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# Indicators for a Resource Efficient and Green Asia and the Pacific

Measuring progress of sustainable consumption and production, green economy and resource efficiency policies in the Asia-Pacific region

UNITED NATIONS ENVIRONMENT PROGRAMME



THE UNIVERSITY OF  
**SYDNEY**

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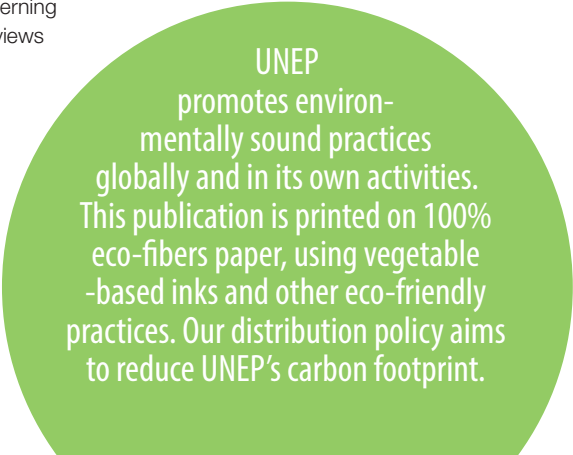
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# **Indicators for a Resource Efficient and Green Asia and the Pacific**

**Measuring progress of sustainable consumption and production, green economy and resource efficiency policies in the Asia-Pacific region**

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## List of abbreviations

ADB	Asian Development Bank
AMI	Adjusted Material Intensity (also referred to as Material Footprint Intensity)
CO <sub>2</sub> -eq	Carbon Dioxide equivalent
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DE	Domestic Extraction
DMC	Domestic Material Consumption (also referred to as Material Use)
EEA	European Environmental Agency
EF	Energy Footprint
EI	Energy Intensity
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GHG	greenhouse gas
GHGF	GHG emissions footprint
GHGI	GHG intensity (also known as carbon intensity)
IEA	International Energy Agency
IMF	International Monetary Fund
MF	Material Footprint
MI	Material Intensity
MJ	Megajoules
MRIO	Multi-Regional Input-Output
OECD	Organisation for Economic Co-operation and Development
PJ	Petajoules
PPP	Purchasing Power Parity
PTB	Physical Trade Balance
SCP	Sustainable Consumption and Production
SEEA	System of Environmental-Economic Accounting
TPES	Total Primary Energy Supply (also referred to as Energy Use)
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
WF	Water Footprint
WI	Water Intensity

## List of units

Tonne (t)	1,000 kg
Kilotonne (Kt)	1,000 t
Megatonne (Mt)	1,000,000 t
Gigatonne (Gt)	1,000,000,000 t
Kilojoule (kJ)	1,000 J
Megajoule (MJ)	1,000,000 J
Gigajoule (GJ)	1,000 MJ
Terajoule (TJ)	1,000,000 MJ
Petajoule (PJ)	1,000,000,000 MJ
Cubic meter	1,000 L
Kilolitre (KL)	1,000 L
Megalitre (ML)	1,000,000 L

# Foreword

At Rio+20 in 2012, heads of State called for “protecting and managing the natural resource base for economic and social development”.

This statement was a recognition that we need to use natural resources efficiently if we want to achieve and maintain our economic and social development goals, especially poverty eradication. Today, natural resources are often used inefficiently and indiscriminately in both industrialized and developing countries because environmental impacts are externalized. The current development paradigm focuses mainly on monetary growth, with a mentality towards resource use as out-of-sight, out-of-mind, that assumes resources will always be abundant and that there is no cost for disposal and contamination.

Understanding how efficiently we use natural resources is a vital step for designing policies to tackle inefficiencies. Indicators play a critical role for policy makers and stakeholders. Over the past three years, the Asia Pacific region has been engaged in a consultative and science-based process to develop a framework of indicators to measure and monitor resource use and understand how it contributes to economic and social development. At the request of governments and other stakeholders, and with the support of the European Union-funded SWITCH-Asia Regional Policy Support Component, the United Nations Environment Programme (UNEP), Australia’s national science agency CSIRO, and the Asia Pacific Roundtable on Sustainable Consumption and Production launched a process to develop science-based indicators that come to fruition through the publication of this report.

This report paints a clear picture of the path taken by the countries in the region over the past 40 years in their resource use. Today, the region dominates global resource use, comprising more than 50 per cent and consumption is rapidly rising as economies grow, infrastructure is built and the middle class expands. But even accounting for economic growth, resource efficiency in the region lags far behind the rest of the world, and varies dramatically between countries. As an illustration, developing countries in the region use an average of 5kg of resources for every dollar they produce, ten times that used by industrialized countries. This begs the question of where we should seek the fastest and best improvements in efficiency and where the Asia Pacific region can find the “low-hanging fruit” to achieve resource efficiency in this high-tech age.

The report and the datasets on which it is based are invaluable tools for countries as they develop their systems and processes for implementing and reporting on the post-2015 development agenda and the new Sustainable Development Goals (SDGs). Resource efficiency and secure access to natural resources and food feature prominently in the proposed SDGs: 13 of the 17 goals refer to the need to sustainably manage natural resources.

As a next step, UNEP will integrate the dataset of 118 indicators into UNEP Live so that it is publicly available. UNEP will also work directly with countries to support national processes to measure progress on resource efficiency and to integrate this vital data into the relevant policy processes including the SDGs.

I would like to thank the CSIRO and the Asia Pacific Roundtable on SCP for their substantive support in developing this report. The report provides the science to drive policies that will help us respond effectively to resource challenges and chart a more resource efficient development pathway.



**Achim Steiner**

Under-Secretary-General of the United Nations  
and Executive Director, United Nations Environment Programme (UNEP)

# Foreword

As the world evolves, balancing the challenges, opportunities and impacts of resource production and consumption becomes increasingly complex. The rapid pace of economic intensification around the world, together with growing concerns regarding energy security, environmental health and social inequity are fuelling international dialogues on how we manage our future development. The outcome document of the 2012 United Nations Conference on Sustainable Development (Rio+20), The Future We Want, clearly established that natural resources and well functioning ecosystems are a necessary condition for human development.

Nations will be affected by this international dialogue. It has therefore been a privilege to work over the past five years with the United Nations Environment Programme on the evolution of global indicators for sustainable consumption and production. This long-term relationship with the global community has enabled us to consider Australia's future position in a dematerializing world. The concepts around resource efficient economies are becoming important policy goals for Australia and its neighbours in Asia. This report presents an evidence base showing how progress towards more resource efficient and sustainable economies can be measured at regional and country level.

The report looks at the interdependencies of resource production and consumption, trade and economic dependency, resource efficiency, labour productivity and environmental footprint over time. In our globally connected future, no country will stand separate on these issues. National transitions towards a more resource efficient, lower carbon and sustainable economy will be set against a global backdrop and global expectations of performance. The data and indicators presented in this report provide a guide for potential transitions in Asia. These transitions will have a global impact.



**Alex Wonhas**

Executive Director: Resources and Energy  
Commonwealth Scientific and Industrial Research Organisation (CSIRO)  
Australia



# Highlights for Policymakers

Natural resources are the **foundation of economic development**. This report reveals the patterns and the evolution of natural resource use in the Asia and the Pacific region over the last 40 years. The analysis shows that resource use in the region is both inefficient and unsustainable. The Asia-Pacific region will not be able to base its future economic growth on declining costs of natural resources as was possible during most of the twentieth century. An increasing reliance on resources from abroad and volatility in the global resource markets will pose challenges to the economic resilience of countries in the region. In this new economic context resource efficiency and decoupling of economic growth and resource use will be fundamental to the economic success of the region. There is a window of opportunity, however, for Asia-Pacific countries to invest in policies and the infrastructure that will support sustainable consumption and production (SCP) in the decades to come. Acting now will reduce economic vulnerability, especially of low income groups, and will help secure the competitiveness of tomorrow in a low carbon resource efficient global economy.

- **The Asia-Pacific region consumes more than half of the world's materials with increasing rates of growth and increasing material use per person.**

This report uses the term “materials” representing an aggregate of biomass, metals, industrial and construction minerals, and fossil fuels. The use of materials in the Asia-Pacific region increased from 5.7 to 37 billion tonnes per year between 1970 and 2010. Global material consumption is 70 billion tonnes per year, so **the Asia-Pacific region uses more than half**. China dominates regional (at 64% of the total) and global (at 33% of the total) material use. At an annual growth rate of 5%, the Asia-Pacific region's material use is now the largest of all world regions and is also growing much faster than in the rest of the world.

Material use per person for the developing countries in the region has **increased fourfold from 2.3 tonnes to 9.3 tonnes per person** since 1970, with the great majority of this growth post-1990. Within the region, there is a wide diversity in trajectories and current rates. The Philippines stands out by not increasing its per capita material use at all between 1970 and 2010 despite major increases in GDP per person. Countries with small populations, such as Bhutan and small island developing states, also show higher per person rates of material use. Material use per person has **continuously increased for all of the region's industrialized countries (to an average of 15 tonnes per person), with the exception of Japan (9.1 tonnes per person)**. The highest material use is

found in Australia, at 44 tonnes per person, caused by the large extractive industry in the country but also resource intensive lifestyles.

- **There is great potential to improve the efficiency by which materials are used in the Asia Pacific region.**

On average, Asia and the Pacific **needs 3 kilograms of materials to produce one dollar of GDP** and this lags far behind of the rest of the world where on average only 1 kilogram is needed per dollar. Developing countries in the Asia-Pacific region **use five times as many resources per dollar of GDP (5kg/\$) as the rest of the world, and ten times more than industrialized countries (0.4kg/\$) in the Asia-Pacific region**. The regional averages mask wide ranges from 17kg/\$ in Mongolia and 12 kg/\$ in the Lao PDR, down to 0.3kg/\$ in Japan, with the poorer countries most dependent on natural resources often having very low resource efficiency. On average material efficiency has been improving in developing countries in Asia and the Pacific at a steady rate of 1.5% per year. The still low efficiency in the region shows that there is potential to improve resource efficiency.

- **Looking at the Asia-Pacific region as a whole, the majority of materials used are not for exports but for consumption in the region.**

For a region known as the “manufacturing hub of the world”, **the Asia-Pacific region is an exporter only in financial terms; in physical terms it is a net importer of materials**. This is true for many countries – China, Thailand, Japan and Singapore. Several countries in the region – China, Cambodia and Fiji among them – shifted from being net exporters to net importers as their domestic markets grew between 1990 and 2010. Others like Australia and Indonesia have remained net exporters.

While material use reflects the production of goods and services, “material footprint” is based on consumption patterns. The material footprint indicates the amount of resources or emissions that can be attributed to final demand (consumption and capital investment) in a country. It shows the responsibility of a country's consumption along the supply chain of resources and emissions which may occur anywhere in the world to satisfy final demand of that country. The footprint approach corrects the direct indicators for the upstream requirements of trade. If we take away all the material use dedicated to consumption outside the region, the Asia-Pacific region's material use for its own domestic purposes is 8% smaller, indicating a smaller regional material footprint than direct material

use, but with big variations among countries. In China and India, it is 15% lower (footprint is smaller than direct use), whereas in Japan and Singapore it is 115% and 95% higher respectively (footprint is larger than direct use). The material footprint of consumption in the **region grew at a rate of 8.7%, much faster than the growth rate of direct material use**, indicating increasing local consumption. Even in industrialized countries, material footprints continue to rise at 1% per year, showing that there is no level of income yet at which material consumption levels off.

The Asia-Pacific's material footprint grew threefold between 1990 and 2010. The sector that contributed the most was **construction with a fourfold increase**. Growth in material footprint was smallest in the agricultural sector, with a 1.8-fold increase.

- **Energy consumption has increased more than fourfold in developing countries in the Asia-Pacific region and is dominated by non-renewable energy sources.**

Regionally, demand for electricity, gas and transport fuel has increased more than fourfold and this is deeply influenced by the growing needs of a rapidly urbanizing China, which represented 52% of the region's energy use in 2010. While most nations have experienced an increase in primary energy use, Japan reached a plateau in its energy needs around 2000 and has achieved a modest decline in the past few years, although it is still the third largest energy consumer.

The growth of energy use in China and India has relied on coal. There has been a growing dependence on petroleum in the Republic of Korea, Singapore and Indonesia and on gas in Australia and Bangladesh. A growing number of private cars, gas powered appliances and plants has seen the increased use of petroleum and gas in the Asia-Pacific region and these primary energy flows that once were destined for export are increasingly finding more local markets. In the developing countries group in the region, **coal and petroleum represent three quarters of energy consumption** while in the industrialized countries **coal and petroleum were two thirds of overall consumption**. The supply of energy from non-hydro renewables (often in the form of biomass) has grown the least of all energy carriers over 40 years although this energy form comprises more than 10% of the region's primary energy supply.

