



Working Paper Number 11

**Resource use and resource
productivity in Asia**

Trends over the past 25 years

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Abstract

This working paper provides the first comparative and quantitative assessment of material consumption and resource productivity in Asia between 1985 and 2005. 19 Asian countries were selected for the analysis, together representing more than 90% of GDP in Asia. The study is based on the methodological framework of material flow accounting and analysis (MFA), as established by the OECD and EUROSTAT. The study shows that 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. By as much as a factor of 40, vast inequalities in per capita consumption exist between the various countries within Asia. Looking at developments over time, we find that overall resource productivity has not significantly improved in Asia over the past 25 years. However, it is again impossible to generalise as there are large differences in resource productivity across Asia. Japan, for example, was almost 20 times more resource efficient in the year 2005 than the country with the lowest resource efficiency, Indonesia. We also show that material consumption and energy-related CO₂ emissions are strongly correlated, despite very different levels of GDP per capita. We conclude that Asian countries need to alter current development trends and help avoid a situation of severe global resource scarcities and (potentially armed) conflicts about access to limited natural resources. Increasing resource productivity, erasing poverty in the developing countries and reducing resource use in the high-consuming countries are key priorities in a joint Asian policy agenda towards “Green Industries”.

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1. Introduction

Our rapidly growing consumption of natural resources (including materials, energy, water and fertile land) i.e. the basis for life on Earth, 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 have 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 consume up to 10 times more resources per capita than the poorest countries of the world (SERI et al., 2009). Therefore, industrialised 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 appropriates more resources today than the planet can provide in a sustainable manner (WWF et al., 2008).

Developing 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 fuels. 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).

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

This paper is based on the study "Resource Use and Resource Efficiency in Asia", commissioned by UNIDO under its programme on "Green Industry for a Low-Carbon Future" which supports green industrial growth in the developing world. In September 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.

While the national statistical offices and agencies of industrialised countries have increasingly collected and published data and indicators on resource consumption and resource efficiency over the past 10 years, this is not yet the case in Asia. The necessity to increase resource efficiency of Asian economies is fully acknowledged, for example in the Manila Declaration. What is now needed is 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. As a first step towards the goal of collecting and comparing data on resource use in Asia, we have enhanced and integrated two large existing data bases, a data base on global resource extraction maintained by the Sustainable Europe Research Institute (SERI) and the Wuppertal Institute's data base on global physical trade. As a result, a number of key questions regarding the challenges related to resource consumption and resource efficiency in Asia could 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 material 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 productivity of different Asian economies developed over the past 20 years?
- What are possible reasons for why large differences in resource productivity are observed between countries in the same world region (e.g. South-East Asia)?
- Are energy-related CO₂ emissions closely linked with material consumption in Asian countries?

In order to investigate the questions listed above, this Working Paper presents comparative data for the following 19 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). Within this group of 19 countries there are different 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.

This Working Paper 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.

The report illustrates the huge differences in resource consumption and resource efficiency across the 19 selected countries. Note that this study focuses on the national level and therefore disregards often high disparities within Asian countries. In order to analyse temporal trends, data has been compiled for three distinct years: 1985, 1995 and 2005.

This Working Paper 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 CO₂ emissions. Section 4 summarises the policy implications derived from the main results.

2. Methodology and data sources

This Working Paper 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 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 ores¹ and metal products (including, for example, machinery or coins).

This study focuses on economically used resources only. It does not consider so-called “unused materials”, such as overburden from mining activities or unused residuals from agricultural harvest.

Economy-wide material flow accounts also provide the basis for many resource use indicators, notably on material inputs, material outputs, material consumption and physical trade. In this paper, 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.

Due to the compatibility between material flow accounting and analysis and data from the System of National Accounts (SNA) we can directly relate material flow indicators and 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-coupling material use from economic growth which contributes to lower resource consumption.

The calculations illustrated in this paper 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 as well as a detailed technical report (SERI, 2010) are accessible in an aggregated form online (www.materialflows.net). Data quality varies for the different types of materials. It is generally good for the extraction of fossil fuels and metal ores. For some metal ores, however, estimations are necessary in some cases for the concentrations 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 to be underestimated, particularly in developing countries. Statistics on the use of minerals are very poor in all investigated countries, except for Japan. The extraction of construction minerals was therefore estimated based on per capita income. The amounts of mineral extraction may thus be over- or underestimated in some 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 is moderate to good. Trade statistics of some countries are excellent (e.g.

¹ 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 become mining waste during the processing and concentration of the metals. This waste often remains in the country where metal extraction takes place.

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 be calculated. This was done for the first time for selected Asian countries during a pilot study for UNIDO, the basis for this paper.

In order to link resource use issues to the dominant environmental policy issue of climate change, the correlations between material consumption and energy-related CO₂ emissions on the country level were also investigated. For energy-related CO₂ 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, material use and CO₂ emissions.

3.1 Resource extraction

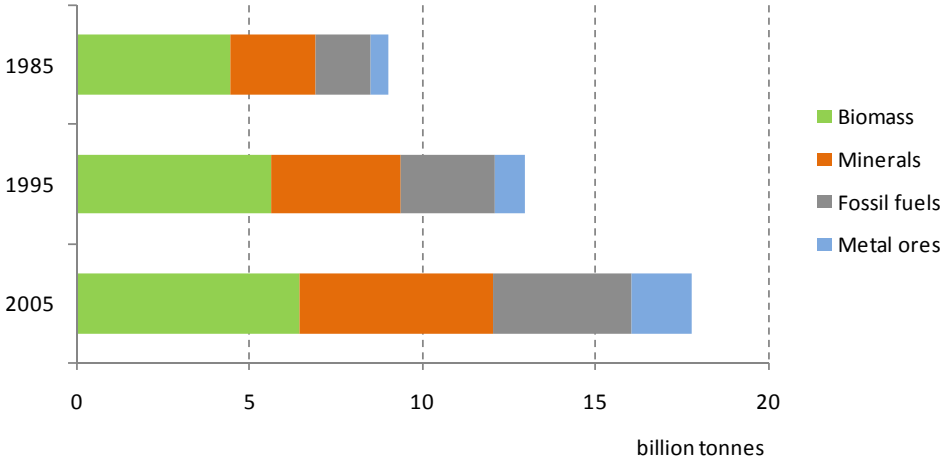
The extraction of natural resources in the 19 Asian countries investigated in this study has doubled over the past 25 years (see Figure 1). Economically used resource extraction increased from 9 billion tonnes of resources in 1985 to 13 billion tonnes in 1995 and reached almost 18 billion tonnes in 2005. 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 increased significantly, 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 between 1985 and 2005 (see Figure 1). While in 1985, renewable resources (biomass) accounted for almost half of all extraction, this share fell to 36% in 2005, as extraction of non-renewable resources (minerals, fossil fuels, metal ores) increased at a much faster 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 a characteristic of the ongoing industrialisation processes, which has accelerated considerably 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 to around 30% (Weisz et al., 2006).

