroad in order to achieve these objectives with locally appropriate solutions for the highest possible resource productivity.

Table of contents

1 Introduction

Natural resources, including materials, energy, water and fertile land, are the basis for human life on Earth. However, humanity's rapidly growing consumption of these resources is causing severe damage. Our climate is changing; fresh water reserves, fish stocks and forests are shrinking; fertile land is being destroyed and species are becoming extinct. In order to continue to thrive on this planet, our lifestyles will need to become more sustainable, so that we are able to protect our natural resource base and the fragile ecosystems of our planet.

Current trends in global consumption of natural resources are not only environmentally unsustainable. They are also socially unjust. Industrialised countries have levels of per capita resource consumption up to 10 times higher than those in the poorest countries of the world (SERI et al., 2009). Therefore, these countries hold a particular global responsibility and are required to change their patterns of economic activity so as to decrease their resource use in absolute terms. Sustaining high levels of economic growth in a business-as-usual manner is not an option, as humanity already today appropriates more resources than the planet can provide in a sustainable manner (WWF et al., 2008).

Less developed countries, on the other hand, will need further economic growth in the future, in order to satisfy demand for higher material welfare. However, in light of increasing resource scarcities, intensifying international competition over these resources and growing environmental problems related to their use, these countries need to follow patterns of economic growth that are significantly more resource efficient than those pursued those countries that industrialized earlier.

Increasing the resource efficiency of production will also be a key determinant for economic competitiveness in a world of rising prices for raw materials and energy. The financial and economic crises of 2008/2009 decreased industrial demand for resources, and as a result commodity prices temporarily dropped, in particular for metal ores, but also for fossil energy. However, with economic growth regaining pace, in particular in Asia, prices have already risen in the past months and are expected to further increase during 2010 (AIECE, 2009).

With its high share in total world population and with high economic growth rates over the past 10 years, the Asian region will be of particular importance for global sustainability in the future. In terms of energy and material use as well as greenhouse gas emissions, development patterns in Asia in the next decades will strongly affect the overall world-wide trends.

UNIDO has recently started a programme on "Green Industry for a Low-Carbon Future" in order to support green industrial growth in the developing world. On September 9, 2009, 22 ministers from Asian countries adopted the "Manila Declaration on Green Industry in Asia", the major outcome of the UNIDO/UNEP conference on "Green Industry in Asia". With this document, the government representatives expressed their support to implement policies, regulatory and institutional frameworks conducive to making industries more resource-efficient and less carbon intensive, to intensify regional and international cooperation in the adoption of strategies for "green growth" and the development of cleaner production and to promote related research and development programmes.

Over the past 10 years, national statistical offices and agencies of the industrialised countries have increasingly been collecting and publishing data and indicators on resource consumption and resource efficiency. This is not the case yet in Asia. While the necessity to increase resource efficiency of Asian economies is fully acknowledged, for example in the Manila Declaration, an empirical basis for performing comparative assessments and evaluations of resource use and resource efficiency for these countries, as envisaged in the UNIDO follow-up programme of the Manila conference and declaration, is still missing.

The objective of this pilot study is to start this process, by further developing and integrating two large existing data bases, SERI's data base on global resource extraction and Wuppertal Institute's data base on global physical trade. Doing this allows a number of key questions regarding the challenges related to resource consumption and resource efficiency in Asia to be addressed:

- How much of the various types of resources do different Asian countries extract, trade and consume, in absolute and per capita numbers?
- How has resource consumption in Asia developed over time?
- To what extent are Asian economies dependent on imports of different types of resources to maintain levels and patterns of national production and consumption?
- What types of resources do Asian economies supply to world markets?
- How has the resource efficiency of different Asian economies developed over the past 20 years?
- What are possible reasons for why large differences in resource efficiency are observed between countries in the same world region (e.g. South-East Asia)?
- Are energy-related CO_2 emissions closely linked with material consumption in Asian countries?

This report contains the first publication of data and indicators that can serve as a basis to analyse and address important policy issues such as resource scarcity and resource security and the design of resource-efficient (industrial) development policies. As the applied methods are consistent with, and fulfil international standards of material flow accounting (OECD, 2007), the results presented allow comparisons between countries and provide the basis for developing policy targets of all Asian countries.

Both the innovative analysis and the indicators on resource consumption and resource efficiency in Asia will be of value for several target beneficiaries:

- For UNIDO and other international organisations, to monitor progress in the implementation of international resource efficiency programmes, such as the recently signed "Manila Declaration on Resource Efficiency in Asia". Both cross-country comparisons and more in-depth country reports can be produced based on the calculated indicators.
- For national policy makers and national development organisations in Asia, to evaluate national resource efficiency trends and monitor resource efficiency policies.
- For international research communities in the areas of sustainability assessments, cleaner production, industrial ecology and ecological economics, who can use the compilation of data on resource use and calculation of resource efficiency indicators for use in a large spectrum of policy-related applications.

In order to investigate the questions listed above, this pilot study presents comparative data for the following 19 Asian countries (note that the Arab states are not included in UNIDO's official definition of Asian countries): Bahrain, Bangladesh, China, India, Indonesia, Israel, Japan, Jordan, Malaysia, Oman, Pakistan, Philippines, Qatar, Rep. of Korea, Saudi Arabia, Singapore, Sri Lanka, Thailand and Turkey. These countries together represent more than 20% of world GDP and more than 90% of GDP in Asia (excluding Russia and other former countries of the Soviet Union).

This group of 19 Asian countries covers all types of development profiles: rich, industrialised countries, such as Japan; small and rich commodity exporting countries, such as Bahrain, Qatar and Oman; big and fast-growing emerging economies, such as China, India and Indonesia; and poor developing countries of different population sizes, including Pakistan, Sri Lanka and Bangladesh. The report illustrates huge difference in resource consumption and resource efficiency that can be observed across these groups of countries. Note that this study focuses on the national level and therefore disregards often high disparities within Asian countries.

Given the limited resources available for this pilot study, it was not possible to construct full time-series over the past decades. However, in order to analyse temporal trends, data has been compiled for three distinct years: 1985, 1995 and 2005.

This report is based on the methodology of "Material Flow Analysis (MFA)" (see section 2 for details). MFA is a young and dynamic research field and therefore some terms are not yet used consistently. In scientific communities it is common to use "efficiency" for technical aspects, concerning single products or sectors. With regard to the macro-economic level of countries the term "productivity" is more common. In international institutions the use is sometimes reverse. Also the terms "materials" and "resources" are often used differently. Standard MFA analysis focuses on materials with fossil fuels as an integrated part; therefore materials are the principal term, resources are used to refer to raw materials or in a broader sense to natural services. In other contexts, the term "resources" is often used in a more general approach meaning all materials and energy (sometimes also including water and land). In this study we apply the scientific terms when describing the methodology and the results (sections 2 and 3), but we follow the more general use of the terms common in international organisations in the policy-oriented parts of the report (executive summary and sections 1, 4 and 5).

This report has the following structure: section 2 will briefly summarise the methodology that was applied to compile the resource use and resource efficiency data as well as the main data sources used. Section 3 illustrates and analyses resource use and resource efficiency as well as the links between resource use and CO_2 emissions. Section 4 summarises the policy implications derived from the main results. Finally, section 5 provides an outlook on the potential of extending this study to cover the full time series and to cover other geographical regions.

2 Methodology and data sources

This pilot study is based on the methodological framework of material flow accounting and analysis (MFA). MFA builds on earlier concepts of material and energy balancing, as introduced already in the 1970s. The MFA concept was developed as a reaction to the fact that it is the overall scale of industrial metabolism rather than the toxicities of specific substances that determine many persistent environmental problems, such as high material and energy consumption and related negative environmental consequences (such as climate change).

Since the beginning of the 1990s, when first material flow accounts on the national level were presented (for example, in Japan, Environment Agency Japan, 1992), MFA has been a rapidly growing field of scientific and policy interest, and major efforts have been undertaken to harmonise the methodological approaches developed by different research teams. Today, the MFA methodology is internationally standardised and methodological handbooks are available, for example from the European Statistical Office (EUROSTAT, 2007) and the OECD (2007).

For MFAs on the national level, two main system boundaries for the accounting of material flows can be defined. The first is the boundary between the economy and the domestic natural environment from which raw materials are extracted. The second is the frontier to other economies with imports and exports as accounted flows.

In general, four major types of resources are considered in MFA studies. All types of resources are accounted in terms of their mass flow (weight in tonnes) per year. This pilot study will thus also present data at this level of aggregation. If products are composed of different types of materials (e.g. steel and wood), the product is allocated to the dominant material group according to a standardised allocation key (EUROSTAT 2007).

- Biomass (from agriculture, forestry, fishery, and hunting) and biomass products (including textiles and wood products such as paper);
- Fossil energy carriers (coal, oil, gas, peat), used for energetic and non-energetic purposes (including chemicals based on fossil materials);
- Minerals (industrial and construction minerals) and mineral products (such as glass or natural fertilizers);
- Metal ores and metal products (including, for example, machinery or coins).

Note that the extraction of metal ores is accounted as “gross ore”, i.e. total amounts of metal-containing ore and not only the net metal content. Large parts of “gross ore” extraction becomes mining waste during the processing and concentration of the metals. This waste often remains in the country where metal extraction takes place.

It is also worth noting that this study focuses on economically used resources. The study does not consider so-called “unused materials”, such as overburden from mining activities or unused residuals from agricultural harvest.

A large number of resource use indicators can be derived from economy-wide material flow accounts. These comprise indicators on material inputs, material outputs, material consumption and physical trade. In this pilot study, we will mainly use the following MFA-based indicators:

- Domestic extraction used (DEU), reflecting all raw materials extracted and further processed within the border of a country;
- Domestic Material Consumption (DMC), which is calculated as DEU plus imports minus exports;
- Physical Trade Balance (PTB), which is calculated as imports minus exports.

The compatibility of MFA with data from the System of National Accounts (SNA) enables direct relation of material flow indicators with indicators of economic performance, such as GDP. These interlinkage indicators quantify the eco-efficiency (or material productivity) of an economic system by calculating economic output (measured in monetary units) generated per material input (in physical units), for example GDP/DMC. Material productivity indicators are thus suitable tools to monitor processes of de-linking or de-coupling of material use from economic growth which contributes to lower resource consumption.