- **Greenhouse Gas (GHG) emissions have increased fourfold, but emissions per dollar have reduced by three quarters in developing countries.**

In 2010 the Asia-Pacific Region emitted a total of **around 20 billion tonnes of GHGs, four times more than what it was emitting in 1970**. Over those 40 years Asia-Pacific regional emissions increased from 20% to 40% of the global total. Within the Asia-Pacific region, China is the largest emitter of GHGs and has increased the most in absolute terms and in its relative contribution: from 32% of regional GHG emissions in 1970 to 56% in 2010. During the last four decades, China experienced fast economic growth and urbanization but despite this, there was a five-year period of carbon decoupling during the mid-to late-1990s mainly caused by the Asian financial crisis. Since then the pace of producing emissions has accelerated and this was the dominant gross underlying trend for the whole region between 2000 and 2010.

Despite the massive increases in emissions, there has been a dramatic reduction of carbon intensity in developing countries. In 1970, carbon intensity was almost 10 kg CO<sub>2</sub>-eq per dollar, whereas in 2010, it came down to below 3 kg CO<sub>2</sub>-eq per dollar. The world average is less than 1 kg CO<sub>2</sub>-eq per dollar, showing that there is still enormous potential to reduce the carbon intensity of the Asia Pacific three fold further.

- **Water use per person is decreasing and water efficiency is improving, driven by the agricultural sector and irrigation.**

On average each person in Asia and the Pacific uses 544 m<sup>3</sup> of water per year in developing countries and 689 m<sup>3</sup> in industrialized countries. The regional averages mask the wide ranges in water use from 1,100 m<sup>3</sup> per person per year in Pakistan (where agriculture produces 22% of GDP and employs 43% of the labour force) but only 18 m<sup>3</sup> in the Maldives (where agriculture produces only 6% of GDP). For the Asia-Pacific region as a whole, the relative sectoral shares of water consumption were 80% for agriculture and 10% each for industry and municipal use.

During the past four decades, the region's share of the global water consumption increased only slightly, from 51% in 1970 to 55% in 2010, with the developing countries group accounting for over 51% of use and the industrialized countries group responsible for less than 4%. That growth in the Rest of the World is even slower than in the Asia-Pacific region further highlights the degree to which water extraction has become decoupled from economic growth. This implies that,

at a national level, it has been relatively easy to improve water efficiency. A key explanation for this trend is **the low financial return per unit of water used in agriculture, the main consumer** of water. Most sectors that compete with agriculture for water can easily out-bid the agricultural sector to secure their relatively modest water requirements in most circumstances, and still that water remains a relatively minor input cost. In **virtually all countries** (with a couple of exceptions) **water use per person declined between 1970 and 2010** indicating possible improvements in irrigation systems and a decline in the amount of agricultural products dedicated to export markets.

#### ▪ How to use this report?

Knowledge of current patterns of resource use can help countries to design and implement policies for resource efficiency. With more than 130 graphs and tables and 115,000 data points available, the report presents a comprehensive set of indicators of resource use at national and regional levels. By reading the full report each expert and decision maker will find information relevant to support decision-making for national policy priorities and development objectives. These highlights emphasize main messages of regional importance for high level policymakers and while they are representative of the main findings of the report, they cannot substitute for the entirety of the information and messages in this report.

As global resource demand grows and supply challenges are becoming more frequent, **countries need a comprehensive set of resource use indicators in order to make decisions about policy priorities, development and implementation.** This is exactly what this report provides: key findings from 118 indicators of resource use, measured over the past 40 years for 26 countries of the Asia and the Pacific region. The knowledge generated by this report helps to improve the understanding of the natural resource use and emissions consequences of economic growth in Asia and the Pacific to support policy formulation, monitoring and policy evaluation in the countries of the region.

To confront the sustainability challenge many Asian developing countries now have well-developed policies to encourage sustainable consumption and production (SCP), investments in the green economy, resource efficiency and

waste minimization, and low carbon development. They will also need to improve their institutional capacity to implement the policies. The information provided in this report is meant to assist countries in monitoring their policy achievements and if necessary redesign their policy tools and in some cases revisit their policy objectives.

The information and country level data in this report can also help countries to increase south-south and north-south cooperation, exchange of experience and technology transfer towards improving the resource efficiency of their economies.

Last but not least the large and comprehensive data set and information compiled in this report could become the foundation of a wider and more inclusive set of environmental information that countries could start to measure and publish in a systematic and comprehensive way that can contribute to measuring progress towards the achievement of the Sustainable Development Goals.



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# Introduction

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## Key messages:

- Natural resources are critically important for economic development, poverty eradication and environmental sustainability - all three pillars of Sustainable Development.
- Resources fundamentally underpin and fuel human development through the provision of food, feed, fuel and fibre for people, and as inputs to all economic activities.
- Low income groups in Asia and the Pacific are far more vulnerable to fluctuations in resource price, availability and quality.
- Natural resource use is the direct interface between the economy and our global environment, since the extraction of resources creates local environmental impacts and land use change, and the use and disposal of resources causes emissions to the air, water and soil systems on which we depend.
- As the global resource demand grows and supply challenges are becoming more frequent countries need a basket of resource use indicators in order to make decisions about policy priorities, development and implementation.
- There is a window of opportunity for Asia Pacific countries to invest in policies and the infrastructure that will support sustainable consumption and production in the decades to come.

## A new industrial revolution is needed to make the most of the spectacular growth and looming challenges characteristic of the Asia-Pacific century.

**“4. We recognize that poverty eradication, changing unsustainable and promoting sustainable patterns of consumption and production and protecting and managing the natural resource base of economic and social development are the overarching objectives of and essential requirements for sustainable development.”**

“The Future We Want”, Resolution adopted by the General Assembly on 27 July 2012, at the 20<sup>th</sup> United Nations Conference on Sustainable Development

In this fast changing world, human development and environmental sustainability need to be aligned. This was emphasized by the Rio+20 outcome document, which underlined the fundamental role for natural resources in enabling sustainable development and identified a process for establishing new sustainable development goals (UNEP, 2014a). The Asia-Pacific region has embarked on a new path of economic development to achieve sustainable development goals for the region based on sustainable consumption and production and sound management of natural resources and ecosystems.

The Asia-Pacific region is unique for a number of reasons. The region is home to an increasingly large share of the world’s population, it has a great number of large cities, and differences between urban populations and people living in rural, agricultural settings are pronounced with regard to income, opportunities, aspirations and identity. Many developing countries in the Asia-Pacific region find themselves in the midst of a rapid industrial transformation, which is occurring at unprecedented scale and speed. Development policy is formulated against the backdrop of the dual objectives of increasing the material standard of living and eradicating poverty, while ensuring the integrity of the resource base and ecosystems at the same time. The need for economic growth and human development often takes a short-term view that marginalizes environmental sustainability, which in turn will constrain future development opportunities over the medium and long term. While many countries in the region have successfully lifted people out of poverty this has come at a cost of increased use of natural resources, growing emissions, and rising amounts of waste as this report will demonstrate.

The Asia-Pacific region has now become the largest world user of natural resources and the systems of production and consumption that have been established are tailored to the current high levels of resource use and emissions. In 2010, Asia and the Pacific housed 3.6 billion people or 55% of the global population, used 36 billion tonnes or 53% of

global materials, 210 PJ or 38% of global energy and produced 20 billion tonnes or 39% of global greenhouse gas emissions. Growth in natural resource use and emissions in Asia-Pacific started from a very low base in 1970 and has since accounted for most of the global growth, demonstrating the enormous economic and social dynamic which comes from this region. On the other hand, per capita material and energy consumption and per capita greenhouse gas emissions are still significantly lower than in industrialised countries and have only just approached global averages, signalling future growth to come. To grow human well-being in the next decades to come, countries have choices about which resource efficiency opportunities to seize.

The demand for natural resources in Asia and the Pacific for building modern cities, transport systems, manufacturing capacity and to furnish the lifestyles of the new urban middle and upper classes has been tremendous. On some occasions, supply systems have not kept up with growing demand, leading to supply insecurities reflected in higher world market prices for food, timber, fossil fuels and many metals, especially in 2008–09. This has put food and energy security high on the political agenda in many countries and working together to reduce risk and vulnerabilities of climate change, food security and natural resources has become a main objective of regional cooperation in Asia and the Pacific. Water is another important natural resource fundamental to human development which has increasingly come under stress in many countries. It has been a challenge to deliver the required amounts for agriculture, the fast-growing manufacturing industry, and urban settlements in many places.

The growing amount of emissions has not just contributed to high levels of urban air pollution but has also accentuated climate change caused by increasing levels of greenhouse gas emissions. In addition, the region has experienced a high frequency of climate-related natural disasters including fires, flooding and extreme wind and heat. Climate change, food and energy security and supply shortages for

certain industrial materials have converged in an unprecedented manner.

The Asia-Pacific region, over the past four decades, has also become more integrated into world markets through the globalization of capital, employment, and – as this report will show – the flow of natural resources. In many countries the local resource base has been degraded and countries increasingly rely on imports of fossil fuels, metals and more recently also food from the world market. Very high and volatile prices for many natural resources have made economic planning more challenging, especially for Asian developing economies whose development has previously relied on affordable natural resources. It can be assumed that developing countries in Asia and the Pacific cannot rely on an economic development model that has been available to today's industrialised countries, which profited from a century of low and decreasing prices for natural resources (UNEP, 2011c).

Not only has the global demand for natural resource use and goods and services increased in recent decades, there has also been growing differentiation between resource exporting and importing economies. The position of a country in international trade of natural resources creates a very specific policy context and economic vulnerabilities that need to be dealt with in policy and planning. Since prices for natural resources were at a highpoint in 2008, importing countries have shown increased interest in adopting policy settings that enhance resource efficiency to reduce costs, improve the environment, and increase economic and social resilience of businesses and households. Interest in resource efficiency in exporting countries characterized by energy and resource-led economic development has been much less pronounced and more difficult. In Asia and the Pacific, we find examples of resource importers such as Japan and China, and exporters such as Australia, Indonesia and the Lao People's Democratic Republic (Lao PDR), and aligning goals among these two groups is an important objective of regional development.

Over the past decade, there have been many efforts in policy development to harmonize economic, environmental and social goals. Many countries now have policy initiatives for material and energy efficiency, climate mitigation, and investment in green sectors such as renewable energy, low-carbon buildings, eco-efficiency of heavy industry, and public transport. Investment in green sectors is growing but often competes with investment in brown sectors. The policy tools of sustainable consumption and production (SCP) are increasingly used by governments and businesses in Asia and the Pacific aiming to decouple economic activity from environmental pressure and

impacts. While the state of policy development is now very mature, implementation is still lacking in many countries because of gaps in funding, human resources and institutional arrangements (UNEP, 2013).

It is now time to measure progress of resource efficiency, green economy and SCP initiatives with regard to their outcome for natural resources and ecosystem health. In this report we present new data and indicators for 19 Asian and two Pacific developing countries and compare their progress in reducing environmental pressure and impact with five industrialized countries of the region. We report national figures for material, energy and water use and greenhouse gas emissions and put them in relation to population and economic trends. For the first time we report territorial resource use and emissions (the production perspective) and resources and emission footprints (the consumption perspective). Providing both a territorial and a footprint point of view is important for a region that has become the workshop of the world and is now producing a large share of manufactured goods purchased by consumers outside of Asia and the Pacific.

The indicators presented here are based on a sound conceptual framework of industrial metabolism, are compatible with the system of national accounts and the System of Environmental-Economic Accounting (SEEA)<sup>1</sup> framework and are based on existing and well-accepted economic data (Schandl and Chiu, 2013). They focus on the physical economy and the natural resource and emission consequences of economic development in the region.

The aim of this data-rich report is to allow the policy and business, as well as the general public, to be informed about progress in their countries and allow for comparisons between countries around efforts to decouple human well-being from ever increasing natural resource use. The report may raise awareness of new policy issues, enable trend analysis and target setting and will allow the evaluation of progress of SCP, green economy, and resource efficiency policies across the whole economy. The data that underpin the analysis presented in this report are available at the UNEP Live online data sharing platform at <http://uneplive.unep.org/>.

<sup>1</sup> <http://unstats.un.org/unsd/envaccounting/seea.asp>





# Indicators for natural resource use

## Headline Indicator 'Natural Resource Use'

- **Natural resource use, total and per capita.**
- **Materials and Waste** – Domestic Material Consumption (DMC) (tonnes; tonnes per capita) In this report the terms DMC and materials use are used interchangeably.
- **Energy and Emissions** – Total Primary Energy Supply (TPES) (joules; joules per capita), Greenhouse Gas Emissions (GHG) (tonnes; tonnes per capita), air pollution (tonnes; tonnes per capita) in this report referred to as energy use and carbon emissions
- **Water** – Total Water Use (m<sup>3</sup>; m<sup>3</sup> per capita)

Normally, natural resource use should include “Land – Land use and land use change (ha; ha per capita)”, but this is outside the scope of this report. A useful reference is The International Resource Panel's assessment report “Assessing Global Land Use” (UNEP, 2014d).