Eight out of the 18 billion tonnes extracted in 2005 were extracted in China, which experienced a growth in extraction of 155% between 1985 and 2005. The strongest growth in China during this period occurred in metal ores (+480%) and construction minerals (+450%), reflecting the country’s increasing investments in its physical infrastructure (buildings, roads, railways, etc.) and the expansion of its metal industries, which are also increasingly served by imports (see the section on trade below).

With a total growth rate of 167%, extraction in Indonesia was even higher than in China. This was 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 occurred in Qatar (+242%) due to the rapid expansion of the oil extraction activities. In line with patterns observed in other industrialised countries, such as those in 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 Republic 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 their GDP per capita was

relatively high (e.g. Qatar) or low (e.g. Indonesia). 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 large-scale heavy industries (such as the Philippines, Bangladesh and Sri Lanka) have only marginally expanded resource extraction. Domestic extraction also stabilised in Japan, 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 to the rest of the world, increased by a factor of almost 3.1, up to 5.44 billion tonnes in 2005 (see Table 2). Between 1985 and 2005, the share of the 19 Asian countries in global trade has mainly grown 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.

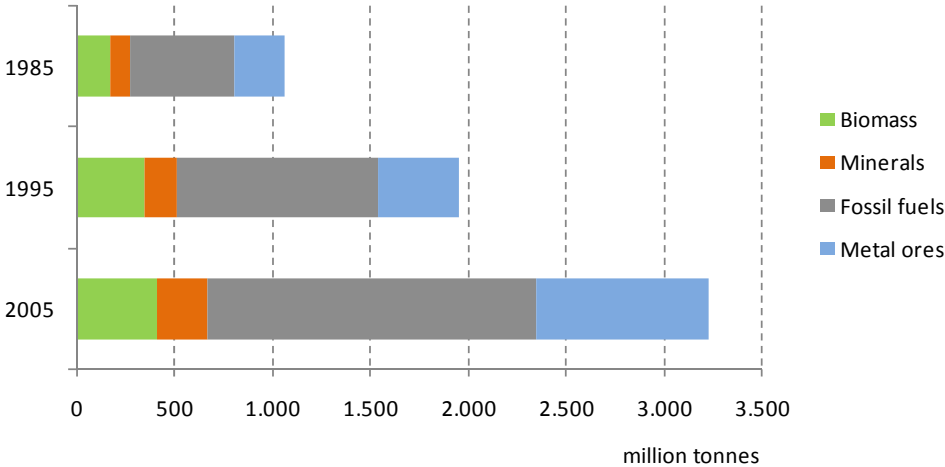
Table 2: Global and Asian trade volume (1985-2005)

	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

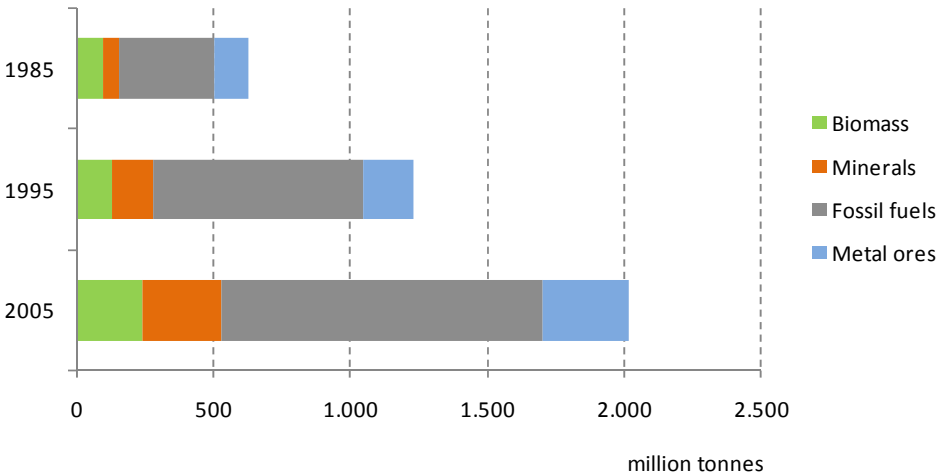
The imports of the 19 countries nearly tripled between 1985 and 2005, up to 3.3 billion tonnes today (Figure 2). Analysing the material composition, imports of all material categories have increased significantly in absolute terms. Fossil fuels, including oil as the dominant globally traded product,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