As mentioned earlier, the calculations illustrated in this pilot study build on the integration of two existing databases. The first is the global database on resource extraction developed and maintained by SERI, which is based on international statistics including the International Energy Agency, the Food and Agriculture Organisation of the UN (UN FAO) and the US and British Geological Surveys. This database is accessible in an aggregated form at the webpage www.materialflows.net, where a detailed technical report can also be downloaded (SERI, 2010). Data quality varies for the different types of materials. It is generally good for the extraction of fossil fuels and metal ores, although with the latter, estimations have to be applied in some cases regarding the concentration of metals in crude ore extraction. With respect to biomass, it can be assumed that part of the biomass extraction for subsistence purposes is not covered in official statistics, so biomass values are likely underestimated, particularly for the poor developing countries. As for mineral use, statistics are very poor in all investigated countries except Japan. Thus, a method was used to estimate extraction of construction minerals depending on the per capita income. Therefore, the exact amounts of mineral extraction may be over- or underestimated in some of the countries. A more detailed study would be needed to develop more accurate estimation methods.

The second database used in the study is the global database on resource trade developed at the Wuppertal Institute in Germany, which is based on UN Comtrade data and includes global accounts of imports and exports in physical (mass) units. A detailed methodological description is given by Dittrich (2010, in press). In general, UN Comtrade trade statistics are good and trade statistics of recent years are more differentiated and complete than older ones. The quality of Asian countries' trade statistics as a whole can be valued as moderate to good. Trade statistics of some countries are excellent (e.g. Japan) while others are quite poor (e.g. Bangladesh). An outstanding issue is petroleum trade in small oil-exporting countries. Data on this in UN Comtrade differ to a remarkable extent from other data sets, e.g. those provided by the IEA. This may be explained by storage of petroleum, specific dates of custom crossing or political security interest. Full time series would provide better information. In this study, disputable data for some small oil-exporting countries were replaced by more plausible data provided by IEA.

Integrating these two components allows national material consumption to be calculated, considering both the domestic extraction and use of resources as well as imported and exported resources. Based on these material consumption indicators, which include international trade, proper indicators on resource productivity can then be calculated. This was performed, for the first time ever, for selected Asian countries in the scope of this pilot study.

In order to link resource use issues to the dominant environmental policy issue of climate change, the correlations between material consumption and energy-related CO_2 emissions on the country level were also investigated. For energy-related CO_2 emissions, data from the International Energy Agency (IEA, 2009) was used.

3 Results

This section presents the main results of the calculations and is divided into sub-sections on material extraction, material trade, material consumption, resource productivity, and material use and CO_2 emissions.

3.1 Resource extraction

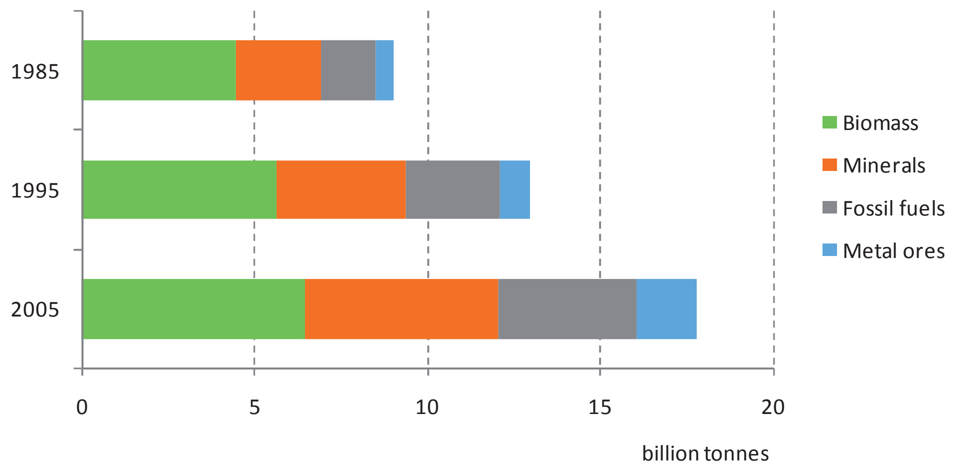
The extraction of natural resources in the 19 Asian countries investigated in this pilot study has doubled over the past 25 years (see Figure 1 below). Economically used resource extraction increased from 9 billion tonnes of resources in 1985 to 13 billion tonnes in 1995 and reached almost 18 billion tonnes in 2005. Growth in extraction in Asia has been much faster than the global average, as Table 1 illustrates. The share of the 19 Asian countries in global resource extraction has thus increased notably, from 22% in 1985 to 31% in 2005. The group of 19 Asian countries today extracts almost one third of the world's natural resources.

Table 1: Global and Asian used resource extraction (1985-2005)

	Global extraction, billion tonnes	Global extraction, 1985 = 100	Asian extraction (19 countries), billion tonnes	Asian extraction (19 countries), 1985 = 100	Share of 19 countries in global extraction
1985	40.9	100	9.0	100	22.1%
1995	46.7	114	13.0	144	27.8%
2005	57.5	140	17.8	197	31.0%

The composition of extracted resources changed considerably over the time period of the study (see Figure 1). While in 1985, renewable resources (biomass) accounted for almost half of all extraction, this share diminished to 36% in 2005, as extraction of non-renewable resources (minerals, fossil fuels, metal ores) increased at a much higher pace.

Figure 1: Resource extraction (used) in Asia (19 countries)



This growing share of non-renewable resources in the material basis of the Asian economies is one characteristic of the ongoing industrialisation processes, which has accelerated significantly in many Asian countries since the beginning of the 1990s. The average composition of material extraction in Asia is thus approaching patterns of material extraction in industrialised countries, such as Western Europe, where the share of biotic resources in total extraction is down at around 30% (Weisz et al., 2006).

Of the 18 billion tonnes extracted in 2005, 8 billion tonnes were extracted in China, which observed a growth in extraction of 155% between 1985 and 2005. Over this period, the highest growth rates in China are found in the categories of metal ores (+480%) and construction minerals (+450%), reflecting the growing demand of China to build its infrastructure (buildings, roads, railways, etc.) and to expand the metal industries, which are also increasingly served by imports (see the section on trade below). With a total of 167%, growth in extraction was even higher in Indonesia, particularly due to the dramatic expansion of the metal mining sector (+480% in 2005 compared to 1985). Almost 80% of Indonesia's metal mining is extraction of tin, a metal with an extremely low metal content in crude ore (0.02% in Indonesia). Thus, huge amounts of crude metal ore need to be extracted in order to produce concentrated tin, which is to a large extent exported. The highest growth in overall extraction of all 19 countries is observed for Qatar (+242%), due to the rapid expansion of the oil extraction activities. In line with patterns observed in other industrialised countries, such as Western Europe, resource extraction has remained on a high, but almost stable, level in Japan (+6%).

There are huge differences in numbers for per capita extraction. The oil-extracting countries by far lead the ranking of the biggest per capita resource extractors: Qatar, the country with the highest GDP/capita of all 19 countries, with almost 100 tonnes per capita, followed by Oman (34 tonnes/cap), Saudi Arabia (31 tonnes/cap) and Bahrain (28 tonnes/cap). Japan, Singapore, the Rep. of Korea and Israel are in the mid-range, between 9 and 11 tonnes per capita. China's per capita extraction is 6.2 tonnes, India's only 2.8 tonnes. The smallest number (1.1 tonnes) is observed for Bangladesh, also the country with the lowest GDP / capita (all numbers for the year 2005).

In summary, some overall patterns of resource extraction can be observed. Countries with large deposits of non-renewable resources suitable to be exported to world markets (particularly fossil fuels and metal ores) have significantly increased extraction, whether with high (such as Qatar) or low (such as Indonesia) GDP per capita. Emerging economies with large populations (such as China and India) show a particularly strong growth in demand for minerals to build up infrastructure. The price to weight ratio for minerals is generally low, so these minerals are almost exclusively extracted from the domestic territory. Poor countries, which have neither resource deposits nor built up large-scale domestic industries (such as the Philippines, Bangladesh and Sri Lanka), have only marginally expanded resource extraction. Stabilisation of domestic extraction is also the case for Japan as a developed country, although on a much higher per capita level.

3.2 Material trade

Asia's trade is the most dynamic in the world. While world trade volume, in physical terms, augmented by a factor of 2.4 between 1985 and 2005, trade volume of the 19 Asian countries, i.e. imports and exports to other Asian countries and the rest of the world, increased by a factor of almost 3.1, up to 5.44 billion tonnes in 2005 (see Table 2). The share of the 19 Asian countries in global trade volume has thus enlarged during the time period of the study, mainly at the expense of European countries, whose share has been declining (Dittrich, 2010, in press). Today, nearly 30% of all traded goods are imported or exported by the group of the 19 Asian countries.

Table 2: Global and Asian trade volume (1985-2005)

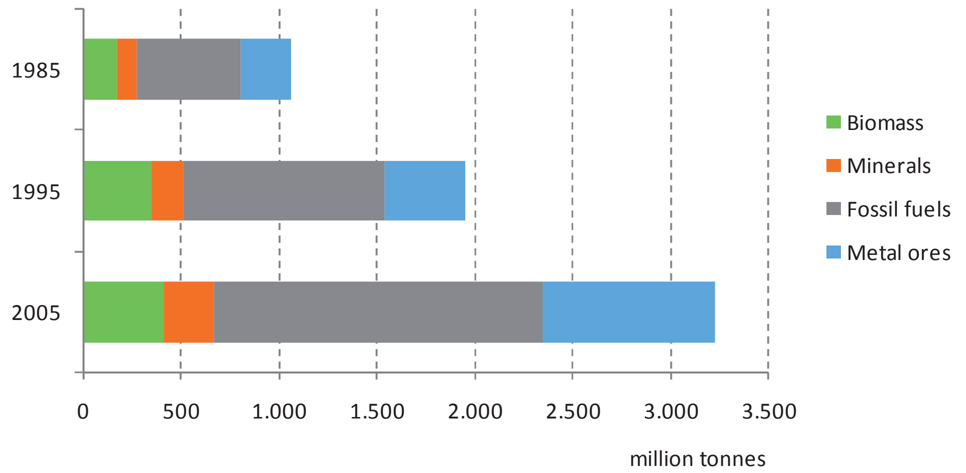
	Global trade volume, billion tonnes[1,2]	Global trade volume[1] 1985=100	Asian trade volume[1] (19 Countries), billion tonnes	Asian trade volume[1] 1985=100	Share of 19 Asian countries in global trade volume
1985	7.56	100	1.75	100	23.1%
1995	12.80	169	3.44	197	26.9%
2005	18.32	242	5.44	311	29.7%

[1] Trade volume = imports + exports; to maintain comparability, traded water is excluded; [2] Source: Dittrich, 2010, in press

The imports of the 19 countries nearly tripled between 1985 and 2005, up to 3.3 billion tonnes today (Figure 2). Analysing the material composition, imports of all material categories have increased significantly in absolute terms. Fossil fuels including oil as the predominant global trade product are also the main imports of the Asian countries, with an almost constant share of 51 to 52%. Imports of metal ores and products mainly produced out of metals increased above average during the period of the study (+250%). The high growth rates are caused mainly by Malaysia (+4,400%) and China (+969%) reflecting their growing demand for metal manufacturing industry and infrastructure. Japanese metal imports, on the other hand, are nearly constant, albeit on a high level. Imports of biomass and minerals other than metals increased "only" by a factor of 2.3 and 2.6, respectively.