Methods for measurement: Methods for measuring natural resource use across all resource domains are well developed and practical to implement at national level, with the exception of waste accounting.

Data sources: Data for material use were sourced from the CSIRO and UNEP Material Flow and Resource Productivity Database, energy use from the International Energy Agency (IEA) scale of physical flows which underpin economic activity, emissions from the EDGAR database, and water use from AQUASTAT. Waste was not included in the analysis because of severe data limitations.

Policy Use: Total natural resource use data is an important evidence base for dematerialization and decoupling policies. These headline indicators show the scale of the scale of physical flows which underpin economic activity. Domestic material consumption (DMC) and total primary energy supply (TPES) are indicators for apparent consumption and include intermediate use. They do not report final consumption. DMC can also be interpreted as national waste equivalent as all resources ultimately will become a waste flow.



Great economic achievements and increased levels of economic well-being have been based on rapid increases in material, energy and water use and greenhouse gas emissions. The Asia-Pacific region is the largest user of natural resources and low per capita use and fast growth rates suggests further growth to come.

This chapter presents an overview of trends in **natural resource use – materials, energy and water – and trends in emissions** using a territorial approach and covering the past four decades. Each chapter presents indicators for 19 developing countries, two Pacific island economies and five industrialized countries in the region.

## 2.1 Material Use

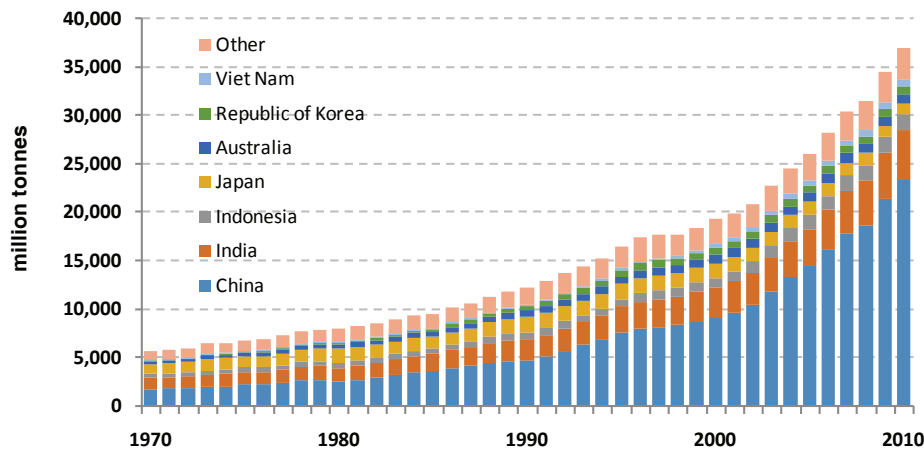
For material use we employ the indicator domestic material consumption (DMC) which reports the overall amount of **materials** (in metric tonnes) used in an economy including such diverse materials as biomass, fossil fuels, metal ores and non-metallic minerals. These materials underpin human nutrition and health, fuel energy systems and provide the structural base for buildings, transport networks, vehicles and all consumer goods. DMC sums materials extracted domestically and imported materials and subtracts exported materials. The four categories dealt with in this report, and their constituent 13 subcategories, are given in Table 2.

**Table 1 The four categories of materials included in DMC, with decomposition into 13 subcategories**

Four material categories	Thirteen subcategories
Biomass	Crops
	Crop residues
	Wood
	Animal products
	Grazed biomass
	Fodder crops
Fossil fuels	Coal
	Petroleum
	Natural gas
Metal ores	Ferrous ores
	Non-ferrous ores
Non-metallic minerals	Industrial minerals
	Construction minerals

DMC is an indicator of apparent consumption, and measures the amount of materials that are physically managed by the country. It includes the intermediate use of materials in production for domestic and final demand. DMC is the most widely used indicator from material flow accounting. The OECD uses DMC as a headline indicator for Sustainable Materials Management (OECD, 2011), and the European Union reports DMC as a headline indicator for resource policy dialogue and monitors it for all its member countries through the European statistical office (Eurostat, 2013). DMC can also be interpreted as an indicator for the waste equivalent of an economy since all materials reported in DMC will end up, sometimes with a long time lag as is the case for construction materials, as waste flows.

It should be noted that because DMC is a flow indicator, on its own, it cannot give us sufficient information to determine the sustainability of resource use. For a more complete picture, material use data should be paired with information about the quantity and quality of the resource base from which the resources are being obtained.

**Figure 1 Domestic material consumption, Asia-Pacific region (1970-2010)**

The large magnitude and rapid pace of increase in the region's materials use is a key finding of this report. The use of materials in the Asia-Pacific region increased from 5.7 to 37.0 billion tonnes in the 40 years from 1970 to 2010. The seven countries with the highest DMC in the Asia-Pacific region in 2010, shown in Figure 1, accounted for over 91%

of the regional total of 36.8 billion tonnes. DMC for the region as a whole grew at an annual compounding rate of 4.8% p.a. for the full time period (1970–2010), with this growth trend dominated by the growth in the developing economies. China's DMC grew at 6.6% p.a. over the period, increasing its share of regional DMC from 31% in 1970 to 64% in 2010. In the later period, some other developing members of the region also posted very rapid growth in DMC, most notably Viet Nam, which grew at 9.9% p.a. from 1990 to 2010, off a very low initial base.

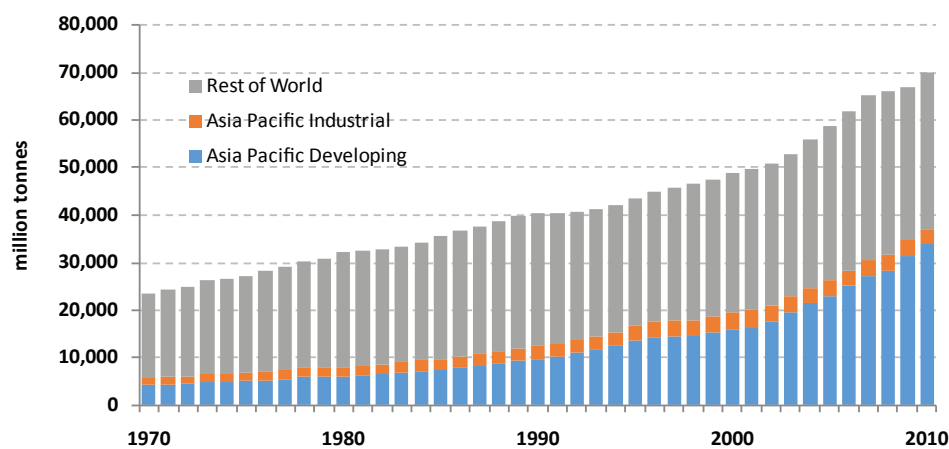
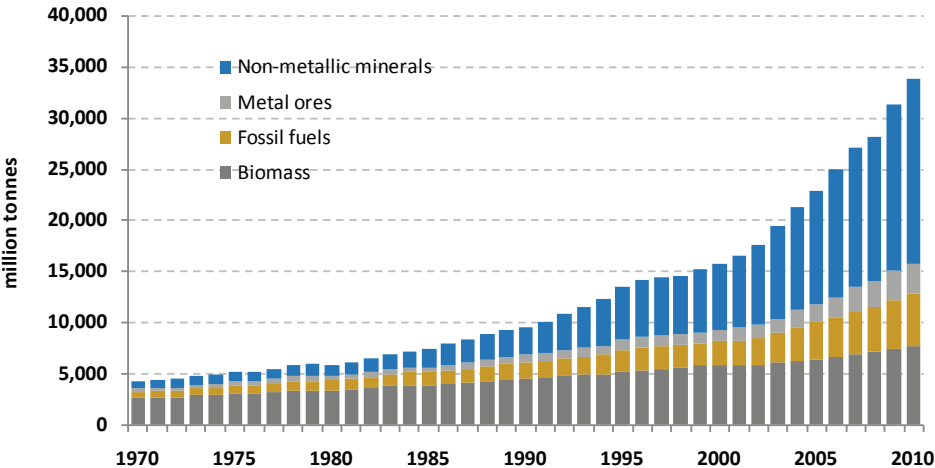
**Figure 2 Domestic material consumption, Asia-Pacific region and rest of world (1970-2010)**

Figure 2 illustrates how exceptional regional growth in DMC has been for the developing group, averaging 5.3% yearly growth, compared to the rest of the world, which only grew at 1.6% per year from 1970 to 2010. As a consequence, the regional share of global total DMC increased from 24% at the start of the period to 53% by

2010. While the region's industrialized group has been increasing DMC at a much slower rate than the developing group, at around 1.8% per year, this is faster than the average for the Rest of World. An important feature of the growth trajectory for the region as a whole is that it actually accelerated in the latter half of the time period, from 3.9% for 1970–1990, to 5.6% per year for 1990–2010. While high growth rates off a low base are common, the rate of growth in resource consumption in the Asia-Pacific region has actually accelerated as its share of World resource consumption increased. This has led to a situation where the largest share of the World's physical economy, far from stabilizing, is also the most rapidly growing. The effects of the financial crisis of 2008 are reflected in a slowing of the rate of growth for 2008 and 2009, but it appears to have substantially rebounded by 2010. The detail in Figure 2 indicates that this slowing was restricted to 2008 alone for the developing group. The key message of this is that the Asia-Pacific region's developing countries are increasingly dominating global resource use and there is no sign of slowdown in the expansion of material use.

**Figure 3 Domestic material consumption by material category, Asia-Pacific developing countries (1970-2010)**

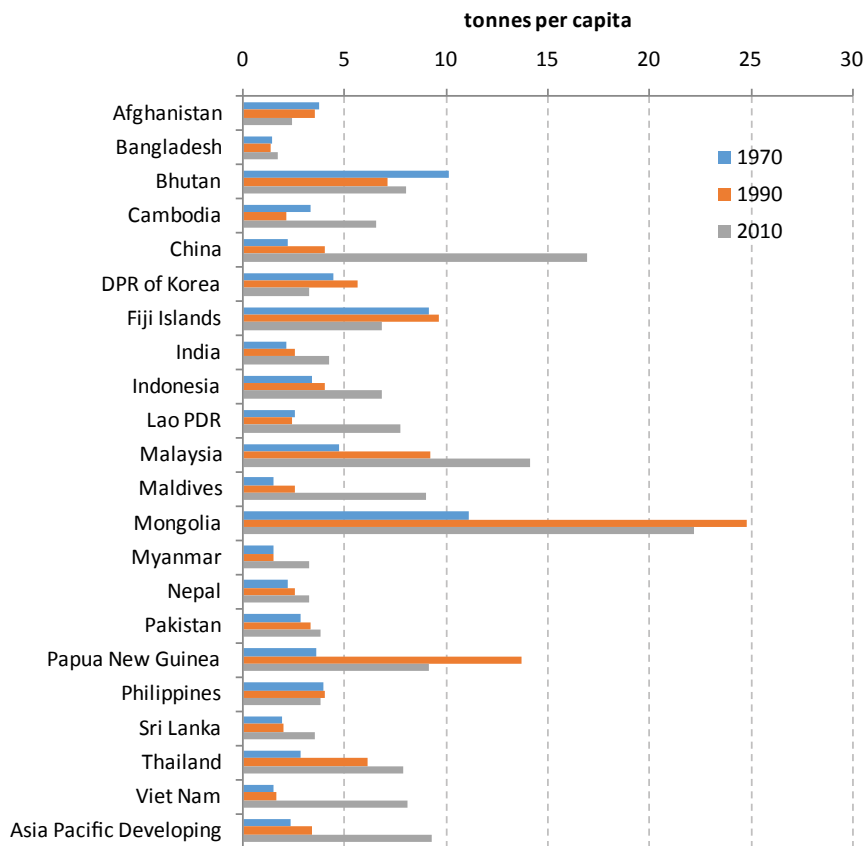


Policymakers engaged in resource efficiency policies will have an interest in the composition of material use to identify options for policy intervention for specific materials. When we look in more detail at the composition of the primary materials consumed by the developing group, (Figure 3) we see clearly that the relative rates of growth between different categories of materials vary greatly, with construction materials having the highest growth rate. The patterns in the changing shares between materials are consistent with what we expect of nations undergoing socio-metabolic transitions from advanced agrarian to industrialized society. A move away from biomass resources towards minerals is a common feature of a developing nation changing from the biomass based materials and energy systems of an advanced agrarian society to the mineral based systems of industrial society (Fischer-Kowalski and Haberl, 2007). This transition did not lead to a decrease in total consumption of any material group, however, with a much higher requirement for all materials in 2010 compared to 1970.