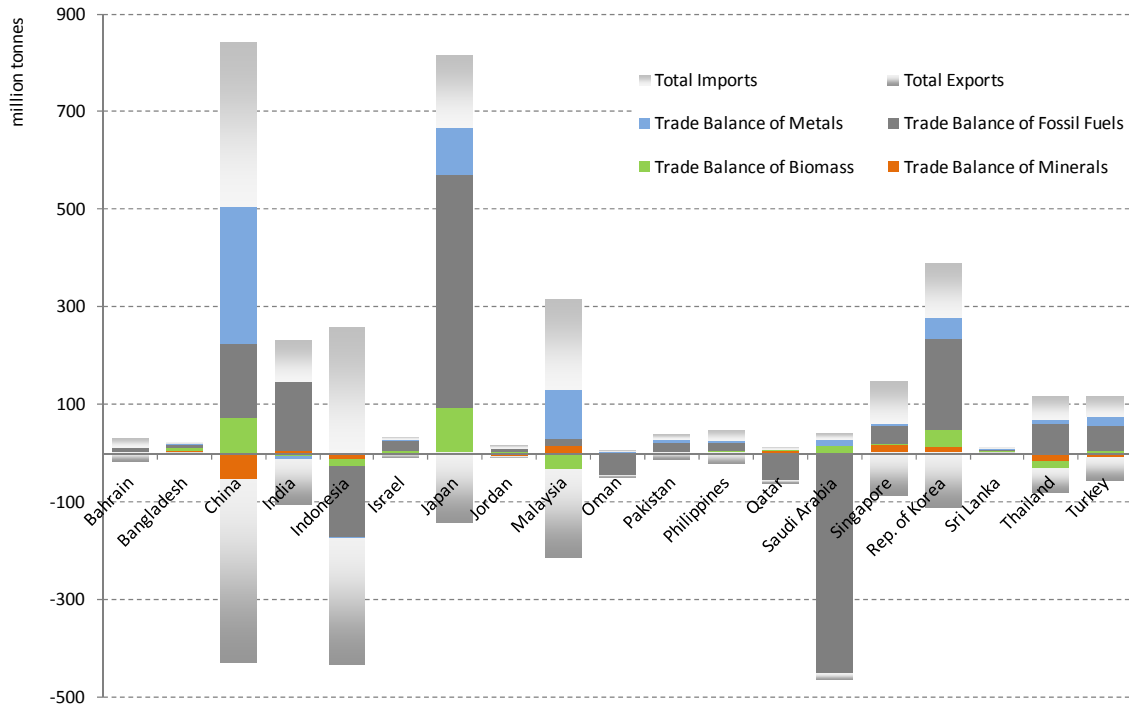


Fossil fuels clearly dominate exports, with a share between 55% and 60%, showing the importance of these exports from the oil-exporting countries, in particular Saudi Arabia and Indonesia. Remarkable growth rates are found in mineral exports (+442%). China, whose mineral exports grew by +1,880%, accounted 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 by factors 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%), mainly reflecting 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 exporting (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 consumers 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, Asia is the world’s third largest resource consumer, 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 consumers *and* resource suppliers are located in Asia. This variety of resource use patterns cannot be observed in any other world region.

Some important supplying countries, especially Russia, Kazakhstan and Iran, are not included in this study; therefore the group of 19 Asian countries investigated overstates the Asian role as a resource demanding region. In 2005, the group of 19 Asian countries had the same amount of net imports as the United States: 1.2 billion tonnes, and slightly more than Europe (around 1 billion tonnes) (Dittrich, 2009, 2010, in press; Weisz et al., 2006).

Japan has consistently been the biggest net-resource importer on the world market over the past decades. It was only overtaken 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. This is typical for countries with important manufacturing and consumption sectors but with a missing, poor or already exploited resource base within their own territory. The Republic 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 consumer world-wide, with 411 million tonnes imported in 2005. China’s trade profile is clearly dominated by metals, especially caused by the 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 resource suppliers in Asia. Their trade profile is dominated by fossil fuels, although Indonesia has a more diverse range of exports: 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. Altogether, the 19 Asian countries consumed around 19 billion tonnes in 2005 (nearly one third of resources extracted globally).

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

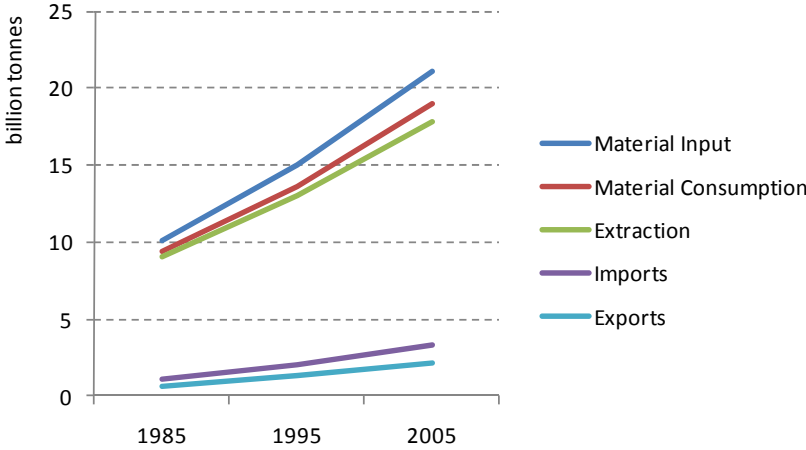


Figure 5 also illustrates Asia’s increasing dependency on imports. Import dependency is usually measured by the share of imports in material consumption. Numbers of 100% or below show to what extent material is imported for consumption, a number above 100% indicates that imports are re-exported (in general, 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. 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