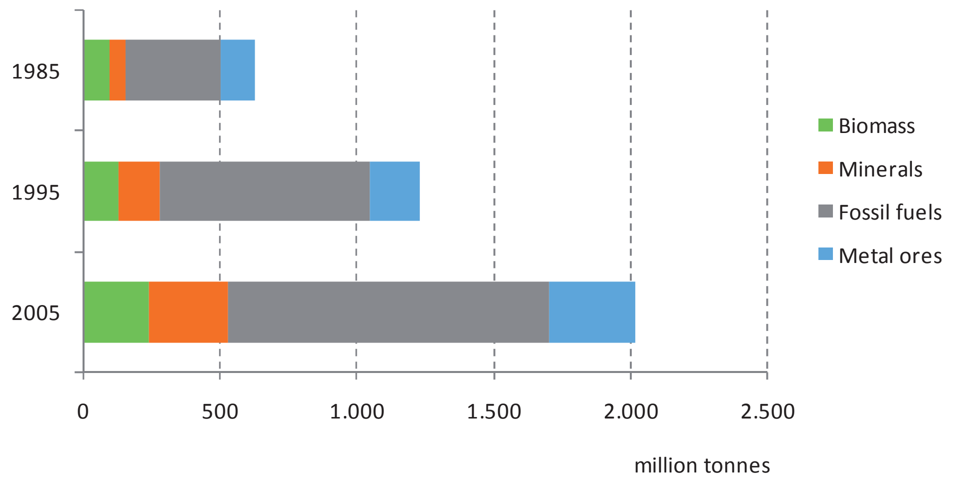
Above average growth rates in biomass-imports are found mainly in Thailand (+688%), Turkey (+591%), Indonesia (+441%) and China (+404%) reflecting population growth and changes in consumption patterns. In general, minerals are traded less because most of them are available in almost all countries (such as sand and gravel for construction purposes). In absolute terms, China is importing most minerals due to its high demand (55 million tonnes in 2005, +178% since 1985).

Figure 2: Material imports of Asia (19 countries)



Exports from the 19 Asian countries grew even more strongly during the period of the study, by a factor of 3.2 (see Figure 3).

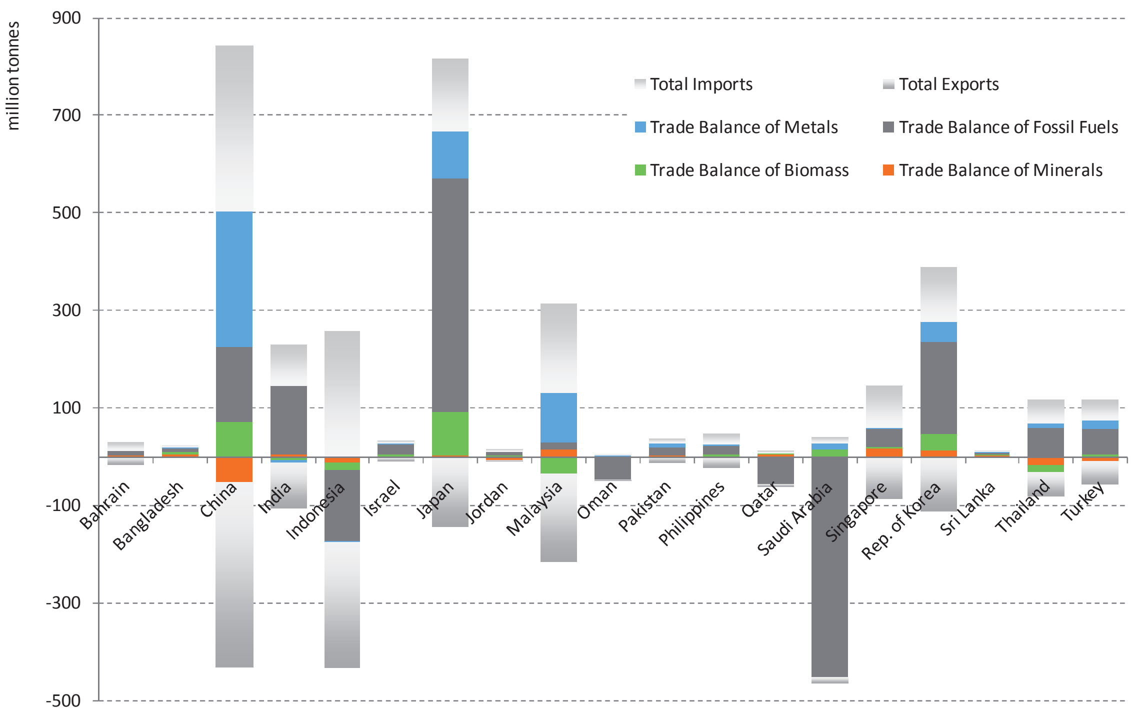
Figure 3: Material exports of Asia (19 countries)



Fossil fuels clearly dominate exports, with a share between 55% and 60%, showing the importance of these exports from the oil-exporting countries, in particular Saudi Arabia and Indonesia. Remarkable growth rates are found in mineral exports (+442%). China whose growth alone was +1,880%, accounted for more than two thirds of total mineral exports of the 19 countries in 2005. The bulk of Chinese mineral exports are sand and gravel as well as cement. Exports of metal ores and biomass grew in absolute terms, but "only" by a factor of 2.6 and 2.4, respectively. Concerning metal exports, a division can be clearly observed: on the one hand, extremely high growth rates of metal exports are found in Malaysia (+4,157%), China (+2,725%) and Thailand (+1,530%), reflecting mainly their growing exports of (semi) manufactured and finished metallic goods. On the other hand, some countries decreased their metal exports, in particular India (-24%) which nearly stopped its exports of (mostly iron) ores during the period and used the growing amounts of metal extraction for domestic production and consumption.

The physical trade balances of the 19 countries (Figure 4) show the net-redistribution of resources and allow identifying resource demanders and resource suppliers on the global level. Note that the physical trade balance is calculated as imports minus exports, in contrary to standard monetary trade balances. Positive values therefore mean net-imports of materials and negative values net-exports.

Figure 4: Total physical imports and physical exports and Physical Trade Balance by material category (2005)



Ever since the beginning of trade statistics in UNComtrade in 1962, Asia has belonged to the net resource importing regions mainly because of Japan. In fact, total Asia is the world's third largest resource demanding region following Europe and North America, while all other world regions are net resource suppliers. However, it is important to note that some of the most dominant global resource demanders *and* resource suppliers are located in Asia; in no other world region can this variety of resource use patterns be observed.

Some important supplying countries, especially Russia, Kazakhstan and Iran, are not included in this pilot study; therefore the group of 19 Asian countries investigated overstates the Asian role as resource demanding region. As a group, the 19 Asian countries' net imports were 1.2 billion tonnes in 2005 compared to around 1 billion tonnes for Europe and 1.2 billion tonnes for the United States (Dittrich, 2009, 2010, in press; Weisz et al., 2006).

Over the past decades, Japan has consistently been the biggest net-resource importer on the world market. It was only being outstripped by the United States at the millennium change. Japan net-imported 673 million tonnes of a large variety of raw materials and products in 2005 (see Figure 4). Its material trade profile shows the dominance of fossil fuels and related products followed by metals and metal products, which is typical for countries with important manufacturing and consumption sectors but with an absent, poor or already exploited resource base within their own territory. The Rep. of Korea and Thailand have very similar material trade profiles, with some differences in biomass and mineral trade. Despite China's immense exports of manufactured products, it is actually the third biggest resource demander world-wide, with 411 million imported tonnes in 2005. China's trade profile is clearly dominated by metals, especially caused by rapidly growing demand for its expanding industry, infrastructure and consumption. Malaysia's net-imports are also dominated by metals, reflecting Malaysia's important metal refining industries.

Saudi Arabia, Indonesia, Oman and Qatar as oil-exporting countries belong to the important global resource suppliers. Their trade profile is dominated by fossil fuels, although Indonesia's exports are more diverse than the others: it has remarkable net-exports of biomass (especially palm oil) and minerals (building stones).

3.3 Material consumption

The increasing extractions and net-imports of the 19 Asian countries have resulted in a doubling of their material input and consumption from 1985 to 2005. Figure 5 shows extractions, imports and exports at a glance as well as the material input (extraction plus imports) and material consumption (extraction plus imports minus exports) during the period. Together, the 19 Asian countries were consuming around 19 billion tonnes in 2005 (nearly one third of resources extracted globally).