While the share of biomass of total DMC decreased from 63% in 1970 to 23% in 2010, the total tonnage of biomass consumed actually increased by 185%, a growth rate of 2.7% per year. This compares with compounding growth rates of 5.8%, 6.1%, and 8.3% respectively for fossil fuels, metal ores, and non-metallic minerals. The massive growth rate in non-metallic minerals (a category overwhelmingly composed of construction aggregates) resulted in consumption increasing by a factor of over 24 times over the period, and its share of total DMC increasing from 17% in 1970 to 53% by 2010. This is indicative of a very large investment in durable, long-lived infrastructure. The corresponding factors of increase in consumption of fossil fuels and metal ores over the period were nine times and 11 times respectively.

How much of this growth is simply due to the increase in population between 1970 and 2010? To answer this question, we investigate the per capita figures.



**Figure 4 Domestic material consumption per capita, Asia-Pacific developing countries (1970, 1990, 2010)**

Some increase in DMC would be expected due to the increase in population of the region over time, however, as Figure 4 shows, it is increasing DMC per capita within the developing group which has been the main driver of increasing DMC overall. In Figure 4 we see that DMC per capita for the developing group increased fourfold from 2.3 tonnes to 9.3 tonnes per capita over the period, with the great majority of this happening post-1990. The aggregated measures for the developing group inevitably reflect mainly an average of the region's two population giants, China and India. This means that while there is great diversity in the DMC trajectories of individual nations, with a number of countries showing roughly constant

or even decreasing DMC per capita from 1970 to 2010 (e.g. Afghanistan, Bhutan, Fiji, DPR of Korea, the Philippines), the regional average remains roughly intermediate between China and India for all periods. With this in mind, it can be seen that when both China and India had roughly equal per capita DMC in 1970 (2.1–2.2 tonnes per capita), the developing group also averaged around 2.3 tonnes per capita. By 2010, China and India's DMC per capita had diverged markedly, to 16.8 and 4.2 tonnes per capita respectively, with the regional average climbing to 9.3 tonnes per capita.

The nation specific data in Figure 4 also highlights the effects that some economic reforms have had on per capita resource requirements of a number of countries. Of particular interest are China, India, and Viet Nam. An earlier take-off in China's consumption, which nearly doubled between 1970 and 1990, reflects the economic growth subsequent to a programme of major economic reforms which began by the late 1970s, around halfway through this early period. In contrast, the major economic reform in the other two countries did not take place until considerably later, with "Doi Moi" in Viet Nam initiated in 1986, and the dismantling of many economic controls in India following that country's Balance of Payments crisis in 1991<sup>2</sup>. Both countries' per capita levels of DMC grew little over the 1970 to 1990 interval<sup>3</sup>. In the full post-reform period, from 1990 to 2010, we see in contrast that India's DMC per capita almost doubled, while Viet Nam's increased fivefold.

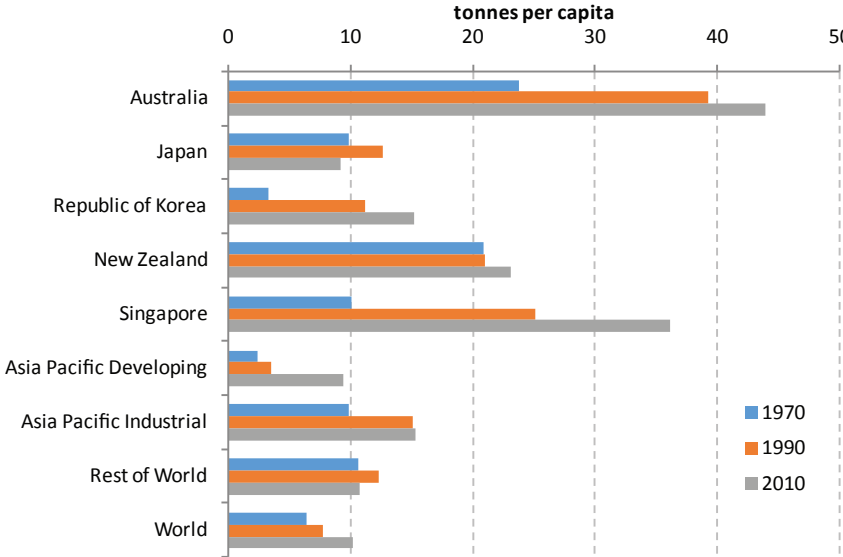
<sup>2</sup> Ghosh (2006) provides a description of the external and internal constraints on India's path through this crisis, while Szalontai (2008) provides good context on the genesis of Viet Nam's Doi Moi.

<sup>3</sup> In the case of Viet Nam, it must be kept in mind that the quality and consistency of statistics for the first decade (1970–1980) is likely questionable, due to the economic devastation accompanying several decades of post-colonial and other wars, and the subsequent merger of two separate states (North and South Viet Nam) into one.

Within the south-east Asian countries two groups and two different growth trajectories can be discerned, with Thailand and Malaysia on the one hand, which have shown steady growth over both periods, and the Lao PDR/Cambodia/Myanmar group where, like Viet Nam, DMC per capita grew little or contracted over the 1970 to 1990 period, but then grew strongly in the second period. Indonesia's trajectory appears intermediate between these two groups. In the case of the Lao PDR and Cambodia, their profiles might perhaps be linked to their proximity to Viet Nam and the influence of political and economic developments there. On the other hand, the growth spurt seen from 1990 to 2010 might also be explained by the regional effects of Chinese demand for primary and partially processed imports, which became massive during the second period (discussed further in Chapter 5). The Philippines stands out as a country that grew economically over the 40 years, but maintains the same DMC per capita.

The strong declines in per capita DMC seen for the two large Pacific island states, Papua New Guinea and Fiji, for the 1990 to 2010 period, appear to have different origins. While Papua New Guinea had a strong decline in DMC from its fossil fuel sector, this accounted for less than one tonne per capita. The main cause was the rapid rate of population growth, which increased by 65% from 1990 to 2010, the second-highest rate (after Afghanistan) for the developing group. In contrast, Fiji's population growth over the period was modest, at 18%. There, the declines in per capita DMC were mostly a result of falling total DMC in its two dominant categories, biomass and metal ores, which declined by 39% and 33% respectively.

**Figure 5 Domestic material consumption per capita, Asia-Pacific industrialized countries (1970, 1990, 2010)**



In Figure 5 we see that the pattern of DMC per capita has been one of continuous increases for all of the region's industrialized countries, with the exception of Japan. The Japanese economy is such a large portion of this group's total DMC, however, that its reductions over the period from 1990 to 2010, curtailed any growth in the industrialized countries group's average per capita DMC over this period. Total growth in per capita DMC for the industrialized countries group over the full

period 1970 to 2010 at 1.0% per year was modest compared to the 3.6% per year for the developing group, however it was high compared to the Rest of World, which did not grow at all over the full period (an increase of around 0.7% per year from 1970 to 1990 was offset by a decrease of -0.7% per year from 1990 to 2010). This highlights the pre-eminent role that the Asia-Pacific region had in driving global growth in materials consumption from 1990 onward. The largest absolute increase in for any country in the Asia-Pacific region overall was for Singapore, which saw per capita DMC increase by over 26 tonnes between 1970 and 2010, with Australia, China, and the Republic of Korea following with increases of 20.2, 14.7, and 12.0 tonnes per capita respectively.

A particularly noteworthy feature of Figure 5 is that Japan's decrease in DMC per capita, to 9.1 tonnes per capita, has positioned it below the average level of the developing group at 9.3 tonnes per capita. This might be taken to indicate that Japan has achieved a model of growth which enables it to enjoy one of the highest standards of living on Earth with relatively modest (and declining) materials consumption. This interpretation, while superficially true, misses the important caveat that such a model is in essence a zero-sum game which in large part relies on outsourcing materials- and energy-intensive processes to other countries. As such, it is not a development model which can be applied at a global scale. Indeed, we see a larger scale manifestation

of this phenomenon in Figure 5. The decrease of the Rest of World DMC we see there can, in large part, be explained by countries like China, the Republic of Korea, some of the south-east Asian countries, and Australia collectively performing a disproportionate share of materials- and energy-intensive industrial processes for the Rest of World. This issue has been raised in previous UNEP reports, e.g. UNEP (2010, 2011), with detailed discussion of some of the key mechanisms operation in the academic literature e.g. Giljum and Eisenmenger (2004), Muñoz et al. (2009), and Schandl and West (2012). What if we account for the materials needed to produce the imported products? Importantly, this report includes alternative methods of attributing resources use to true end users, which reduce the effect of lowering apparent resource use by outsourcing. For materials, this is done via the “material footprint”, discussed in Section 6.1 Material footprint of consumption.

## 2.2 Energy Use

Energy use is measured with the indicator primary energy supply. This indicator reports the total amount of energy (in joules) available to businesses and households in an economy by summing up domestically produced energy and energy imports and subtracting energy exports. The supply of **primary energy** may come from different energy sources including **coal, petroleum, natural gas, uranium, and renewable energy sources** such as hydro, solar and wind. **Electricity** is only included if it is exported or imported – in all other cases it is derived from one of the energy sources already measured. There is an important link between economic growth and the amount of energy that is available and hence energy can be considered as a factor of production which importance is well beyond its share of factor cost. The amount of energy used and the characteristics of energy sources, most importantly their carbon intensity, determine the emission profiles of an economy.

The energy needs of Asia-Pacific nations are indicated here by the measure of **total primary energy supply<sup>4</sup> (TPES)**, which we define as in the International Energy Agency’s Energy Balances. This is the sum of domestically produced energy and energy imports subtracting energy exports. Primary energy refers to energy sources prior to refinement, transformation or losses in the delivery of “final energy” for consumption by end users. The supply of primary energy may come from different energy sources including coal, petroleum, natural gas, uranium, and renewable energy sources such as hydro, solar and wind. There is an important link between economic growth and the amount of energy that is available and hence energy can be considered as a factor of production which has importance well beyond its share of factor cost. The amount of energy used and the characteristics of energy sources, most importantly their carbon intensity, determine the emission profiles of an economy.

The initial source for time series data was the Energy Balances published by the International Energy Agency (IEA). This provides annual data from 1971 by energy flows (domestic production, imports, exports TPES and final consumption) and energy carriers or products. The IEA Energy Balances are more detailed than the requirements of this report and we aggregated their list of energy carriers to the following categories: coal, electricity, hydropower, natural gas, non-hydropower renewables, nuclear and petroleum (including oil and LPG). For Fiji, the Lao People’s Democratic Republic and the Maldives, other energy forms also contribute to energy totals and our reported total may differ from the sum of TPES over energy carriers.

There were six countries that were not covered by the IEA data: Fiji, the Maldives, the Lao People’s Democratic Republic, Afghanistan, Bhutan and Papua New Guinea. Data for the first three of these countries were obtained from the US Energy Information Administration (EIA)<sup>5</sup> though these records only commence in 1980. Data for Afghanistan, Bhutan and Papua New Guinea were sourced from United Nations Energy Balance publications (2007–2010), which had detail on sectoral energy use, otherwise unavailable from EIA.

All raw data were either measured or converted to Petajoules or Gigajoules per capita. International marine and aviation bunkers have not been included in our accounting and the energy sector’s own consumption is accounted for here as a positive entry in final energy consumption, which is different from the usual IEA format of it being a negative entry in energy transformations and losses. Totals include heat where there are data for heat flows.

4 <http://www.iea.org/stats/defs/Tpes.asp>

5 <http://www.eia.gov/>

It is important to acknowledge that there are transformation processes between primary energy supply and final energy consumption that we have not shown here. These processes, including distribution, may involve different efficiencies, and energy requirements for some nations may reflect high losses in their energy systems rather than high final energy consumption in society and the economy.

The long-term trends in TPES for significant energy users in the Asia-Pacific region are shown in Figure 6. Regionally, demand for electricity, gas and transport fuel has increased more than fourfold and this is deeply influenced by the growing needs of a rapidly urbanizing China, which represented 52% of the region's TPES in 2010. Chinese TPES increased from less than 20,000PJ per year to over 120,000PJ per year between 1970 and 2010. Until 2000 the rate of Chinese TPES growth was 3.7% per year but between 2000 and 2010 there was an acceleration of energy use at a rate of over 8% per year. Over the whole study period there was more steady growth in primary energy needs in India (3.9% per year) where TPES also increased sixfold though, again, there was an acceleration in that growth over the last 10 years (4.7% per year).

While most nations have generally experienced an increase in TPES, Japan is notable for reaching a plateau in its energy needs around 2000 and even experiencing a modest decline in the past few years, although it is still the third largest energy consumer. In 1970 Japan represented 26% of the region's TPES (11,200PJ per year) and now this is 10% (21,000PJ per year).