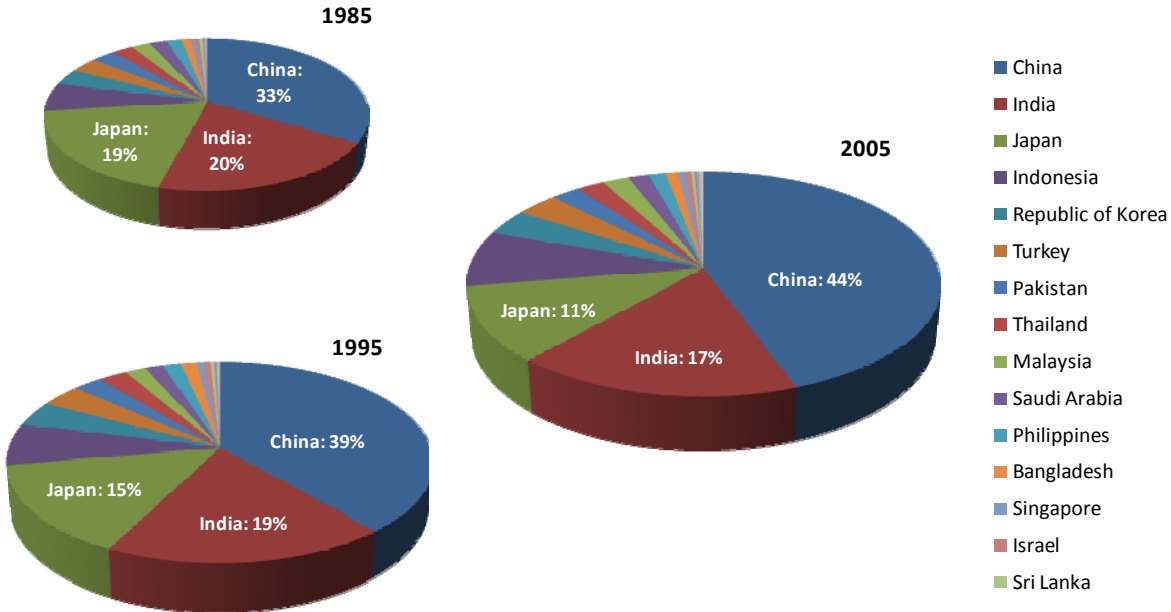
areas of arable land and important agricultural sectors (such as India or Turkey).

The absolute amount of materials consumed varies widely across Asia (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 between 1985 and 2005 (+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 Republic of Korea, Singapore and Israel increased their consumption by 96%. Thus, the Asian countries that industrialised earlier together consume around 3.4 billion tonnes, or 18%, of the group of 19 countries analysed in this study. The highest growth of absolute material consumption occurred in Bahrain (+352%), Malaysia (+265%) and Qatar (+207%) between 1985 and 2005. This contrasts sharply with the low growth rates in absolute material consumption in poor countries such as 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 Asia’s material consumption (1985-2005)



The per capita data on material consumption reveal a highly differentiated picture across Asia (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. There are very large differences across Asia. 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 global spectrum of material consumption profiles is represented in this group of 19 Asian countries.

On the upper end of the large spectrum are the small and rich oil-exporting countries of Bahrain, Qatar and Oman as well as Singapore (Figure 7a). With already high per capita consumption levels in 1985, they further increased their consumption levels, up to 45 tonnes in Bahrain. The eye-catching deviation in 1995 from an otherwise linear trend found within this country group 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.

On the other end of the spectrum, 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 (Figure 7b). Per capita consumption in Bangladesh is only 1.2 tonnes per year, which is far below a material subsistence level that would fulfil the basic human needs. Per capita consumption in Sri Lanka, Pakistan and India were also very low (2.5 to 2.9 tonnes per person in 2005), but have been slightly increasing.

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

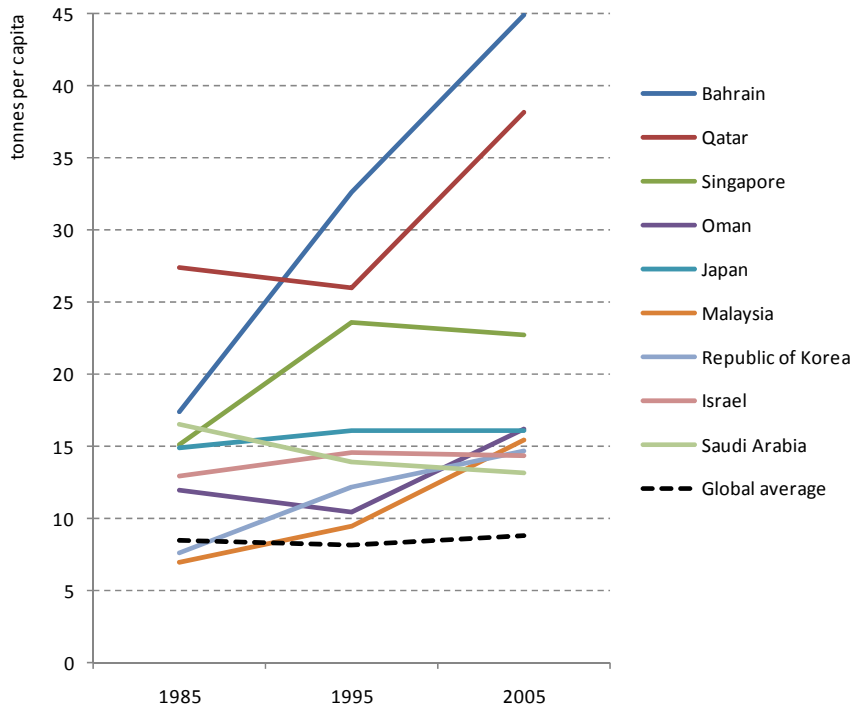
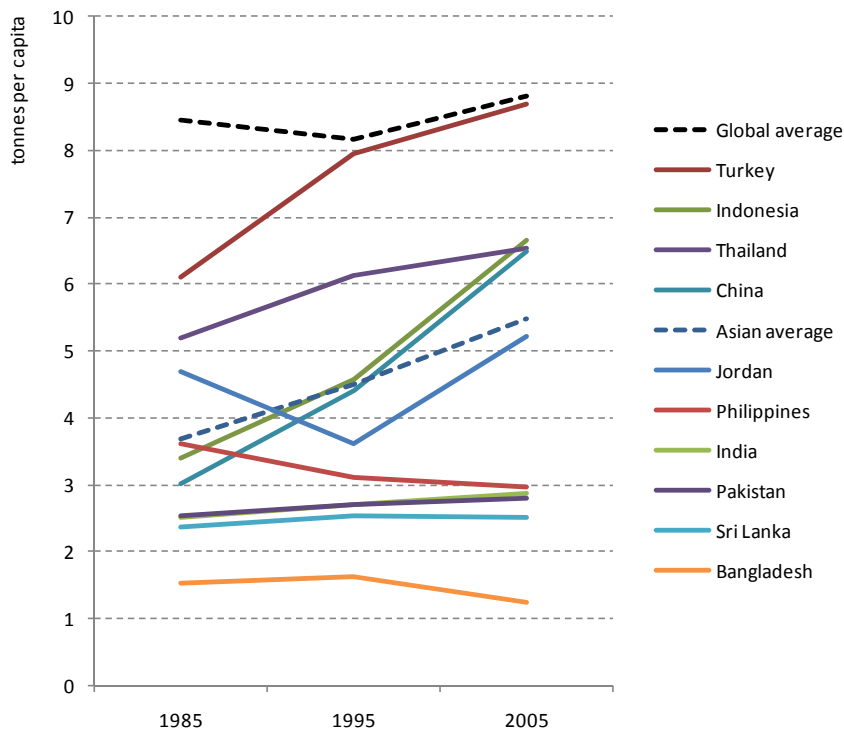