Figure 5: Extraction, trade, material input and material consumption of the 19 Asian countries (1985-2005)

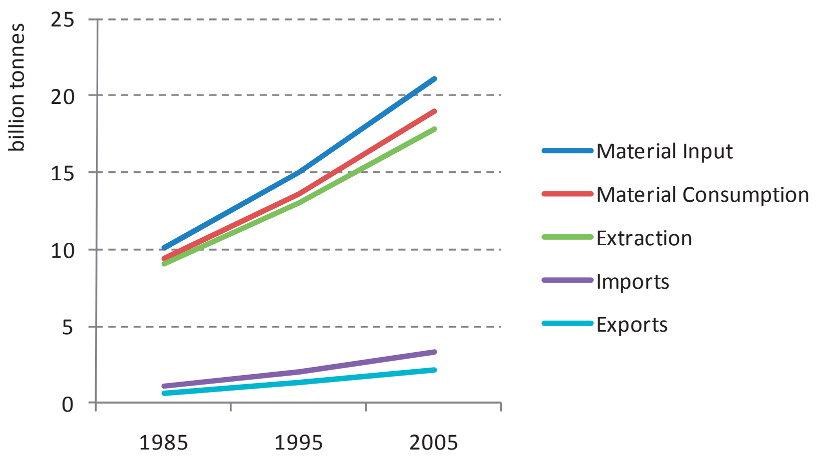


Figure 5 also illustrates Asia's increasing dependency on imports. Import dependency is usually measured by the share of imports in material consumption. Numbers of 100% or below show to what extent material is imported for consumption, a number above 100% indicates that imports are re-exported (in general, after further processing). On average, in 2005 around 17% of the 19 Asian countries' material consumption was imported (up from 11.4% in 1985), but huge differences can be observed between countries as well as concerning the material composition (see Table 3). While biotic materials and minerals are predominantly produced within the respective countries, the 19 Asian countries depend to a remarkable extent on imports of fossil fuels and metal ores. On average, more than one third of consumed fossil fuels and metal ores are of foreign origin. Note that these numbers are even higher for some industrialised regions, such as Europe: 62% for fossil fuels and 80% for metal ores (Weisz et al., 2006).

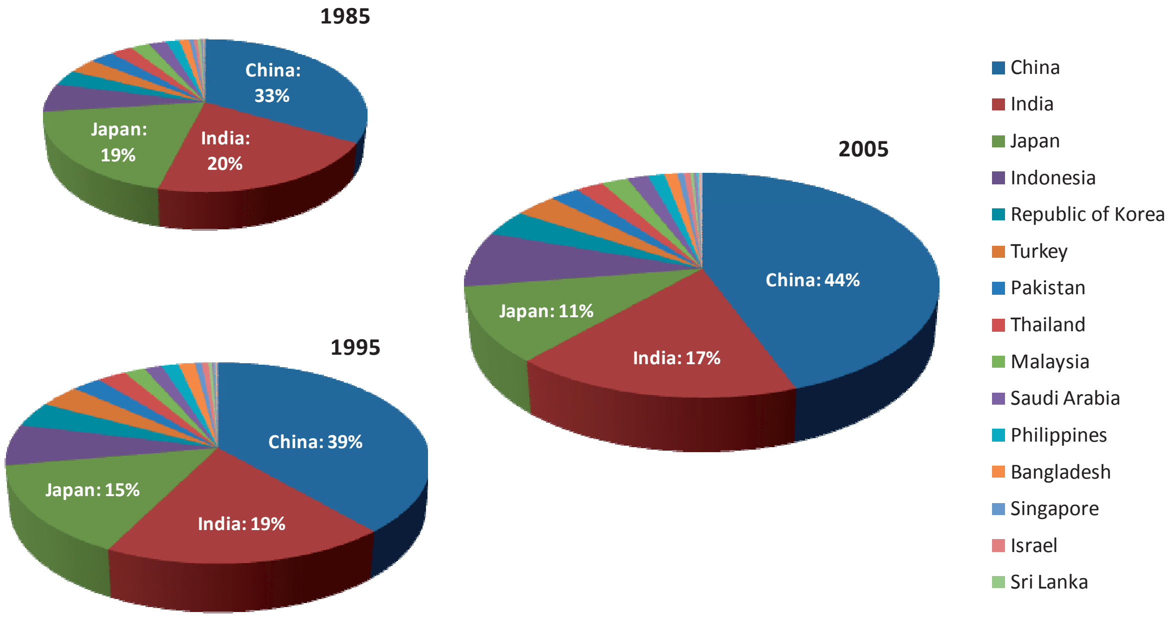
Import dependencies of countries with large domestic resource endowments are minor or negligible, e.g. imports of fossil fuels and oil-based products (e.g. plastics, chemicals) of oil-exporting countries are small. Concerning metal ores, only Indonesia and India can be described as being minor dependent. It is clearly visible that small countries and countries with less bio-productive land (such as Bahrain or Singapore) depend to a high degree on biomass imports in contrast to those countries with large areas of arable land and important agricultural sectors (such as India or Turkey).

The absolute amount of materials consumed varies among the countries as is shown in Figure 6. The populous countries of China, India and Indonesia, which together have consistently consumed more than half of all materials consumed by Asian countries, have furthermore increased their consumption above the average (+133%); they now consume more than 13 billion tonnes or two thirds of all 19 Asian countries. Japan increased its high material consumption only slightly (+15%; in 2005: 2 billion tonnes), but its share almost halved. The 'Tiger States' (Rep. of Korea, Singapore) and Israel increased their consumption by 96%; thus the Asian countries in the group of 19 that industrialised earlier together consume around 3.4 billion tonnes, or 18%, of the group. Highest growth rates of absolute material consumption are found in Bahrain (+352%), Malaysia (+265%) and Qatar (+207%) while poor countries increased their absolute material consumption but little: Bangladesh (+25%), the Philippines (+28%) or Sri Lanka (+27%).

Table 3: Import dependencies of Asian countries in 2005 (share of imports in DMC, in %)

	All materials	Biomass	Minerals	Fossil fuels	Metal ores
Bahrain	88.5	98.8	43.0	86.6	1327.3
Bangladesh	12.1	6.4	10.7	42.5	102.2
China	10.0	4.0	2.7	11.7	36.2
India	7.1	0.7	3.6	27.2	11.2
Indonesia	5.4	4.5	5.6	37.5	1.3
Israel	33.9	49.8	3.5	97.8	177.6
Japan	39.5	60.0	2.4	105.2	168.5
Jordan	50.4	51.4	6.0	99.0	124.6
Malaysia	79.1	34.2	30.8	93.5	149.3
Oman	13.4	31.3	4.8	6.9	140.7
Pakistan	8.7	2.7	4.3	40.9	104.0
Philippines	18.3	7.7	4.7	88.6	93.8
Qatar	40.6	73.3	64.9	1.6	112.6
Saudi Arabia	13.1	47.5	3.8	1.3	110.5
Singapore	147.6	242.0	31.8	297.2	474.9
Rep. of Korea	55.3	44.6	6.3	128.2	167.9
Sri Lanka	23.3	14.7	16.1	100.5	120.4
Thailand	28.0	8.2	5.4	70.9	128.2
Turkey	18.3	5.6	4.0	52.0	112.9
Asian average	**17.4**	**6.2**	**4.6**	**37.6**	**38.1**

Figure 6: Shares of countries in Asian material consumption (1985-2005)



Material consumption in Asia provides a very different picture when the focus is on per capita numbers (Figure 7). The average per capita consumption of the 19 Asian countries has increased, from 3.7 tonnes per capita in 1985 to 5.5 tonnes in 2005. This number is still far below the global average per capita consumption, which remained relatively stable over the same period at around 8.5 tonnes.

Extremely wide ranges between the countries and quite different dynamics can be observed. With a difference of a factor of 40 between the countries with the highest and lowest per capita material consumption, one can argue that the whole world-wide spectrum of material consumption profiles is represented in this group of 19 Asian countries.

In poor countries, per capita consumption is very low and in some cases has even been falling due to high population growth, e.g. in Bangladesh or the Philippines. A Bangladeshi consumes only 1.2 tonnes per year. Until now there is no absolute material subsistence level discussed or analysed, but Bangladesh's per capita amount can be described as far below any human material subsistence level that would be required to fulfil the basic human needs. Also very low, but slightly increasing, is per capita consumption in Sri Lanka, Pakistan and India (2.5 to 2.9 tonnes per person in 2005).

On the other side of the large spectrum are the small and rich oil-exporting countries Bahrain, Qatar and Oman as well as Singapore. Having already a high consumption level per capita in 1985, they further increased their consumption levels, Bahrain even up to 45 tonnes. The eye-catching deviation from a linear trend found especially within this country group in 1995 cannot be explained fully at this moment. Explanations may be found in storing or incomplete trade statistics especially concerning petroleum exports; complete time-series are needed to verify these trends.

Figure 7a: Material consumption per capita, upper part (1985-2005)