**Figure 6 Total primary energy supply, Asia-Pacific region (1970-2010)**

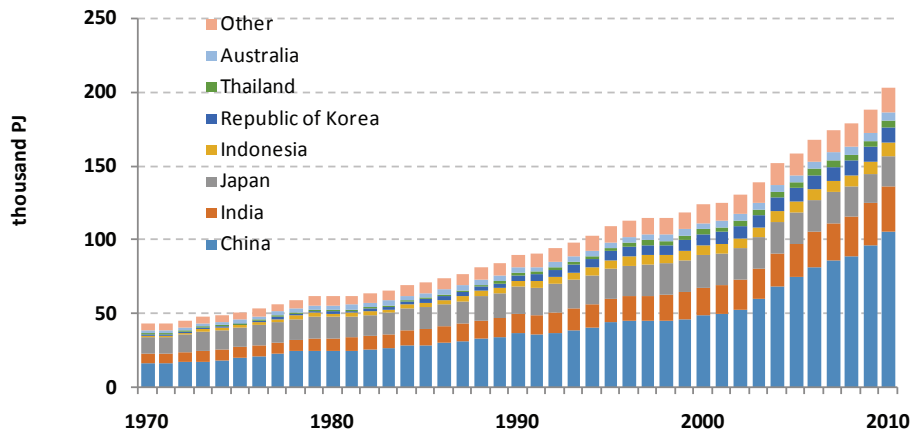
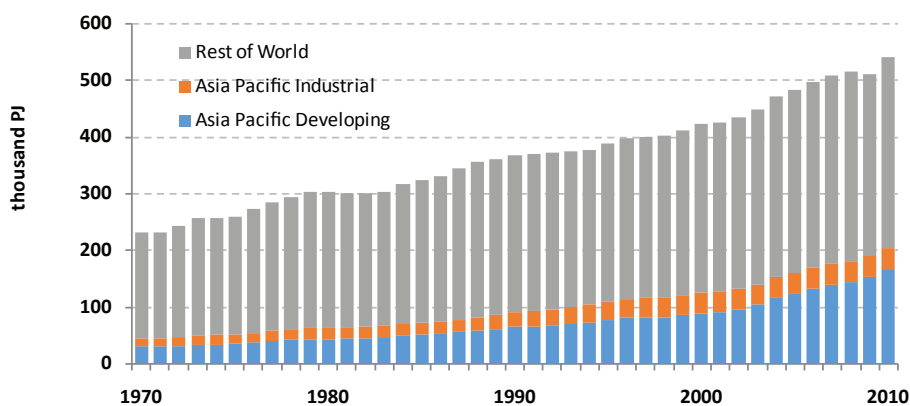


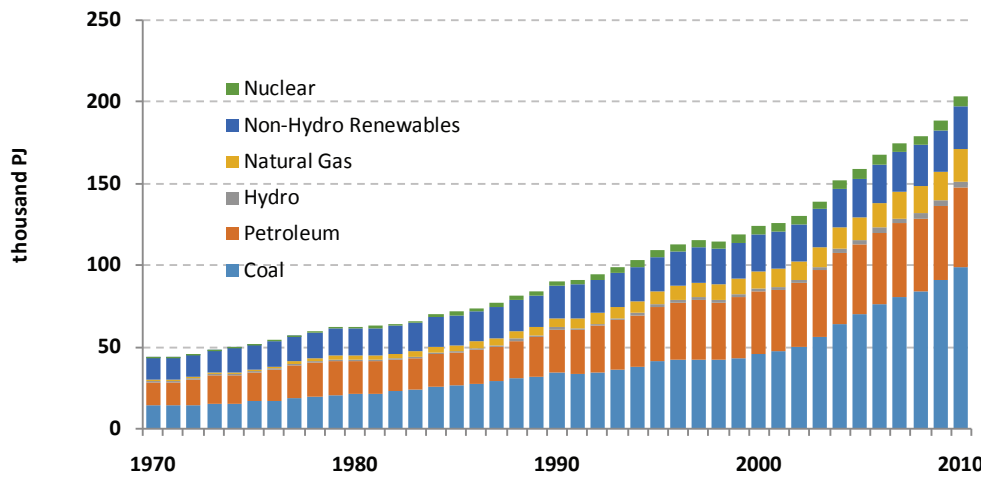
Figure 7 shows the TPES for Asia-Pacific industrialized countries and developing subregions and the Rest of the World. The prominence of the developing Asia-Pacific nations has risen from 12.5% to over 30% of global TPES, underlining the faster rate of growth in this subregion.

**Figure 7 Total primary energy supply, Asia-Pacific region and rest of world (1970-2010)**



Whereas a large component of the growth in China and India has relied on coal, there has been a growing dependence on petroleum (notably in the Republic of Korea, Singapore and Indonesia) and gas (notably in Australia and Bangladesh). Southern Asian nations are proximal to oil and gas reserves and recent international investment has made deep water and other marginal fields more accessible.

**Figure 8 Total primary energy supply by energy carriers or products, Asia-Pacific (1970-2010)**

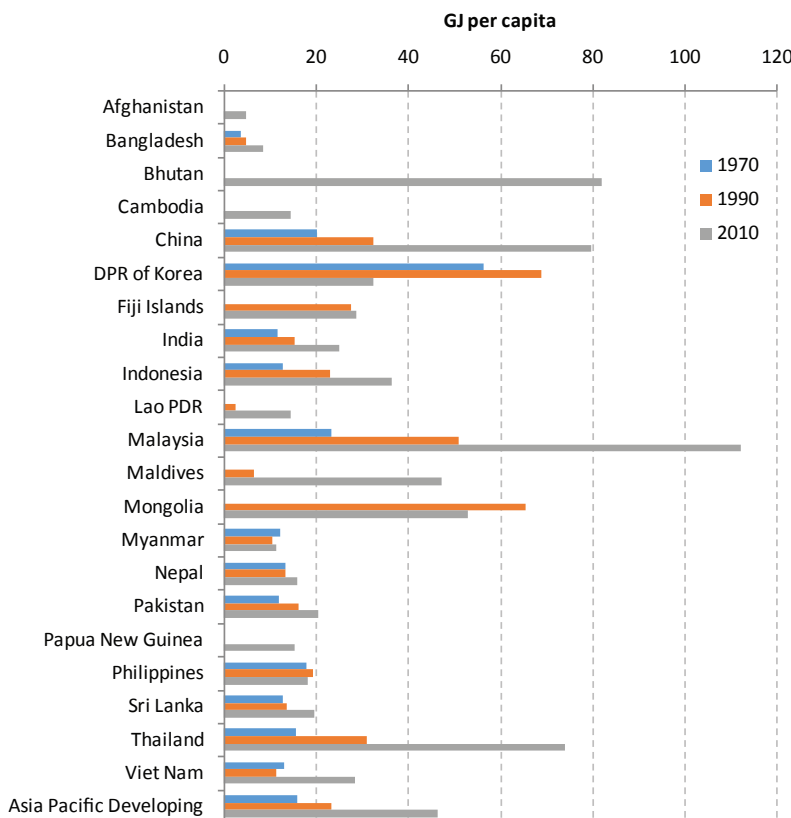


Penetration of automobiles, gas powered appliances and plant has seen the increased use of petroleum and gas in the Asia-Pacific and these primary energy flows that once were destined for export are increasingly finding more local markets.

The supply of energy from non-hydro renewables (often in the form of biomass) has grown the

least of all energy carriers over 40 years (1.6% per annum) although this energy form comprises more than 10% of the region's TPES. Hydropower has increased 4.5% per year since 1970, petroleum supply has risen 3.1% per year, and coal at 5% a year. The energy carriers with the largest increase in supply are natural gas (9.6% per year) and nuclear (10.7% per year). A small amount of nuclear power is used by India but only three countries are responsible for 94% of the Asia-Pacific region's nuclear power: 53% in Japan, 27% in the Republic of Korea and 14% in China in 2010. In records not presented here, Japan's nuclear power has diminished dramatically since 2011.

**Figure 9 Total primary energy supply per capita, Asia-Pacific developing countries (1970, 1990, 2010)**



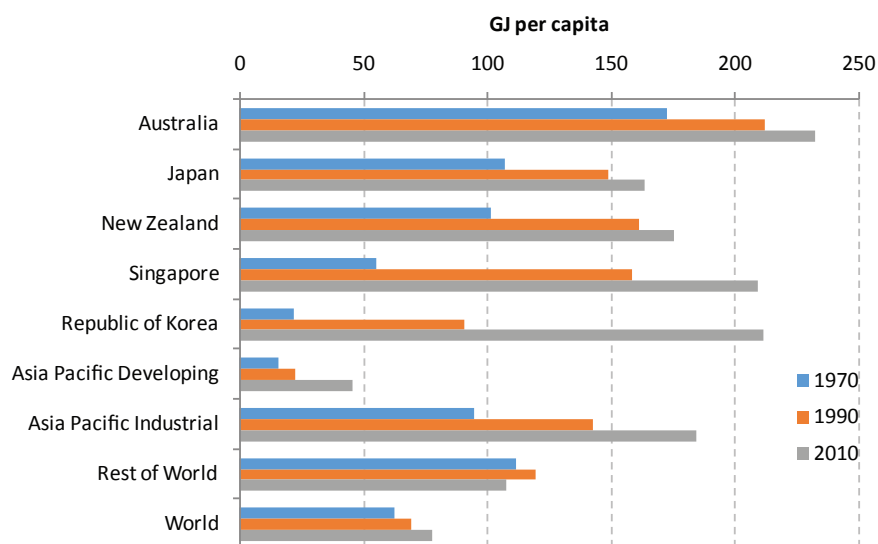
The results shown in Figure 9 have limited records for Bhutan, Afghanistan, Papua New Guinea and Cambodia, being only for 2010, and the Lao PDR and Maldives possibly suffer from incomplete data collection rather than the apparent large increase in energy consumption. The results do, however, show that growth in total energy use has been driven more by energy affluence per capita than by increases in population. TPES per capita has also increased substantially (more than doubled) in China, Indonesia, India, Malaysia, Thailand and Viet Nam. Figure 9 also displays the diversity in the magnitude and change of per capita energy use, within the developing Asia-Pacific. Other developing countries such as the Philippines and Sri Lanka have increased their total energy use but not proportionately increased TPES per capita.

Apart from the large contribution by China, there have been huge changes in energy use since 1970 in Thailand (8.6-fold) and Malaysia (12-fold) and there is a general, though not universal, southern Asian experience of exponentially increasing use of petroleum and gas.

As a group, the industrialized countries currently have a per capita level of consumption approximately four times that of the developing nations in the region (see Figure 10) but since 1970 TPES per capita has doubled in Asia-Pacific industrialized countries while tripling in the group of developing Asia-Pacific nations.

Malaysia serves as an example of a developing nation that is bridging towards the energy consumption characteristics of an industrialized country. Although Malaysia's fuel mix is quite different, its per capita energy consumption is matching the same sort of levels as in Asia-Pacific industrialized countries. Malaysia is the world's second-largest exporter of liquefied natural gas and the second-largest oil and natural gas producer in south-east Asia. Perhaps as important are the changes in demand in the Malaysian economy. Between 1985 and 2005 Malaysia had a net export of energy greater than 1000 Petajouless per year. That is, subtracting imports from exports there were far more exports of energy. While Malaysia continues to export energy, its net export is much closer to zero and domestic production now more closely matches its TPES. This is because of the greatly increased local demand for petroleum and gas and implicitly a reduced dependence on revenue from exporting these products (Viet Nam has a similar recent experience).