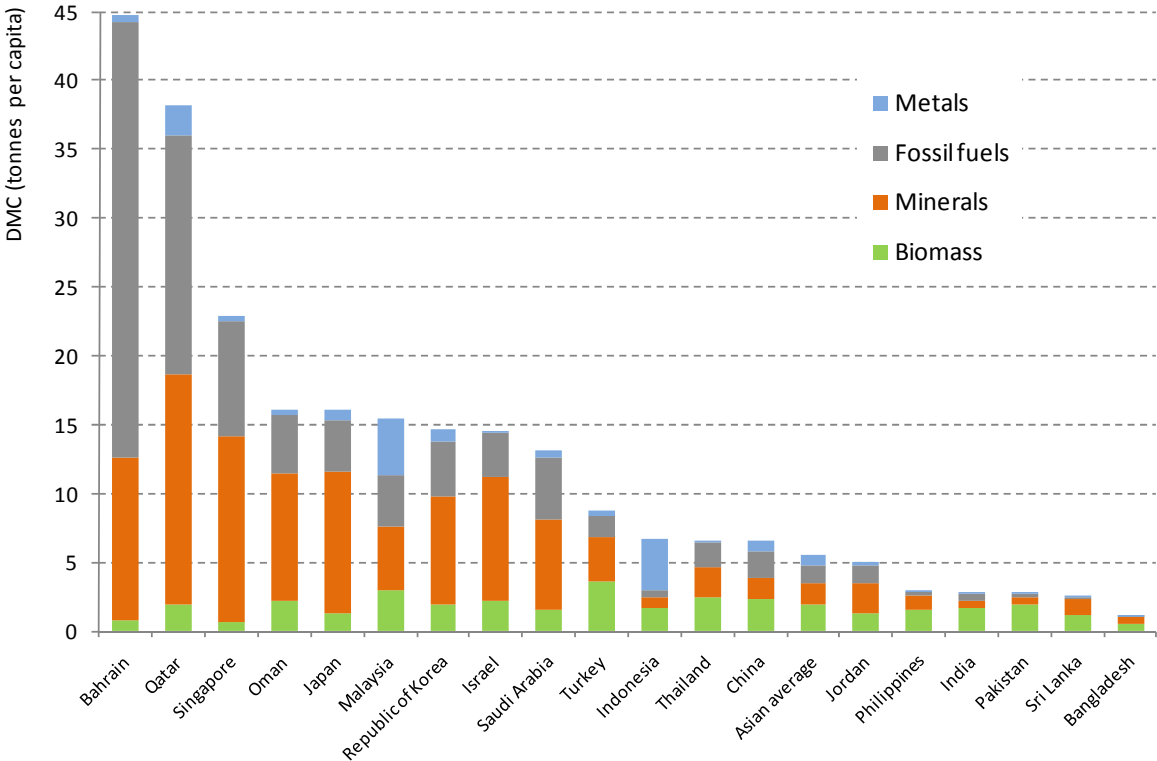
Figure 7b: Material consumption per capita, lower end (1985-2005)



The 19 countries have experienced different dynamics in terms of material consumption. 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 Republic of Korea, which however started from higher consumption levels. On average, inhabitants of Malaysia and the Republic of Korea consume similar amounts of materials as those in Japan, Israel or Saudi Arabia, where per capita consumption has been almost constant or declining. Average per capita consumption in these countries is about 15 tonnes per capita. This nearly equals the per capita consumption of the majority of industrialised countries, which is 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 distinctive 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, the values of mineral extraction are based on estimations. Therefore, the exact amount of mineral consumption may be over- or underestimated in some countries. However, the following overall trends can be considered as correct: A significant number of buildings and – to some extent – infrastructure in poor countries is constructed completely or partly with biotic materials. This pattern changes when countries become richer. The richer a country becomes, the more infrastructure is built with abiotic materials (concrete, steel, etc). The more infrastructure is constructed the more has to be maintained.

For a long time, the role of biomass differed considerably between industrialised and developing countries. In the former, it was mainly used for food consumption, while it was also used for construction and energy supply in the latter. This trend is now 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 a disproportionate share of metal ores in domestic material consumption.