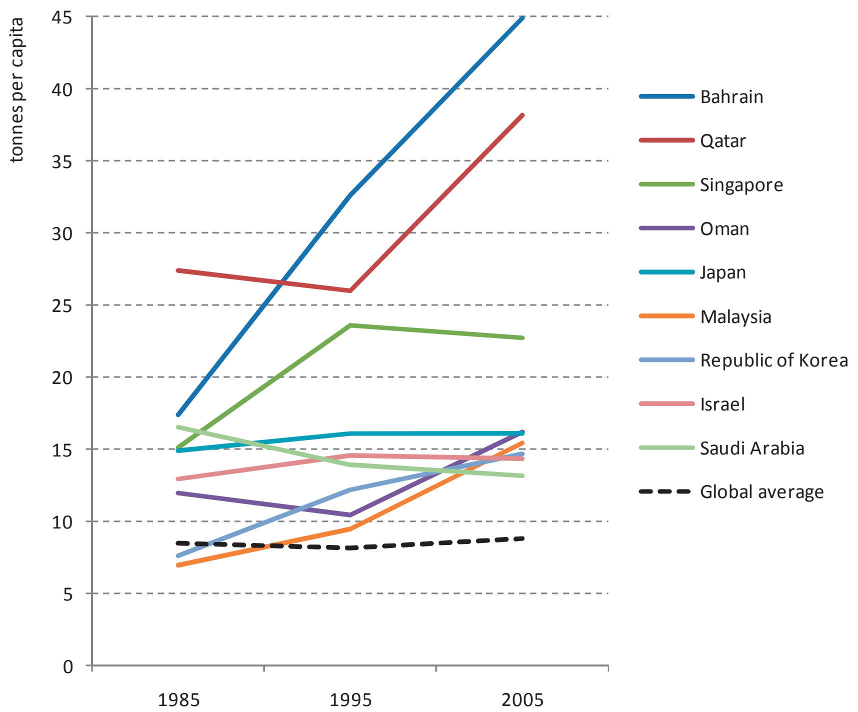
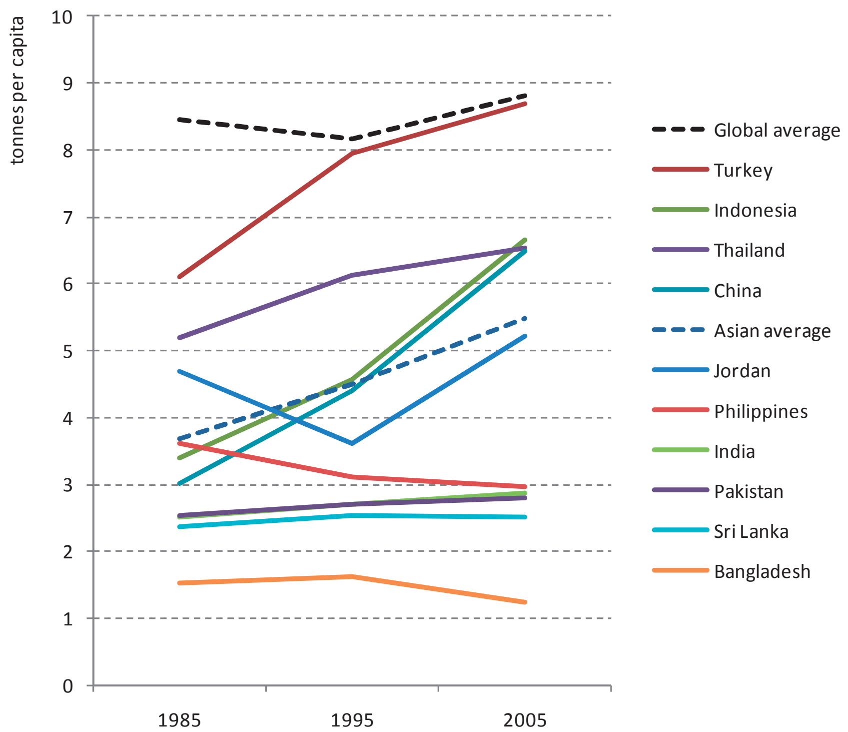


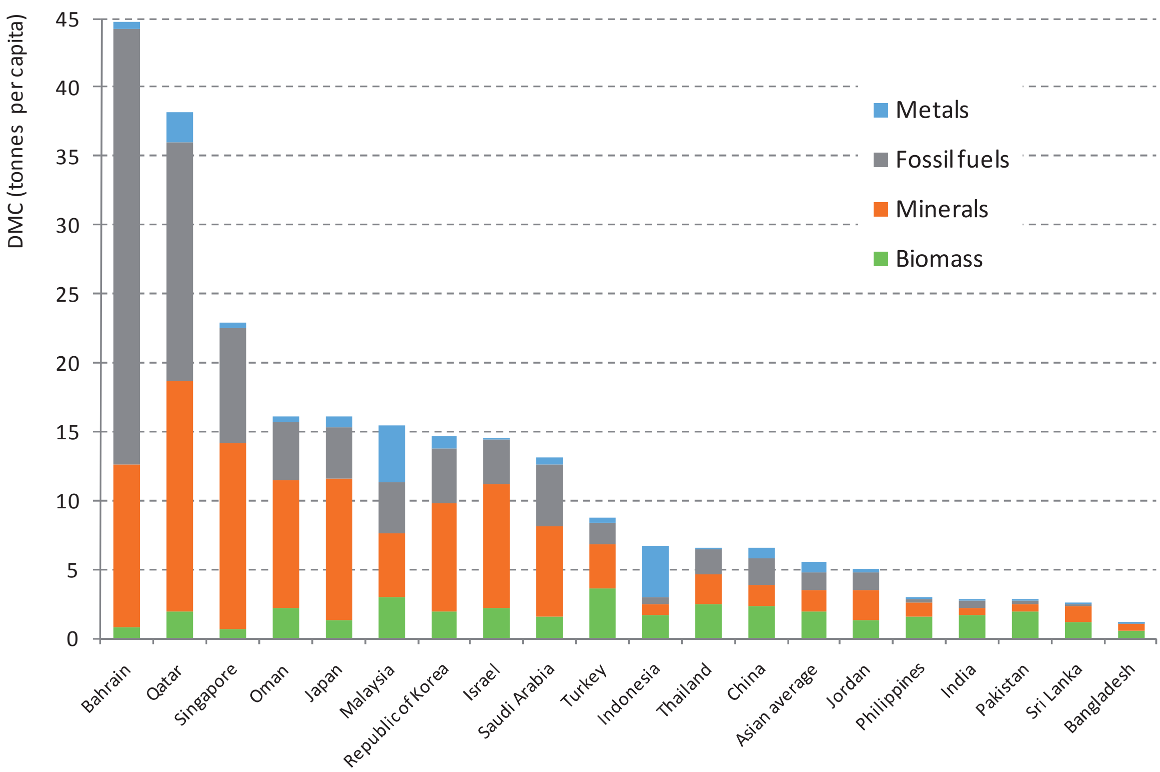
Figure 7b: Material consumption per capita, lower part (1985-2005)



The populous countries of China and Indonesia started with low per capita consumption levels of around 3 tonnes per person and doubled them between 1985 and 2005 up to 6.5 tonnes per capita. A similar dynamic can be seen in the less populous countries of Malaysia and the Rep. of Korea, which however started from higher consumption levels. On average, inhabitants of Malaysia and the Rep. of Korea consume similar amounts of materials as those in Japan, Israel or Saudi Arabia, where per capita consumption has remained almost constant or is declining. Average per capita consumption in these countries clusters around about 15 tonnes per capita. This nearly equals the per capita consumption of the majority of industrialised countries, which lies between 15 and 20 tonnes per person (OECD average was 18.9 tonnes in 2005, OECD, 2008).

Analysing the per capita consumption in terms of material composition, again some typical patterns can be observed: poor countries mostly consume biomass and non-metallic minerals, while the share of fossil fuels and metal ores in richer countries are high due to changing consumption patterns and growing industrial demand (Figure 8).

Figure 8: Material consumption (DMC) per capita (2005)



The very high consumption of fossil fuels in Bahrain and Qatar probably indicates a certain amount of dissipation and squandering. As explained in section 2 above, values of mineral extraction are estimated. Therefore, the exact amount of mineral consumption may be over- or underestimated in some countries, but the overall trends can be considered as correct: while in poor countries a significant number of buildings and – to some extent – infrastructure is constructed completely or partly with biotic materials, this pattern changes when countries become richer. Buildings and infrastructure are built increasingly with abiotic materials (concrete, steel, etc), and the richer countries are, the more infrastructure is constructed and has to be maintained. While biomass serves not only for food but also for construction and energy supply in poor countries, it is mainly used for food consumption in richer countries. This trend is now again changing due to rising biomass-based energy production (biofuels, etc.). The relatively low per capita consumption of biomass especially in Bahrain, Singapore and Japan can be explained by the fact that food and biomass products (especially paper and paper-products) are imported to a high degree (see Table 3 above, import dependencies of biomass), while the extractions for the corresponding production are attributed to the per capita consumption in the producing country. Thus, per capita consumption of biomass is higher in countries with a significant agricultural and forestry sector (Malaysia, Israel, Turkey). Important metal extracting countries, such as Indonesia and Malaysia have an over-proportional share of metal ores in DMC.

3.4 Material consumption, GDP and material productivity

Combining data on material consumption with GDP data allows indicators of resource or material productivity to be derived. These efficiency indicators illustrate how much economic value is being generated per unit of material consumption in each country or world region. In this study, material consumption is used to measure material productivity. Figure 9 illustrates the overall trends across the 19 investigated Asian countries, indicating GDP (in constant US $ of the year 2000), population, material consumption and material productivity.

Figure 9: GDP, population, material consumption and material productivity in 19 Asian countries (1985-2005)

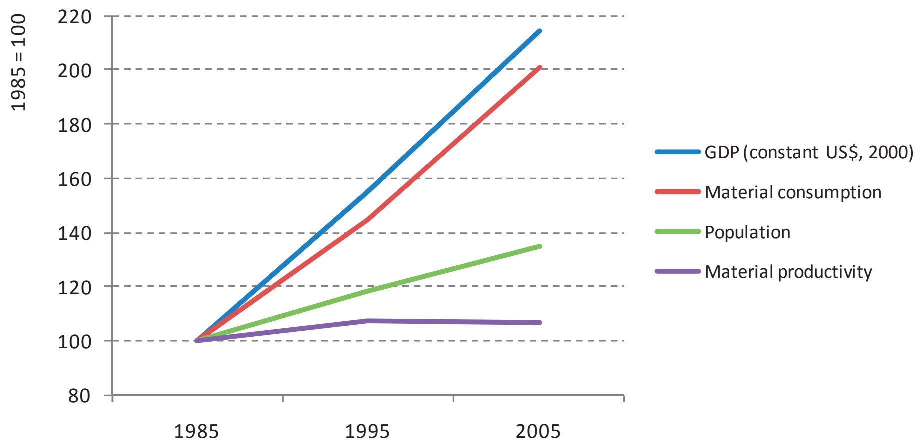
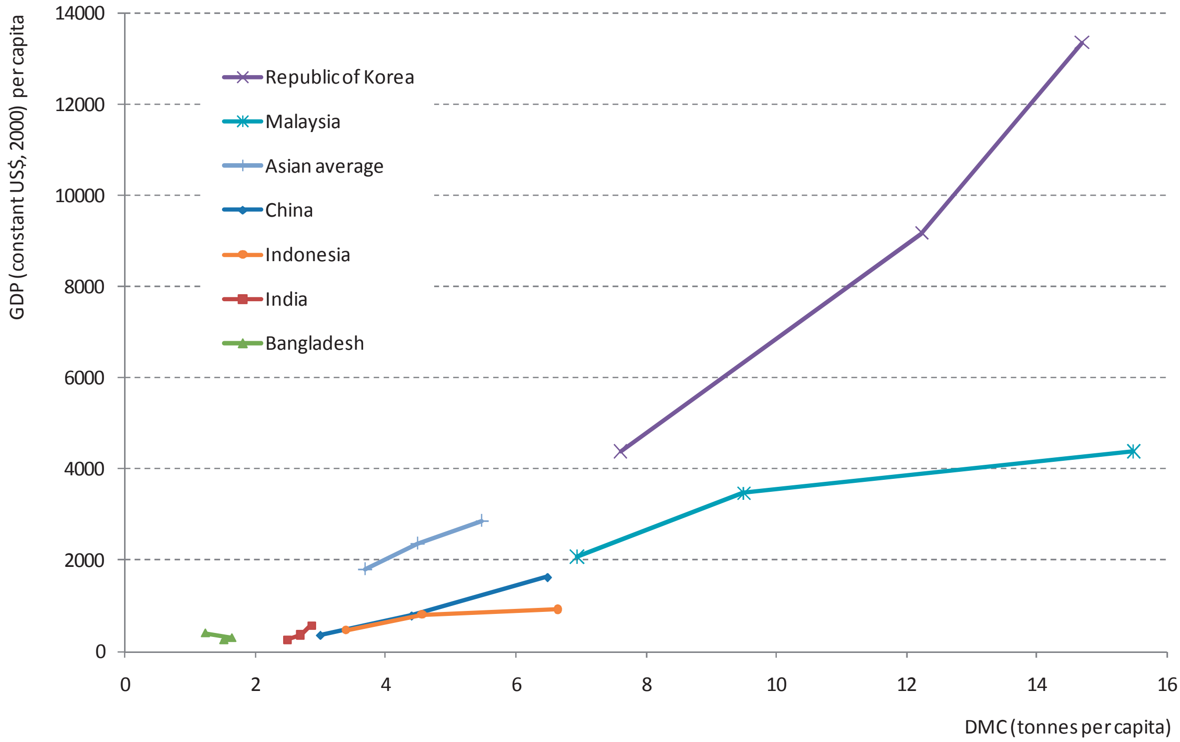