**Figure 10 Total primary energy supply per person, Asia-Pacific region and rest of world (1970, 1990, 2010)**



### 2.3 Water use

Economies use water in far larger quantities than any other natural resource, constituting around 84% of overall use, compared to air (around 9%)<sup>6</sup> and all other materials (around 7%). Unlike many of the materials included in DMC, water is often reused multiple times in the same year. Furthermore, the great majority of it is extracted from sources which will replenish themselves naturally, via the hydrologic cycle, so issues of its usage are really those of managing a renewable resource flow rather than managing a depleting non-renewable resource stock<sup>7</sup>. The water use indicator presented here reports **total fresh water abstractions for use in agriculture, industry and in the residential sector, from all surface and underground sources**. Direct rain fed onto crops is not included. The total water withdrawals indicator by itself is not an indicator of water stress as it does not include information on the natural availability of water in the region where withdrawals take place. The base data for total water withdrawals were sourced from FAO (2014). This data source has no continuous time series, and is usually very sparse with four or fewer data points for any individual country over the period from 1970 to 2010. To allow comparison of different countries for the same time periods, it was necessary to

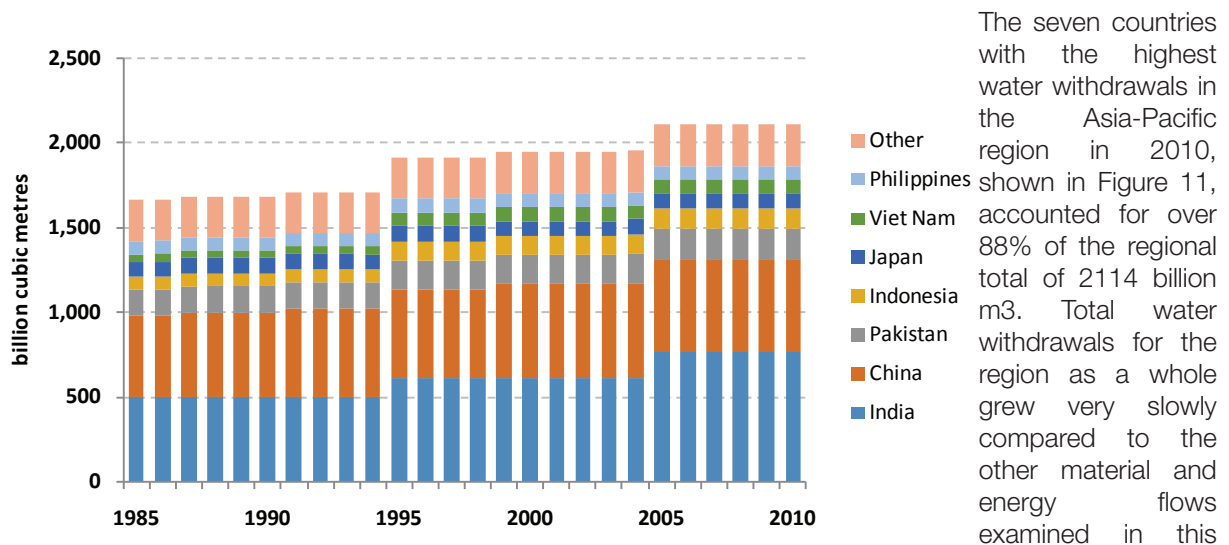
<sup>6</sup> The use of air, in volumetric terms, is dominated by the use of O<sub>2</sub> in combustion processes. The associated production of gaseous CO<sub>2</sub> is the main anthropogenic source of GHGs, however most CO<sub>2</sub> will revert to O<sub>2</sub> eventually naturally via photosynthesis, so air 'used' should not be thought of as depleting a non-renewable resource.

<sup>7</sup> An important exception here is water sourced from many aquifers which recharge on such long time scales that they can effectively be thought of as non-renewable. These sources can be locally very important.



complete full time series. Water usage, while apparently gradually increasing over time, is different to measures such as DMC and GDP in that it commonly varies considerably over a period according to transient water availability (i.e. if a water survey takes place during a drought, withdrawals can be quite depressed). The signal to noise ratio is thus large, and so interpolating trends from sparse data can be highly misleading<sup>8</sup>. To improve transparency, a conservative approach to extending data series was adopted here, infilling all vacant year values for a country with a repeat of the nearest real survey data point. This, combined with the fact that there tend to be a few years in the base data where many countries were surveyed simultaneously, followed by long periods with no surveys, gives a stepped appearance to any full time series charts. As there were very few data points for the early years, the three years used for most comparisons below were 1985, 1995, and 2005 rather than 1970, 1990, and 2010 as used elsewhere in the report.

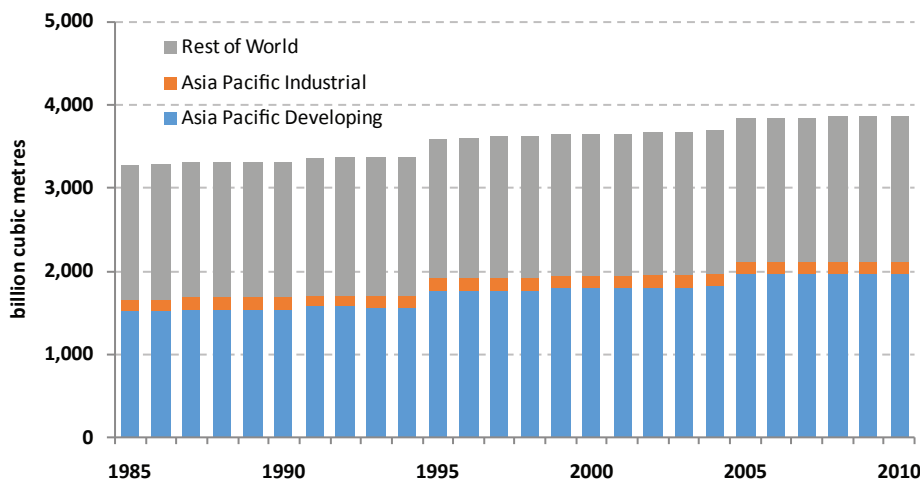
**Figure 11 Total water withdrawals, Asia-Pacific region (1970-2010)**



report, at an annual compounding rate of 0.6% p.a. for the full time period (1970–2010). All but one of the greatest water consumers were part of the developing group, with Japan being the sole industrialised representative. In contrast to other materials and energy flows, India supplants China as the largest total consumer of water. All of the above reflects the key role of water in biomass production, and is consistent with biomass being proportionally more important for countries at earlier stages of the socio-metabolic transition from advance agrarian to industrial societies, as outlined in Fischer-Kowalski and Haberl (2007). Water use is one category where a very strong relative decoupling between a physical material flow and economic growth can clearly be seen.

<sup>8</sup> For the purposes of an initial region-wide data set for the indicators for a resource efficient green Asia, this approach is a good start. For future updates to the report, national statistics organizations could engage and provide national data sets where available.

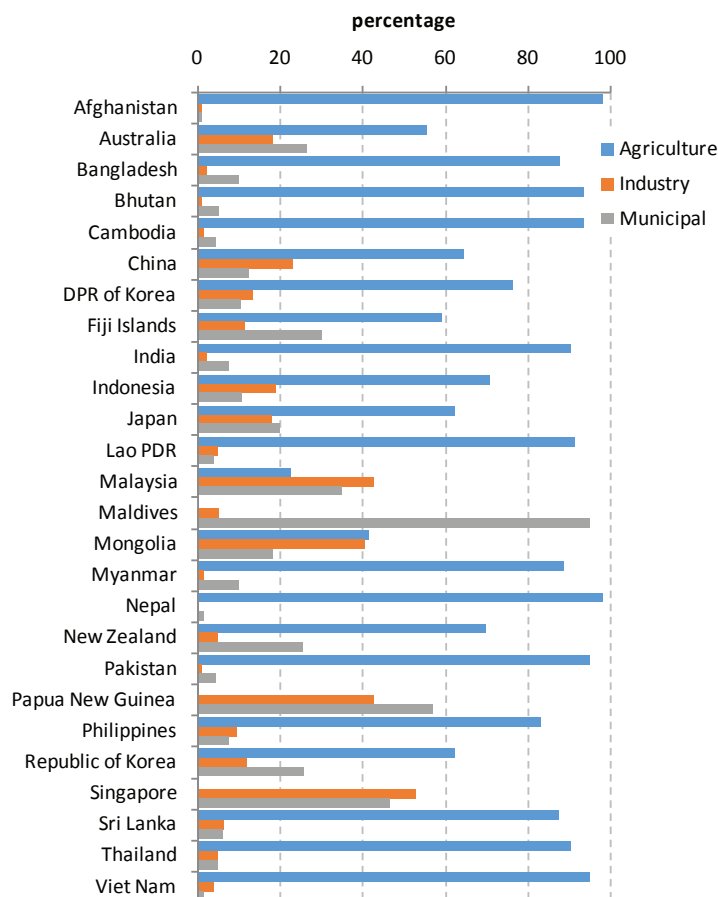
**Figure 12 Total water withdrawals, Asia-Pacific region and rest of world (1970-2010)**



In Figure 12 we can see that, in contrast to other material and energy flows, the Asia-Pacific region accounted for the majority of total water withdrawals for the entire study period. Over the period, the region's share of the global total increased only slightly, from 51% in 1970 to 55% in 2010, with the developing group accounting for over 51% by itself and the industrialized countries group less than 4%. That growth in the Rest of World is even slower than that

seen for the Asia-Pacific region further highlights the degree to which water extraction has become decoupled from economic growth. This implies that, at an economy-wide level, it has been relatively easy to improve water intensity. A key explanation for would be the low financial return per unit water used in agriculture, the main consumer. Most sectors that compete with agriculture for water can easily out-bid the agriculture sector for their relatively modest water requirements in most circumstances, and still that water remains a relatively minor input cost.

**Figure 13 Water withdrawals, by sector in the Asia-Pacific region (2005)**



The very small shift in regional shares also demonstrates that in contrast to the situation for DMC, water extraction intensive industries have not simply been outsourced by one region to another. This could in large part be explained by the dominant role of agriculture in water use. The agricultural sector is particularly prone to local political pressures to maintain local production, for a number of reasons. The populations of most countries have strong reservations about the threat to security posed by becoming heavily dependent on imported food, in effect losing the ability to feed themselves from local sources. This will manifest itself in local policies directed to supporting some base level of agriculture. To this may be added politically influential agricultural lobbies in many countries, which can push to maintain high levels of subsidies to agriculture even where that country has agricultural output well in excess of local needs.

Figure 13 is included to clarify the point made above regarding the degree to which biomass production, and so the agricultural sector dominates water extraction. This remains the case even in the most industrialised nations, except for special cases where we



are effectively dealing with a city state with extremely restricted land supply, e.g. Singapore. In the case of Papua New Guinea, the dominance of direct rain-fed agriculture probably explains the low apparent share of agriculture there. For the Asia-Pacific region as a whole, the relative sectoral shares of water used were approximately 80%, 10% and 10% for agriculture, industry, and municipal respectively.

**Figure 14 Water withdrawals per capita, Asia-Pacific developing countries (1985, 1995, 2005)**

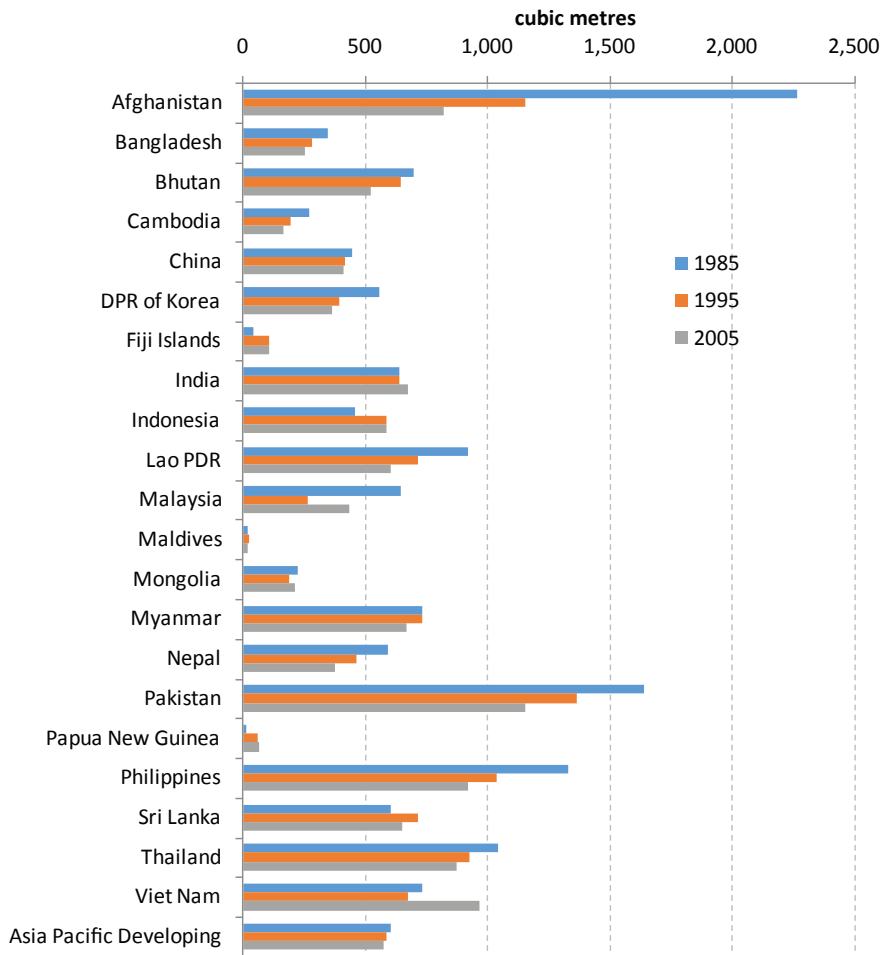
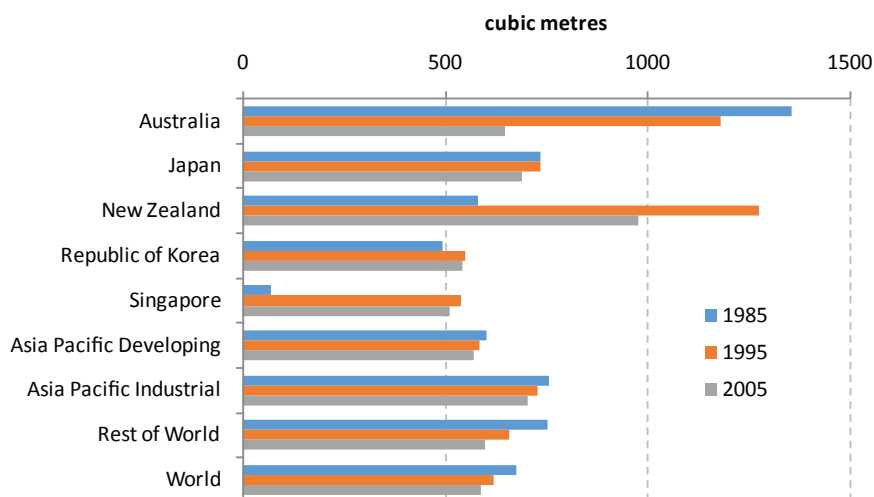


Figure 14 shows that the developing group's three most populous nations saw either only minimal reductions in per capita usage, or increased, with China's per capita withdrawals declining by 7% in total over the period 1985 to 2005, while India and Indonesia increased per capita withdrawals by 6% and 28% respectively. Other more populous nations that saw significant reductions in per capita terms were Pakistan and the Philippines (35% and 34% respectively), while Viet Nam saw an increase of 25%. The developing group as a whole saw a reduction in withdrawals per capita of 10% in total for the full period. Six of the 21 nations saw an increase in per capita water withdrawals from 1970 to 2010.