3.4 Material consumption, GDP and material productivity

Combining the data on material consumption and GDP 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 USD 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)

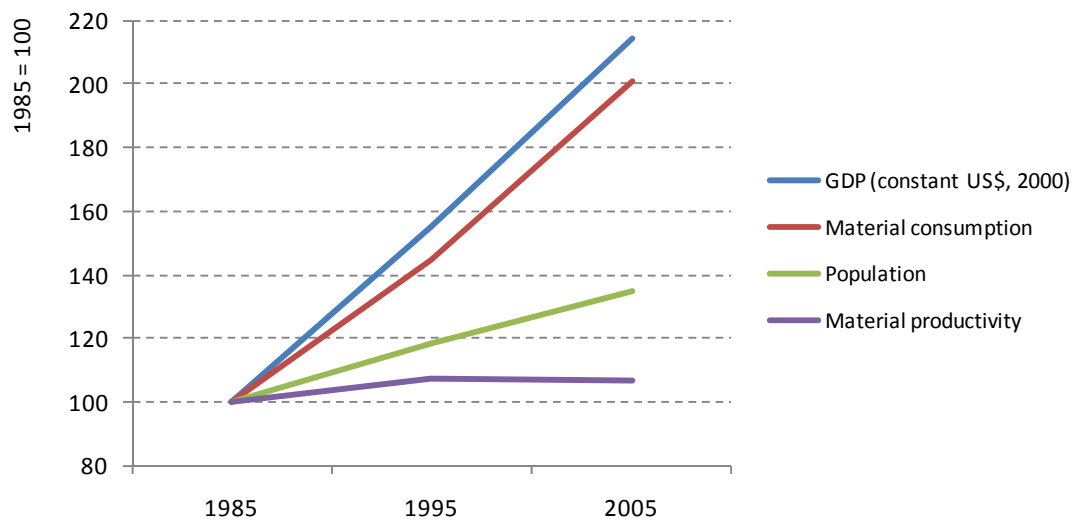
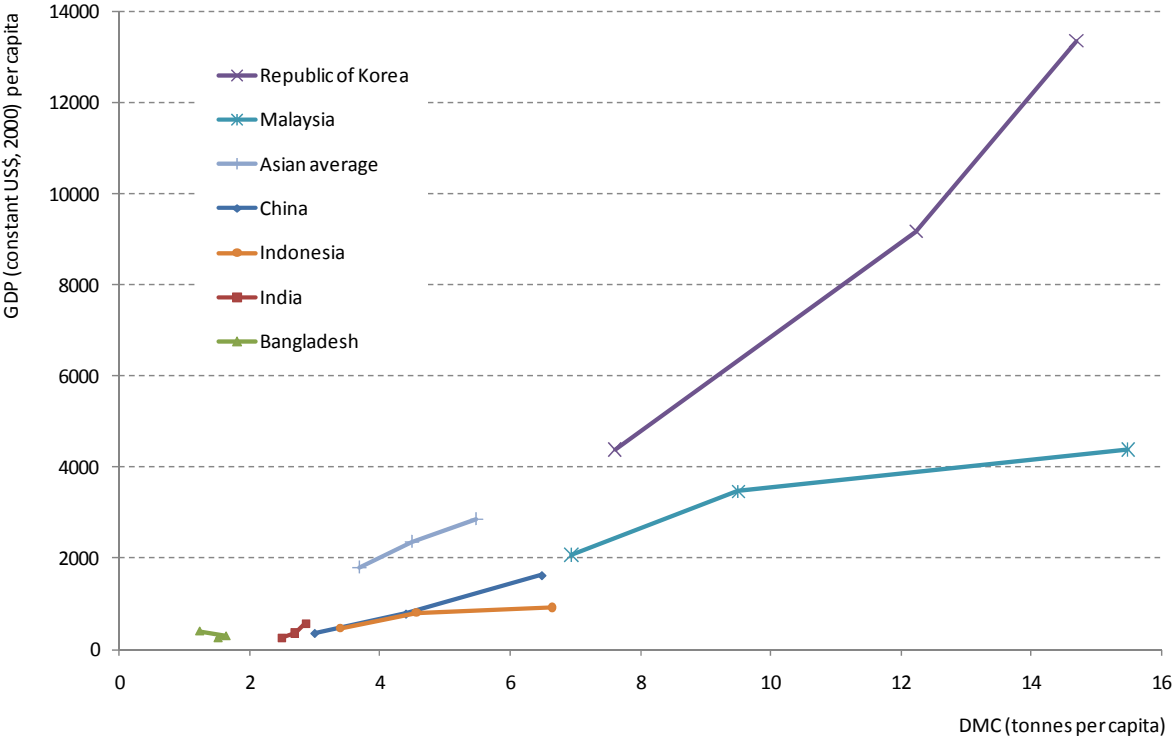


Figure 9 shows that increased production (reflected by the GDP) was the main driver for increased material consumption in the 19 Asian countries being studied and that GDP growth and growth in material consumption are closely correlated. Between 1995 and 2005, growth rates of GDP and material consumption were almost identical (114% and 101% respectively). Growth in material consumption was significantly higher than growth in population (35%). Resource productivity, calculated as GDP divided by material consumption, did not improve markedly: 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 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 for six countries as well as for the average across 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 in 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, has led to fast growing GDP, and almost doubled material consumption. With the development of industries of higher manufacturing and of service sectors, GDP per capita has 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 have been very limited.
- (iii) Developing countries with large populations and low average per-capita incomes, such as Bangladesh and India, have neither experienced significant growth in GDP per capita, nor in material consumption per capita.

On average, material productivity in 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 increased less 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, Japan has had by far the most resource efficient economy of all the investigated Asian countries. Japan thus has been almost 20 times more resource efficient than Indonesia, the country with the lowest material productivity (with 140 US\$ per tonne). Israel, Singapore and the Republic of Korea follow as countries with high material productivity.