Figure 9 shows that increased GDP was the main driver for increased material consumption in the 19 Asian countries being studied and that a close correlation between GDP growth and growth in material consumption can be observed. Between 1995 and 2005, growth rates of GDP and material consumption were almost identical, with GDP increasing by 114% over the 20 year period and material consumption growing by 101%. Growth in material consumption thus was significantly higher than growth in population (35%). Resource productivity, calculated as GDP divided by material consumption, did not improve notably: it increased by 7% between 1985 and 1995 and then remained unchanged between 1995 and 2005.

On an aggregated basis, the 19 Asian countries are currently in a situation in which economic development is very closely linked with increased material consumption. This trend is further illustrated in Figure 10, which illustrates the links between changes in GDP per capita and material consumption per capita, taking the example of six of the 19 Asian countries plus the average over the 19 countries. The lines for each country illustrate the development path from 1985 to 2005.

Figure 10: Material consumption (DMC) and GDP, per capita, selected Asian countries (1985-2005)



Two main conclusions can be drawn from this graph. First, a clear positive relation between per capita income and material consumption can be observed. Second, the wide range in material consumption and GDP per capita between the different Asian countries has expanded over the analysed time period. In many countries, material consumption per capita is growing faster than GDP per capita. This implies that in those countries, no de-coupling between per capita GDP and per capita material consumption can be observed. This is in contrast to the recent developments in industrialised regions, where GDP per capita is increasing faster than material consumption per capita (for an overview, see Bringezu and Bleischwitz, 2009).

Three main groups of countries can be distinguished. (i) Rapid industrialisation in some Asian countries, such as in the Rep. of Korea, led to fast growing GDP, but also almost doubled material consumption. With the development of industries of higher manufacturing and of service sectors, GDP per capita increased more rapidly than material consumption since 1995. (ii) Important resource extraction countries (e.g. of metal ores and biomass), such as Malaysia and Indonesia, have significantly expanded material consumption, while positive impacts on GDP per capita were very limited. (iii) Poor, developing countries with large populations, such as Bangladesh and India, neither significantly improved their affluence per capita, nor did material consumption change notably.

On average, material productivity for the 19 countries improved only slightly from 490 constant US$ per tonne of resources in 1985 to 530 US$ in 1995, then dropping marginally to 520 US$. Material productivity in Asia therefore seems to have developed worse than the global average trend, which improved from 500 US$ per tonne in 1985 to 640 US$ in 2005. However, this global trend was mostly driven by high GDP growth in the rich industrialised countries (see Behrens et al., 2007). Comparing Asian countries with other emerging and developing regions would require extending this study to other continents.

As in the case of per capita material consumption, the average material productivity hides considerable variation from country to country, as Figure 11 illustrates. With 2,400 US$ of value generated per tonne of material consumption, the Japanese economy has been by far the most resource efficient of all the investigated Asian countries. Japan thus has been almost a factor 20 more resource efficient than the country with the lowest material productivity, Indonesia (with only 140 US$). Israel, Singapore and the Rep. of Korea follow as countries with high material productivity.

Figure 11a: Material productivity by country, upper part (1985-2005)

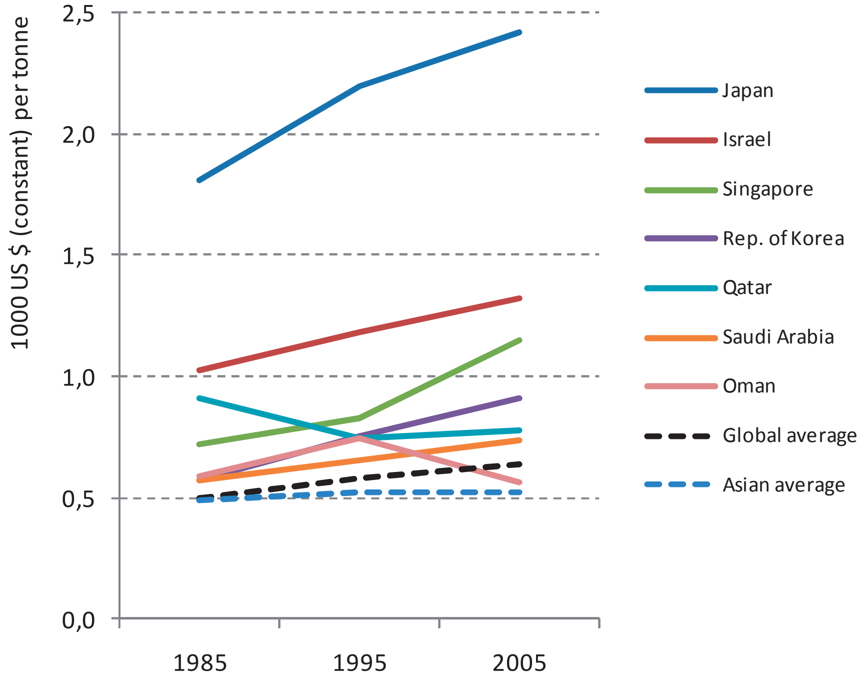
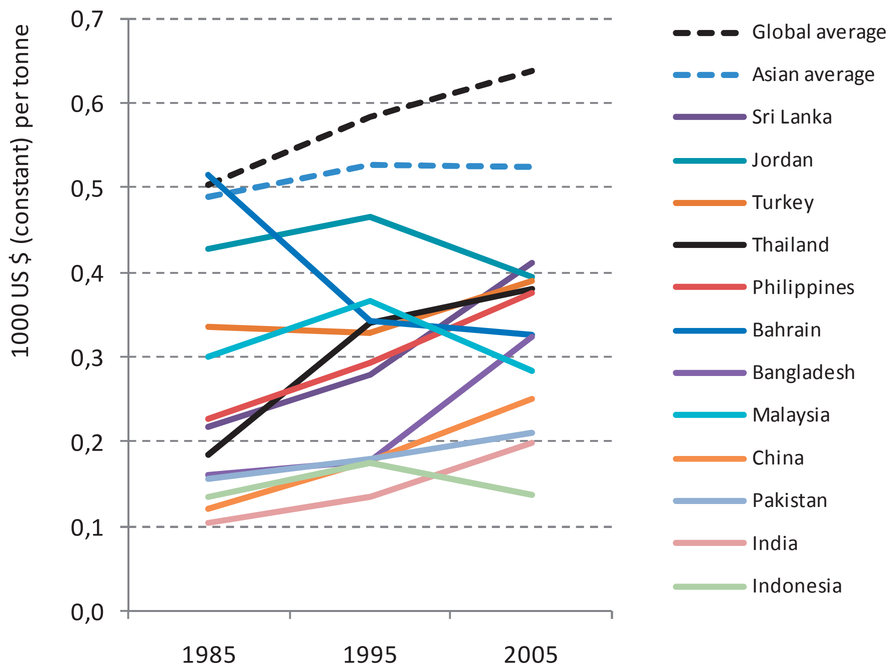


Figure 11b: Material productivity by country, lower part (1985-2005)



The big emerging economies China, India, Malaysia and Indonesia are among the least resource efficient countries, with less than 400 US$ of GDP per tonne of material consumption. In China and India material productivity only doubled over the 20 year period while it nearly stagnated or dropped slightly in Indonesia and Malaysia. Against the background of annual economic growth rates in the range of 6 to 10%, these small improvements are surprising and not yet fully explicable. One important aspect is that these countries built up highly material- and energy-intensive infrastructure (buildings, transport infrastructure, etc.) and basic industries, such as metal and chemical industries, during the period. Thus, the low or lagging changes in material productivity of these emerging countries may be interpreted as a phase in a longer transition process from an agricultural-oriented profile to an industry-oriented profile (similar to the metabolic process observed in western countries, see Krausmann et al., 2008). This phase is characterised by building of a highly resource-intensive physical stock within a very short time period. The low material productivity could also reflect the still high share of the agricultural sector in these emerging countries or could also be a result of an dislocation of material-intensive industries from the industrial countries. The specific drivers and barriers for improving material productivity in emerging economies would need to be investigated in more in-depth country studies.

It is interesting to note that some of the poorest countries, such as Bangladesh, have higher material productivity values than emerging economies, such as China. It could be the case that in a situation of widespread poverty, people use the few available resources relatively efficiently. In these countries, the very small GDP is thus connected to a small material throughput, as a broader process of industrialisation, including expansions of resource-intensive industrial sectors, has not yet started in these countries.