**Figure 15 Water withdrawals per capita, Asia-Pacific industrialized countries and selected regional Groupings (1985, 1995, 2005)**



From Figure 15 there is no consistent pattern in water withdrawals per capita for the industrialized countries group. New Zealand, the Republic of Korea and Singapore all experienced increases (74%, 7%, and 548% respectively), with the result for Singapore coming off a very low initial base, so that even after this very major relative increase, it still had the

lowest per capita withdrawals of any country in the group. Australia and Japan both showed declines in water withdrawals (56% and 6% respectively). The case of Australia helps illustrate the point made in the introductory section about the large short to medium term variations common in water withdrawals, and their ability to mask any subtle longer term trends, especially when combined with sparse data records. Australia was in the midst of a prolonged and severe drought for the decade centred on 2005, with water withdrawals for irrigation severely curtailed. Differentiating that drought's effects, from the effects of real and major improvements in agricultural water efficiency that have been achieved there, is not straightforward.

The larger regional groupings presented in Figure 15 are interesting for the overall similarity of both trend and total magnitudes of water withdrawals displayed. All groups reduced their per capita withdrawals, with 9% for the industrialized countries group the minimum reduction, and 26% for the Rest of World the greatest. After these reductions, all groups had per capita withdrawals between 540 and 690 m<sup>3</sup> per capita.

## 2.4 Greenhouse gas emissions

The greenhouse gas (GHG) emissions (expressed in CO<sub>2</sub>-equivalents) reported here indicate the contribution to atmospheric GHG concentration over time from human activity. Over the 40 years covered, GHGs from the total of human activity have been increasing and there is scientific consensus that this is a driver of climate change (IPCC, 2014). GHG emissions depend on the characteristics of the domestic energy system, land use and livestock. This indicator reports the territorial emissions of a country but excludes the upstream emissions of imported energy and products. Many countries now have policy objectives to reduce overall GHG emissions or to reduce the emissions intensity of economic activities.

In general, data for GHG emission types (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and F-gases<sup>9</sup>) from 1970 until 2008 for this report came from the European Commission's EDGAR database<sup>10</sup>, which has detail on 55 different sectoral sources for each of the GHG types, from all the countries under investigation here. EDGAR reports with the TIER 1 scope as in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Other details on this data are outlined in the UNEP Emissions Gap Report (UNEP, 2014b). We have not included short cycle carbon emissions from agricultural burning or savannah fires but we have included forest fires and emissions from peat in our analysis.

Data for 2009 to 2012 were derived from two sources: the World Bank's World Development Indices as updated in September 2014 and the EDGARv4.2 FT2012 time series updated in November 2014. The former set had total emissions of CH<sub>4</sub>, N<sub>2</sub>O and F-gases and five aggregate sectors for CO<sub>2</sub> emissions, however, the scope of this data did not include forest fires and emissions from peat fires and decay. The updated EDGAR time series had even less detail but it did provide a total GHG emissions data set for each country, summed over all GHG emission types, and its scope included forest fires and emissions from peat fires and decay. For 2009 to 2012, where possible, data from the World Bank was assigned to particular sector categories. All other data was calculated for individual sectors *pro rata* according to the detailed reported data for 2008 using totals for emission types from the updated EDGAR time series.

The raw data on the quantity of emissions (in tonnes) has been converted to the 100-year global warming potential (GWP) measured in tonnes of CO<sub>2</sub>-eq. This permits aggregation and comparison across the emission types using a single common denominator. The UNFCCC standard values for GWP were used for different GHG emission types.

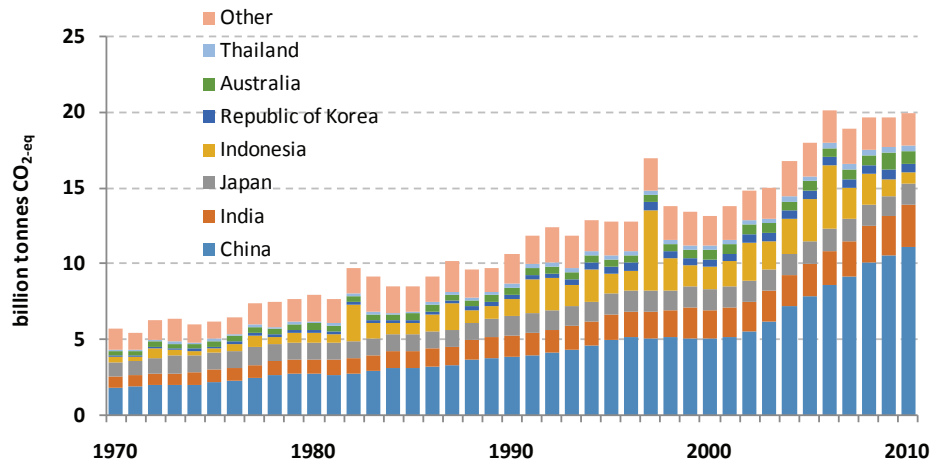
It should be noted that for some countries, even aggregate data on CH<sub>4</sub>, N<sub>2</sub>O and F-gases for the years 2009 to 2012 were not available at all. For completeness, we have included all the data that was available even where the record is incomplete for particular countries. As this notably affects Afghanistan, Bhutan, the Lao People's Democratic Republic, the Maldives, Fiji and Papua New Guinea, their country profiles may be underestimated or their records may be incomplete in particular years. The impact on regional totals, however, is an underestimate of less than 0.05% and so this does not appreciably affect the results presented here. Within the Asia-Pacific region, China is the largest emitter of GHGs and has increased the most in absolute terms and in its relative contribution: from 32% of regional GHG emissions in 1970 to 56% in 2010. During the study period, China experienced large-scale economic growth and urbanization but despite this, there was a 5-year period of carbon decoupling during the mid to late 1990s. This has been attributed to broad scale

<sup>9</sup> F-gases include the groups of fluorinated compounds: HFCs, PFCs and SF<sub>6</sub>

<sup>10</sup> <http://edgar.jrc.ec.europa.eu/>

replacement of ageing and inefficient electricity generation infrastructure. Subsequent to this, the pace of producing emissions has accelerated and this is the dominant gross underlying trend for the whole region over 2000 to 2010 – refer to Figure 16.

**Figure 16 GHG emissions, Asia-Pacific region (1970-2010)**

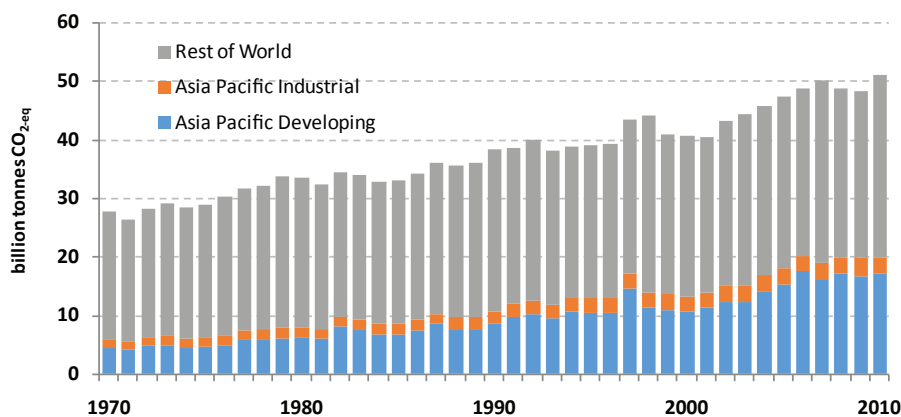


Other developing countries have grown at similar rates, though their economic structure and industrialization influences which sectors and emission types are most important. Singapore and the Republic of Korea have significant CO<sub>2</sub> emissions from industry and the energy sector while Indonesia, Cambodia and the Lao People's Democratic Republic

have experienced fluctuating emissions from land-use change and fire events. It is the variable emissions from the latter that are responsible for the large intermittent peaks that overlay the regional emissions trend.

Global emissions of all GHGs (weighted by GWP) have increased by about 80% since 1970 and Asia-Pacific regional emissions have increased from 20% to 40% of the global total – see Figure 17.

**Figure 17 GHG emissions, Asia-Pacific region and rest of world (1970-2010)**



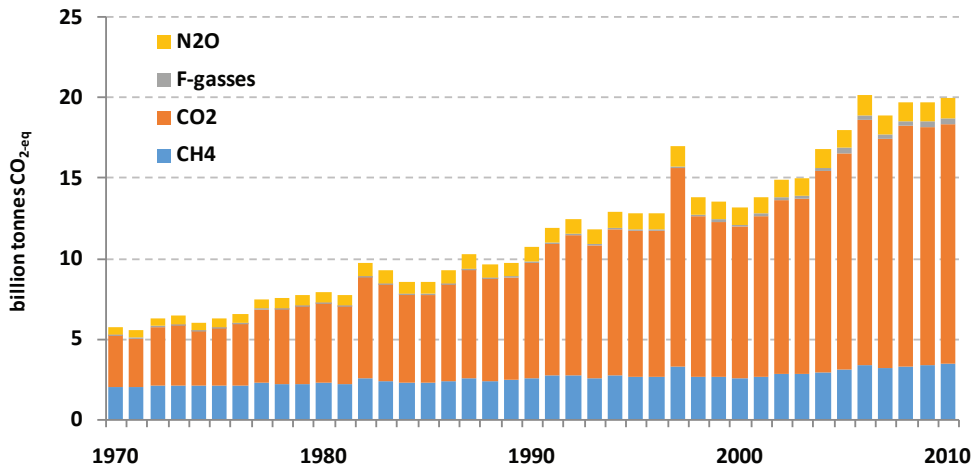
Although China's emissions have increased nearly 440% since 1970, there have been similar increases in Mongolia (425%), Papua New Guinea (517%), the Republic of Korea (573%), Singapore (557%) and Cambodia (666%).