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

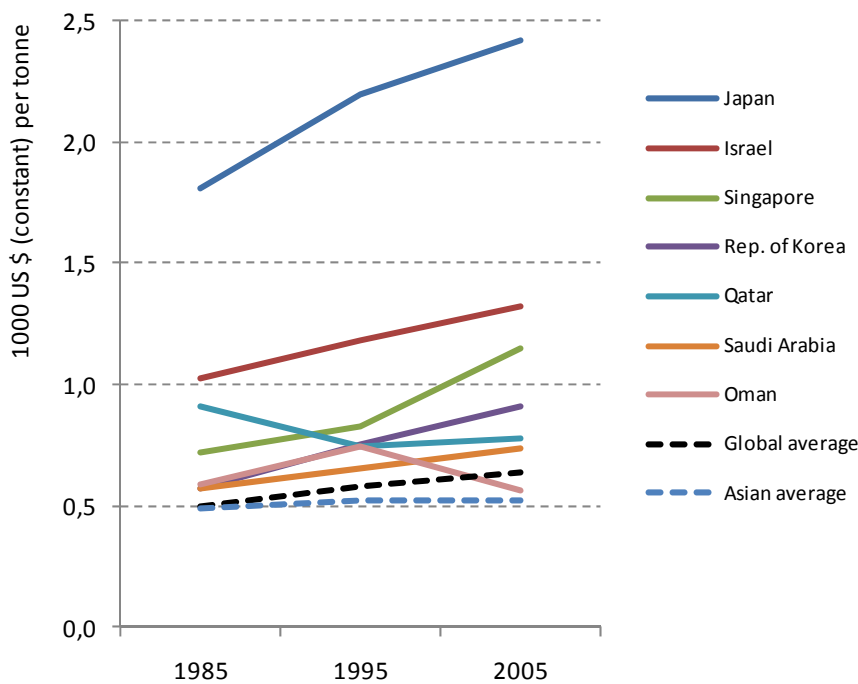
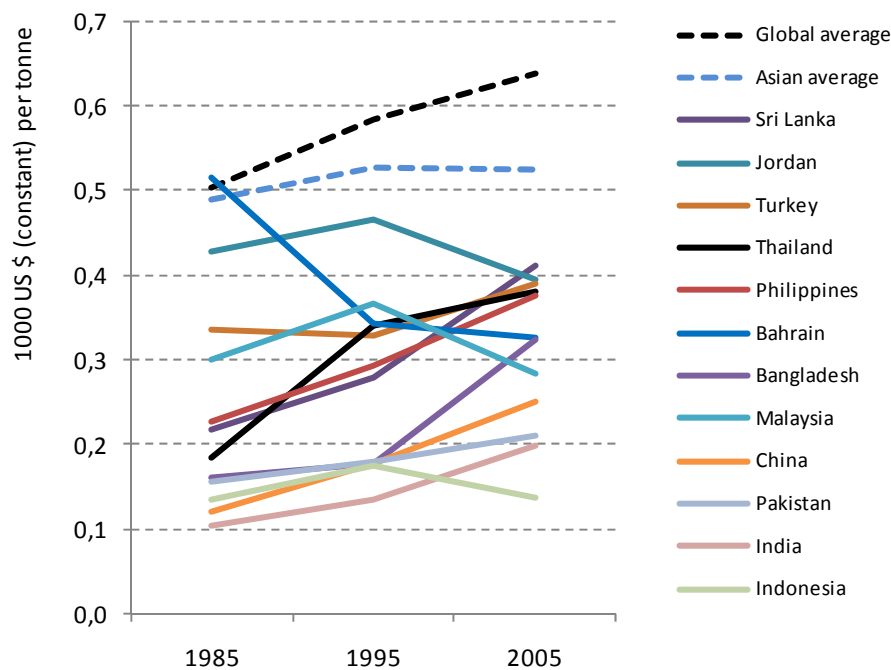


Figure 11b: Material productivity by country, lower end (1985-2005)

The large emerging economies of 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. Given annual economic growth rates in the range of six to ten percent, these small improvements are surprising and not yet fully explicable. One important aspect is that these countries have built up highly material- and energy-intensive infrastructure (buildings, transport infrastructure, etc.) and basic industries, such as metal and chemical industries. 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 fact that the share of the agricultural sector in these emerging countries remains relatively high. It could also be a result of a 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 the absence of a broader process of resource-intensive industrialisation, a very small GDP thus goes hand in hand with a small material throughput 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.

One of the key challenges for sustainable development arises from the fact that no country in the world has so far achieved a sustainable situation in which high resource productivity and high levels of social and human development are combined with low per capita consumption. 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, have also outsourced domestic industries to other world regions and substituted domestic resource extraction and processing by imports of raw materials and semi-manufactured products. In order to illustrate these shifts, material productivity indicators need to include the indirect (or up-stream) material flows related to international trade. Japan may have less positive material productivity results if more comprehensive indicators were applied that included the indirect (or upstream) material requirements of imports and exports.

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 the 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 borders (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 and lower 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 the 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 CO₂ emissions

One of the purposes of this study was to investigate the interlinkages between material consumption and energy-related CO₂ 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 shows the correlation between material consumption (expressed with the Domestic Material Consumption indicator) and energy-related CO₂ emissions in the 19 Asian countries in 2005. The trend line illustrates a high correlation between these two indicators (Spearman coefficient: $r_s = 0.81$), implying that countries with high absolute levels of resource consumption also have high CO₂ emissions. Material metabolism and energy-related CO₂ 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 (Figure 13). The graphs for each country illustrate the development from 1985 to 2005. The figure reveals similar trajectories as Figure 10, which illustrated the relation between material consumption and GDP per capita. In some countries, notably China and the Republic of Korea, a linearly proportional increase in CO₂ emissions can be observed with growing material consumption. In some resource extracting economies (Indonesia, Malaysia) material consumption increased faster than CO₂ 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 supported the development of material-extensive sectors (in particular IT service sectors), which increased energy consumption (and thus related CO₂ emissions) faster than material consumption. CO₂ emissions per capita are almost negligible for the poorest developing countries, such as Bangladesh.