Industrialised countries such as Japan, but also European countries, have also developed less resource-intensive economic sectors, such as high-tech manufacturing sectors (e.g. electronics in the Rep. of Korea or Japan) and particularly service sectors. Those economic activities generate high economic output with significantly less inputs of materials and energy, although direct energy demand and consumption of certain products (such as electronic equipment, paper, etc.) can also be high in the service sector, and the indirect resource requirements, e.g. through electricity consumption, can be significant.

However, one of the key challenges from the perspective of global sustainable development arises from the observation that so far, no country world-wide has achieved a sustainable situation, in which high resource productivity and high levels of social and human development are combined with low per capita consumption numbers. In general high levels of material productivity have so far only been achieved at a certain level of industrialisation and affluence. Western European countries and Japan are the most resource-efficient countries in the world (see Behrens et al., 2007). However, these countries also have high levels of per capita material consumption and are therefore not environmentally sustainable.

In addition, countries with a combination of high productivity and high per capita consumption, such as Japan, as well as Europe, are also characterised by outsourcing of domestic industries to other world regions and substitution of domestic resource extraction and processing by imports of raw materials and semi-manufactured products. Such patterns require extending the resource productivity indicators as presented above. Japan would likely have less positive material productivity numbers if other more comprehensive indicators would be applied that included the indirect (or upstream) material requirements of imports and exports (see “Outlook” section at the end of this report for a more detailed discussion).

Concluding this section, we briefly summarise the main determinants of material productivity on the national level. The role of each determinant for specific countries would need to be investigated in detail in more in-depth studies.

1. *Economic structure*: Different economic sectors generate very different amounts of value added per tonne of resource input. Material productivity in terms of value added per resource input is low in primary resource extraction and processing sectors and this value improves with an increasing contribution of higher manufacturing industries and service sectors to GDP. However, due to specialisation of countries within an international division of labour, comparisons of material productivity should consider the role of the countries within these specialisation patterns.
2. *Resource endowment*: Countries that have limited endowments of raw materials within their own border (such as Japan, Singapore, etc.) tend to be more resource efficient than countries with resource abundance. Relative resource scarcities support the implementation of policies to increase resource efficiency. In contrast, small and rich countries with large reserves and extraction of key resources with high global demand (particularly oil) tend to have the highest per capita consumption numbers and have less incentives to increase resource efficiency.
3. *International trade*: A factor closely related to resource endowments is international trade. Countries that import high shares of their raw materials and products (such as Singapore) have higher material productivities than countries that extract and process raw materials within their borders. This calls for application of more comprehensive indicators to measure material consumption and evaluate material productivity, including the (up-stream) indirect flows of trade.

3.5 Material consumption and CO_2 emissions

One of the purposes of this pilot study was to investigate the interlinkages between material consumption and energy-related CO_2 emissions. Climate policy currently is the most important environmental policy area worldwide, and the question arises as to what extent climate policies could help reduce resource use and increase resource productivity or, vice versa, to what extent resource efficiency policies could contribute to mitigation of climate change. Figure 12 correlates material consumption (expressed with the Domestic Material Consumption (DMC) indicator) and energy-related CO_2 emissions in the 19 Asian countries for the year 2005.

The trend line in Figure 12 illustrates that a high correlation between those two indicators can be observed (Spearman coefficient: $r_s = 0.81$), implying that countries with high absolute levels of resource consumption are also those countries with high CO_2 emissions. Material metabolism and energy-related CO_2 emissions are therefore closely linked, across countries at very different development stages and with very different levels of GDP per capita.

This link is further investigated in detail for selected Asian countries and the Asian average (see Figure 13 below). The lines for each country again illustrate the development path from 1985 to 2005. The figure reveals quite similar trajectories as Figure 10, which illustrated the relation between material consumption and GDP per capita. In some countries, notably China and the Rep. of Korea, a linearly proportional increase in CO_2 emissions can be observed with growing material consumption. Resource extracting economies (Indonesia, Malaysia) increased their material consumption faster than CO_2 emissions. Growth in emissions was steeper than material consumption in India, albeit on a much smaller absolute level. This could be explained by the fact that India fostered the development of material-extensive sectors (in particular, IT service sectors), which increased energy consumption (and thus related CO_2 emissions) faster than material consumption. CO_2 emissions per capita are almost negligible for the poorest developing countries, such as Bangladesh.

Figure 12: Material consumption and CO_2 emissions, absolute numbers (2005)

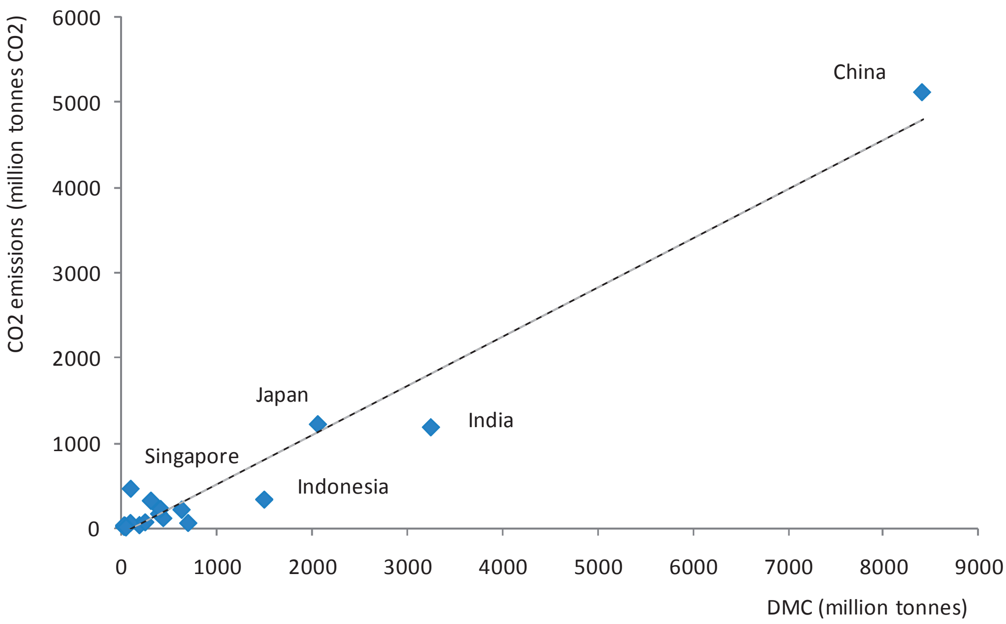
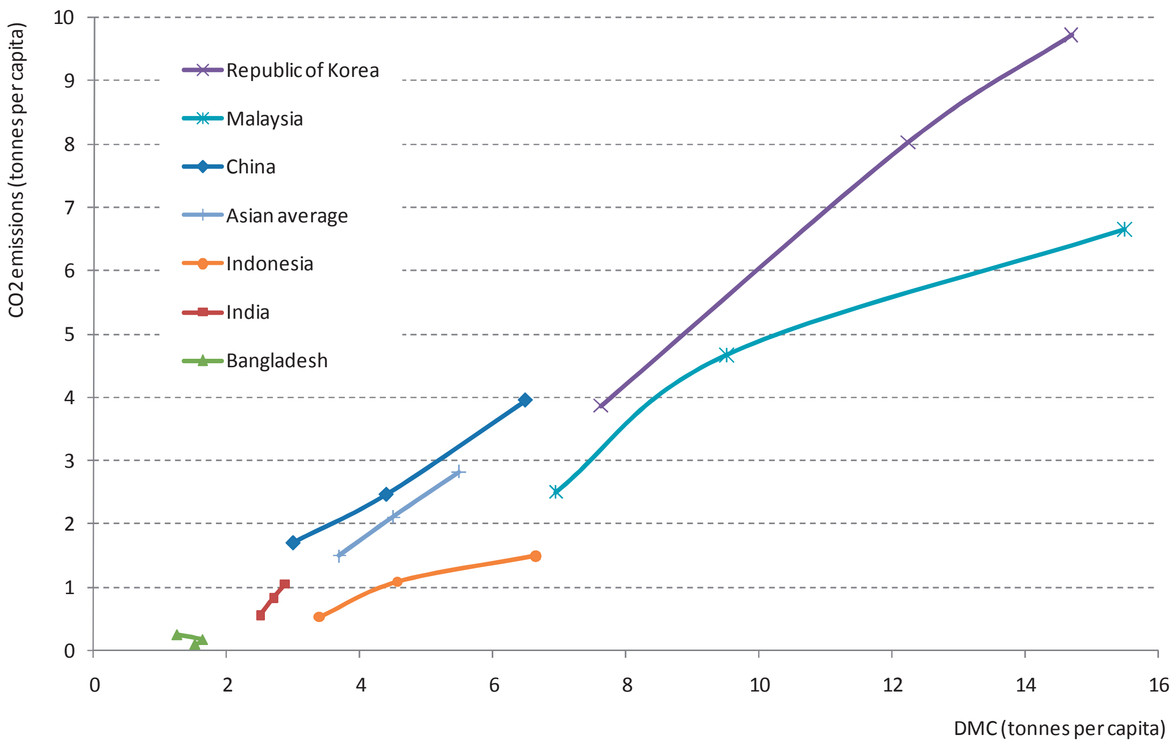


Figure 13: Material consumption (DMC) and CO_2 emissions, per capita, selected countries (1985-2005)



4 Policy implications

This pilot study has illustrated trends of resource consumption and resource efficiency in 19 selected Asian countries between 1985 and 2005. Although a broader, in-depth study covering the whole time period, including more recent years, would be needed to safeguard the underlying data (see next chapter), this report illustrated some highly relevant trends from a policy point of view.

Asia is not only the growth centre of the world economy in terms of monetary production and consumption, it is also the world region with the highest growth rates in material and energy consumption. On the aggregated level, current patterns and trends of resource consumption in Asia are clearly not environmentally sustainable. Asia has increased domestic resource extraction much faster than other world regions, entailing growing environmental pressures on ecosystems and human health due to air and water pollution, generation of (toxic) wastes, soil erosion, etc. Asia is also a huge and rapidly growing net importer of natural resources from other world regions. Industrialised countries such as Japan and the Rep. of Korea have been net importers for several decades. Recently, the big emerging economies, such as China and India, have also turned into net importers, putting additional pressures on global resource reserves and ecological capacities.