Figure 12: Material consumption (DMC) and CO₂ emissions, absolute numbers (2005)

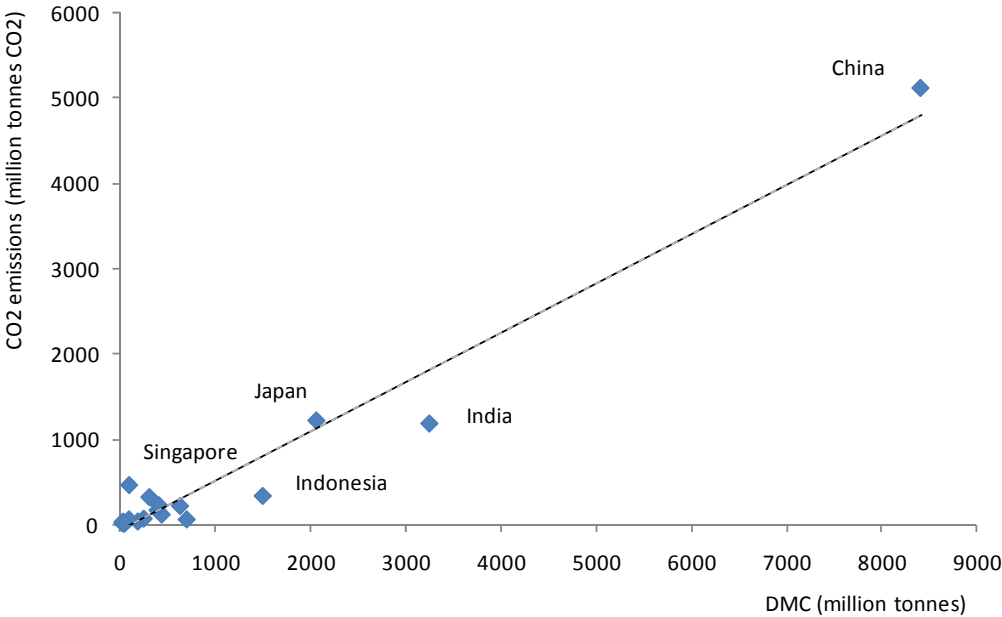
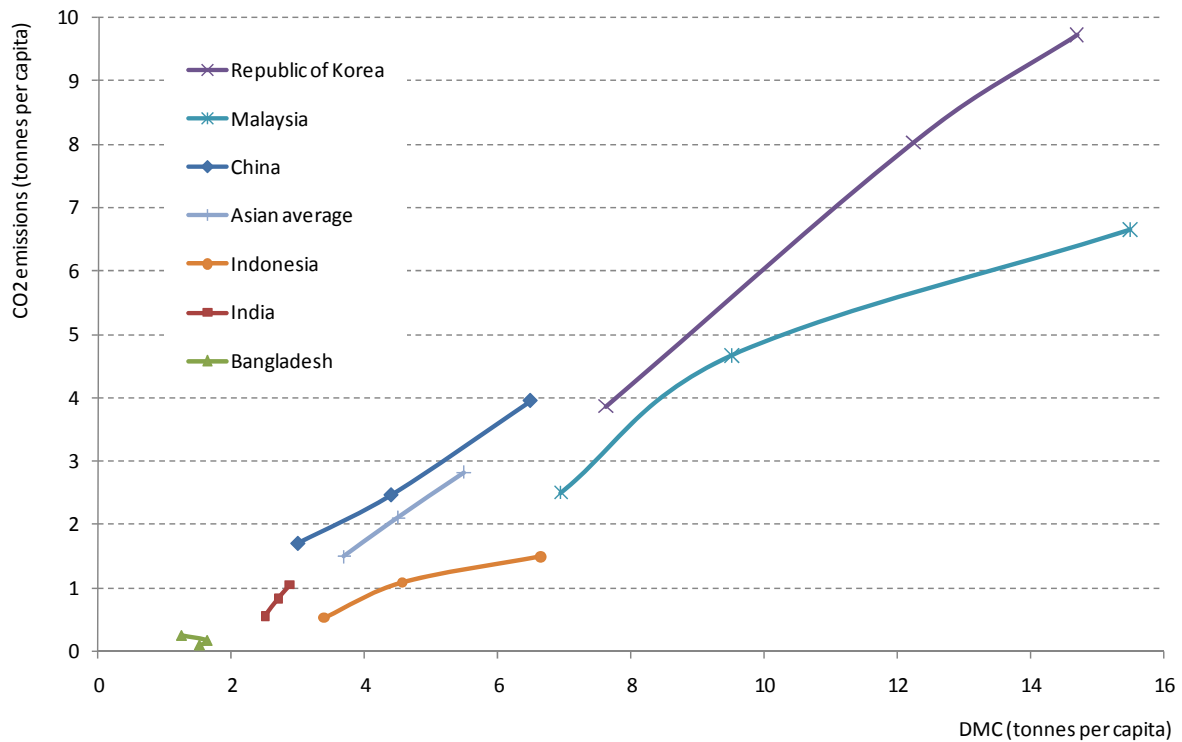


Figure 13: Material consumption (DMC) and CO₂ emissions, per capita, selected countries (1985-2005)



4 Conclusions and policy implications

This Working Paper 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, 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 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 may result in an almost linear growth of material consumption and energy-related CO₂ emissions, as the correlations carried out in this study have indicated.

While resource efficiency has increased significantly in some Asian countries over the past 20 years, economic growth has overcompensated these efficiency gains. Efforts therefore need to be intensified to make future economic growth in Asia “greener” and to further de-couple growth from material consumption and energy-related CO₂ 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 tonnes (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 four and ten (see for example von Weizsäcker 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 Republic 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 issue that can be informed by resource use indicators is the distribution of material affluence within Asia. No other continent has such extreme differences between countries. 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 one or two tonnes of resource consumption per capita, as observed in some Asian countries, even the most basic needs (food, shelter, health, education) can hardly be satisfied. For this group of countries, growth in absolute material consumption to increase well-being and related reduction of poverty is likely to be more important than 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 high consumption, as observed in some Gulf States, need to be identified and addressed.
- (2) For the dynamic emerging economies, it is important to improve the resource efficiency in

infrastructure developments, i.e. fostering energy and material efficiency in buildings, transport systems, etc., as well as improving efficiency in 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)** Low-income 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 to eradicate poverty. This group of countries is can benefit from the transfer of green technologies from abroad in order to achieve these objectives with the highest possible resource efficiency.

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