Extrapolating a level of per capita consumption of around 15 tonnes per person, i.e. the level of countries such as Japan, Israel and the Rep. of Korea (and around the level of average European consumption) to all 19 Asian countries with their aggregate population of around 3.5 billion, the amount of materials consumed in the region would reach nearly 52 billion tonnes a year. This would almost equal the level of today's worldwide used annual resource extraction. It is obvious that this would imply serious environmental, social and economic challenges on the global level as well as for the Asian countries themselves.

From a global perspective, countries with high per capita consumption levels clearly have the greatest responsibility for reducing resource consumption (SERI et al., 2009). However, big emerging economies with rapid growth of material and energy consumption also hold a responsibility to alter current development trends and help avoiding a situation of severe global resource scarcities and (potentially armed) conflicts about access to those limited natural resources. If no effective policies are implemented that drastically increase resource efficiency, growth in GDP per capita will result in an almost linear growth of material consumption and energy-related CO_2 emissions, as the correlations carried out in this pilot study have clearly indicated.

While resource efficiency has increased significantly in some Asian countries over the past 20 years, economic growth has in general overcompensated these efficiency gains. Efforts therefore need to be intensified to make future economic growth in Asia "greener" and further de-couple growth from material consumption and energy-related CO_2 emissions.

In this context it is essential to differentiate between resource efficiency and absolute levels of resource consumption. From an environmental point of view, a limit or even decrease in absolute levels of resource consumption is crucial; increasing resource efficiency can be a key strategy to achieve this objective. In the world economy, industrialised countries with the highest resource efficiency are in general also those countries with the highest per capita consumption.

In industrialised countries, absolute reduction targets to a per capita consumption level of around 6 tons (non-biotic materials, including indirect flows) are currently being discussed (see Ekins et al., 2009). Also strategies which aim at increasing resource productivity by factors between 4 and 10 (see for example von Weiszäcker et al. 2009) are a means to reduce per capita consumption. In general, such goals and strategies can also be applied for the industrialised countries in Asia such as Japan and the Rep. of Korea, and to rich, oil-exporting countries such as Bahrain and Qatar, which are characterised by very high levels of per capita consumption; these countries need to achieve a reduction of per capita resource consumption even in a situation of further economic growth by absolute de-coupling of growth from resource consumption in the future.

Another important policy field that can be addressed by resource use indicators is the distribution of material affluence within Asia. In no other continent can such extreme differences between countries be observed. While the challenge for emerging and industrialised countries is to (further) de-couple growth from resource consumption, there is a clear need in the poorest economies to achieve at least a minimum level of material and energy consumption. With only 1 or 2 tonnes of resource consumption per capita, as observed in some Asian countries, not even the basic needs (food, shelter, health, education) can be satisfied. For this group of countries, growth in absolute material consumption to increase well-being and related reduction of poverty is likely a priority over improving resource efficiency in the coming years**.**

The crucial challenge in implementing policy initiatives such as the "Manila Declaration on Green Industry in Asia" therefore is to actively address the very diverging policy interests of the different nations in the development and realisation of such a joint policy agenda. In summary, different policy priorities can be derived for the different groups of Asian countries:

(1) For countries with high and medium levels of resource consumption, targeted policies to drastically increase resource efficiency need to be implemented, clearly targeted at increasing efficiency and decreasing resource throughput. Resource inefficient patterns of excessive consumption, as e.g. observed in some rich Gulf States, need to be identified and addressed.

(2) For the dynamic emerging economies, priorities are resource efficiency in building up their infrastructure, i.e. fostering energy and material efficiency in buildings, transport systems, etc., as well as improving efficiency in their basic industries, such as metals, chemicals and pulp/paper. The challenge is to avoid being locked into material and energy-intensive development trajectories leading to levels of per capita consumption as high as those currently observed in the industrialised countries.

(3) Poor, developing countries with very low consumption levels will require support from other (Asian as well as non-Asian) countries to increase material affluence to a humane level and reduce or erase poverty. This group of countries will be particularly dependent on the transfer of green technologies from abroad, in order to achieve these objectives with the highest possible resource efficiency.

5 Outlook to a full-scale study

The pilot study presented here provides a survey of trends in material and energy consumption and efficiency of a selected group of Asian countries between 1985 and 2005. The results allow a comparison between European and Asian dynamics as well as differentiations between the investigated Asian countries. The study puts forward good reasons for policy intervention to better manage material extraction and consumption in Asian countries.

However, this pilot study analysed data from only three years within a 20-year-period. Data covering the complete time are needed to corroborate the results and to reduce data uncertainties. Due to the highly dynamic development in many Asian countries, the most recent years possible should be included in a full-scale study (i.e. 2007/2008).

This study discussed the results of the Asian countries by comparing them mainly with European countries due to limited data availability. It is highly questionable to what extent the current European material and energetic throughput is a good reference for Asian countries. But until now, data of other world regions with developing and emerging countries are hardly available if at all. It is therefore recommended to expand this study into a broader context to cover other world regions, in order to derive more suitable benchmarks for developing and emerging economies.

This study only accounted for direct physical trade flows, considering the actual mass of imports and exports. A more comprehensive study should include the so-called “hidden” or “upstream” material flows. As empirical evidence illustrates, the majority of industrialised countries are highly integrated into the global economy, which leads to an increasing shift of environmental burden via trade by importing material intensive products and raw materials from other (often poorer) countries (for example, Dittrich, 2009; Munoz et al., 2009; Russi et al., 2008). Countries that substitute domestic resource extraction (e.g. of crude metal ores with low concentration) by imports (e.g. of concentrated metals), apparently improve their resource efficiency, while the overall environmental situation remains unchanged or even deteriorates, in cases of lower environmental standards in resource extraction countries. In order to detect such kind of patterns and dynamics in the Asian countries requires the calculation of more comprehensive resource consumption and resource productivity indicators. Moreover, this study accounted only for resource extraction which is further processed, leaving aside unused resource extraction, e.g. mining waste, which globally reaches a similar magnitude and determines local damage to the environment. Therefore, more comprehensive accounts on resource extraction should be established as well.

Until now, knowledge about the dynamics of material and energy consumption is still limited, especially for poor and emerging countries. This study has shown some remarkable patterns as well as astonishingly wide ranges in the dynamics between Asian countries. Understanding the driving forces and the impacts of national policies in each of the countries as well as overall patterns and dynamics is urgently needed to define solidly the required policy targets and appropriate instruments.

References

AIECE. 2009. World commodity prices 2009. Association of European Conjuncture Institutes, Working Group on Commodity Prices.

Behrens, A., Giljum, S., Kovanda, J., Niza, S. 2007. The material basis of the global economy: Worldwide patterns of natural resource extraction and their implications for sustainable resource use policies. Ecological Economics 64(2), 444-453.

Bringezu, S., Bleischwitz, R. (Eds.). 2009. Sustainable Resource Management: Global Trends, Visions and Policies. Greenleaf Publishing, Sheffield.

Dittrich, M. 2009. The physical dimension of international trade, 1962-2005. In: Bleischwitz, R., Welfens, P.J.J., Zhang, Z.X. (Ed.), Sustainable growth and resource productivity. Economic and global policy issues, Greenleaf Publishing, Sheffield, UK.

Dittrich, M. 2010, in press. Physische Handelsbilanzen. Verlagert der Norden Umweltbelastungen in den Süden? Kölner Geographische Arbeiten, Köln.

Ekins, P., Meyer, B., Schmidt-Bleek, F. 2009: Reducing Resource Consumption. A Proposal for Global Resource and Environmental Policy. Gws Discussion Paper 2009/5. Osnabrück.

Environment Agency Japan. 1992. Quality of the environment in Japan 1992. Tokyo.

EUROSTAT. 2007. Economy-wide Material Flow Accounting - "A compilation guide". By Weisz, H., Krausmann, F., Eisenmenger, N., Schütz, H., Haas, W. and A. Schaffartzik. ENV/MFA/06 (2007), EUROSTAT, Luxembourg.

IEA. 2009. CO2 Emissions from Fuel Combustion (2009 Edition). International Energy Agency, Paris.

Krausmann, F., Fischer-Kowalski, M., Schandl, H., Eisenmenger, N. 2008. The global socio-metabolic transition: past and present metabolic profiles and their future trajectories. Journal of Industrial Ecology 12, 637-656.

Munoz, P., Giljum, S., Roca, J. 2009. The Raw Material Equivalents of international trade: empirical evidence for Latin America. Journal of Industrial Ecology 13(6), 881-897.

OECD. 2007. Measuring Material Flows and Resource Productivity. The OECD guide. ENV/EPOC/SE(2006)1/REV3, Environment Directorate. Organisation for Economic Co-operation and Development, Paris.

OECD. 2008. OECD Environmental Data Compendium. Environmental Performance and Information Division; OECD Environment Directorate, Paris.

Russi, D., Gonzalez-Martinez, A.C., Silva-Macher, J.C., Giljum, S., Martinez-Alier, J., Vallejo, M.C. 2008. Material flows in Latin America. A comparative analysis of Chile, Ecuador, Mexico and Peru, 1980-2000. Journal of Industrial Ecology 12(5/6), 704-720.

SERI. 2010. Technical Report on the compilation of the material flow database for www.materialflows.net. Sustainable Europe Research Institute, Vienna.

SERI, GLOBAL 2000, Friends of the Earth Europe. 2009. Overconsumption? Our use of the world's natural resources. Vienna & Brussels.

Von Weizsäcker, E. U., Hargroves, K., Smith, M. H., Desha, C., Stasinopoulos, P. 2009: Factor Five. Transforming the Global Economy through 80 % Improvements in Resource Productivity. London.

Weisz, H., Krausmann, F., Amann, C., Eisenmenger, N., Erb, K.H., Hubacek, K., Fischer-Kowalski, M. 2006. The physical economy of the European Union: Cross-country comparison and determinants of material consumption. Ecological Economics 58(4), 676.

WWF, Zoological Society of London, Global Footprint Network. 2008. Living Planet Report 2008. WWF, Gland, Switzerland.