The greatest increase belongs to the Maldives (2940%) where an exponential increase in

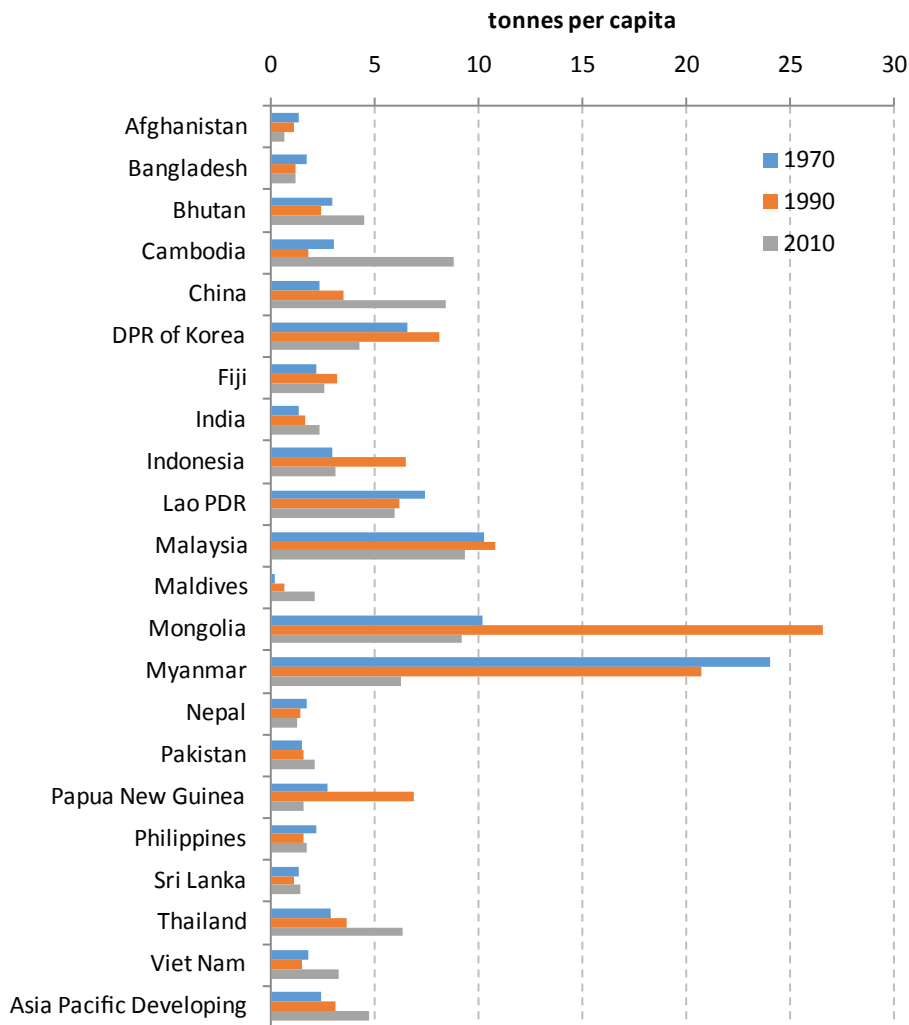
emissions followed the upgrade of Malé International Airport in 1981 and subsequent other tourism infrastructure development between 2000 and 2010.

A number of countries have reduced their per capita GHG emissions over time through institutional changes and the uptake of renewable energy sources, notably hydropower. In Myanmar nearly 68% of electricity generated in 2010/2011 was from hydropower, and 23% was production from gas power plants. A number of other developing nations in Myanmar's geographical neighbourhood, including Bangladesh, Nepal and Bhutan, have also developed hydropower though their low electricity consumption is because the majority of the population is not connected to the grid.

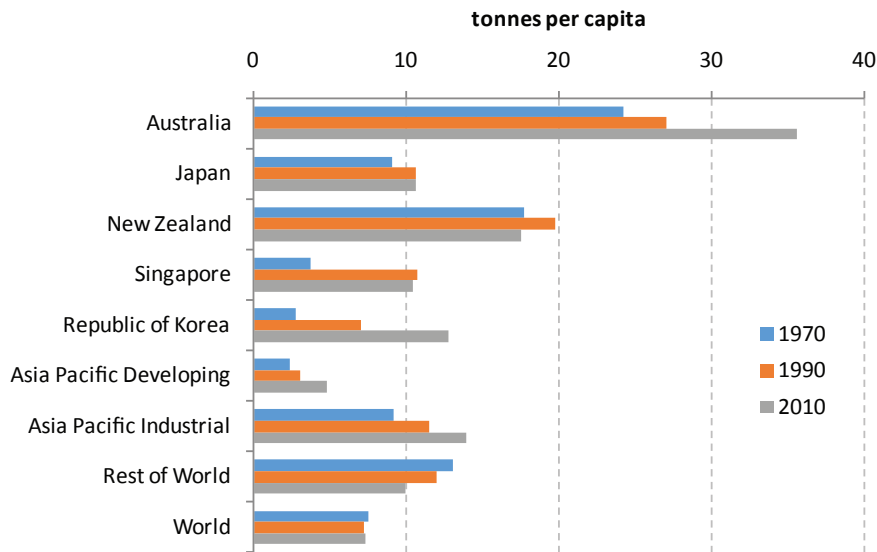
**Figure 18 GHG emissions by emission types, Asia-Pacific region (1970-2010)**



**Figure 19 GHG emissions per capita, Asia-Pacific developing countries (1970, 1990, 2010)**



Per capita emissions in the Asia-Pacific industrialized countries have remained stable or increased from 1970 levels, with Australia starting and ending the 1970–2010 period as the highest per capita GHG emitter. In Japan, the uptake of nuclear power and energy efficiency measures have contributed to its low change in emissions. Whereas New Zealand has invested in renewable electricity generation for the majority of its power supply, Australia has continued to use both black and brown coal as the main means of electricity generation.

**Figure 20 GHG emissions per capita, Asia-Pacific region and rest of world (1970, 1990, 2010)**

### Trends observed in GHG emissions

There have been two qualitatively different trends in the region that interact with development and the environment. The first is a steady urbanization and industrialization in industrialized countries, India and China that has dominated the global trajectory of GHG emissions while being indirectly connected to international trade and consumption patterns inside and outside of the region. While this deep, decadal shift in economic growth and capacity has contributed to global climate change effects, there have been localized impacts, for example, the heavily compromised air quality in some Chinese cities from particulate emissions.

The second trend is far more variable over time but no less pronounced, and it is connected with land-use change, forestry and agricultural practices in countries where natural resource extraction is a large part of the economy. The relaxation of controls on land use and the provision of economic land concessions have enabled the clearing of large areas of forest in southern Asia. Directly or indirectly because of this, forest fire events have released globally significant quantities of CO<sub>2</sub>.

Indonesia is notable for the scale of GHG-producing events like the fire that destroyed 30,000 km<sup>2</sup> of tropical forest in Kalimantan Timur Province in 1983. Another Kalimantan fire in 1997 released more than 5 billion tonnes of CO<sub>2</sub> (more than the total emissions from the USA in that year).

Cambodia also experienced extremely rapid annual economic growth in the decade to 2008 and faces three key issues of the carbon intensity of energy production, efficiency of energy use and emissions from forestry and agriculture, which remain a large part of the domestic economy. The lifting of a moratorium on economic land concessions, affecting more than 2 million hectares, has coincided with a 20-fold spike in national CO<sub>2</sub> emissions.





# Trade dependency

## Headline Indicator 'Trade Dependency'

- **Physical Trade Balance (PTB)** – mass of Imports minus mass of exports – a negative PTB means the country is a net exporter, whereas a positive PTB means the country is a net importer (tonnes; tonnes per capita)
- **Physical Trade Balance** for main natural resource trade flows differentiating biomass, fossil fuels, metal ores and industrial minerals, and construction minerals (tonnes; tonnes per capita)
- **Unit price of trade** – (\$ per kg)

Methods for measurement: Well established indicator with some potential for improvement in data set development.

Data sources: Data for PTB were sourced from the CSIRO and UNEP Material Flow and Resource Productivity Database.

Policy Use: Whether a country is a net importer or net exporter of primary resources is significant for their specific policy context. This is increasingly the case as the demarcation between primary resource exporters and importers increases, a result of the increasing globalization of trade. Resource importers can reduce their dependency on imported primary resources by pursuing higher resource productivity. Exporters might seek policies to minimize the deleterious effects that the highly cyclical nature of commodity prices can have on the structure of their economies. The risk of incurring "Dutch disease", during periods of high commodity prices might be reduced by monitoring and seeking to reduce large imbalances between the unit prices received for exports and imports. This should also help reduce the serious balance of payments problems which often plague resource exporters during the lows of commodity price cycles.

Increasingly, Asia-Pacific economies depend on natural resources from abroad. This means economic vulnerability to changes in global resource prices. Supply security issues are growing fast.

The Asia-Pacific region, over the past four decades, has become more dependent on natural resources from outside the region because domestically available supply has not kept up with demand. This has become the case for fossil fuels and metals and most recently for biomass. Industrial inputs and food for the region are increasingly sourced from outside, which the physical trade balance demonstrates. For most countries in the region, the unit prices for imports and exports are quite similar, which is an expression of the strong manufacturing base of many countries in the region. A reasonable amount of value adding in manufacturing and services takes place in many countries and hence the region sells mostly final goods rather than large volumes of low price primary materials. Developing countries in Asia and the Pacific utilize their relatively low labour costs to compete on the world market with products which embody a high amount of labour but not a great share of natural resources. The exceptions are Indonesia and Australia, which export primary materials at a very low unit price and still import goods of an average unit price .

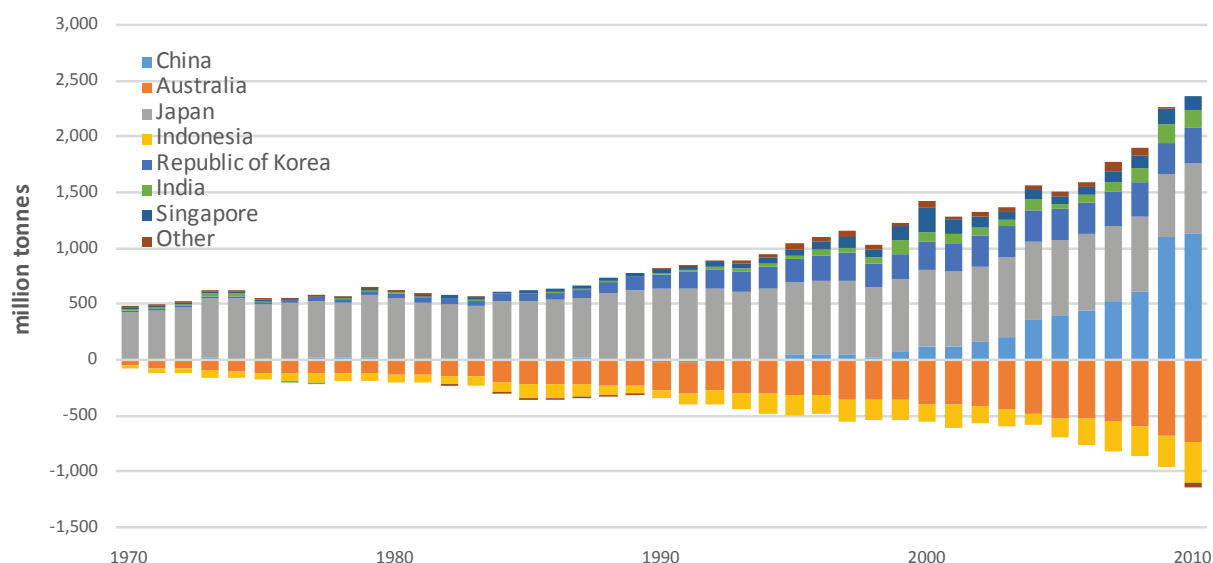
### 3.1 Physical trade balance

The physical trade balance subtracts exported materials from imported materials (in metric tonnes) and determines whether a country is a **net importer** (positive PTB) or a **net exporter** (negative PTB) of the material base of its economy. A growing dependence on imports of primary materials means that a country's economy is relying more on primary materials and goods from abroad and is more susceptible to changes in world market price of these materials in terms of input costs. When the price of natural resources becomes more volatile economic certainty and the ability to plan are reduced. It is reasonable to expect that policies directed at increasing resource productivity should - all other things being equal - simultaneously reduce a country's dependence on imports of primary resources and reduce the environmental impacts associated with domestic extraction. This helps to increase the resilience of the economy.

In contrast, economies relying on a large export sector may experience windfall incomes when prices are high but will take a hit to their balance of trade and national income when prices are low. The business cycles for global resource demand will directly affect their economies, national budgets and national currencies. This makes economic planning less secure. For such trade-based primary resource economies, mitigating the negative side effects of changes in global demand and price as well as dealing with inequities that arise from the extractive focus of the economy will become important.

The division of labour between resource importers and exporters has become more accentuated over the past couple of decades resulting in significant environmental, social and economic pressures in resource rich exporting economies and reduced economic resilience in both importers and exporters. Figure 21 demonstrates that both types of countries are represented in Asia and the Pacific.



**Figure 21 Physical trade balance, Asia-Pacific region (1970, 1990, 2010)**

Individual data for the seven countries which have the highest absolute values of PTB in 2010 (i.e. regardless of whether the PTB is negative or positive) are displayed in Figure 21. This shows the major net physical trade flows in the region, regardless of whether the nations involved are net importers such as Japan and China or net exporters such as Australia and Indonesia. These seven countries account for 93% of the region's total tonnage in net physical trade. China accounts for the largest single share of this indicator, as seen previously for DMC, but is nowhere near as dominant here. China's net imports account for less than 30% of the total net trade balance of the region, with the next largest share of 20% accounted for by Australia's net exports.

Japan's 17% share is net imports. Where the three highest DMCs in the region belonged to the three most populous nations, for PTB only China is in the top three, with the second most populous nation, India, ranking only sixth for their PTB. While China's share of PTB is small compared to that seen for DMC, the rate at which it grew over the final decade of the series is quite remarkable. From a position of near self reliance in net terms in 2000, China's net imports increased at a compounding rate of 32% per year<sup>11</sup>, to just over 1 billion tonnes, a figure roughly equivalent to the total of the region's two major net exporters, Australia and Indonesia.

The major step up in China's net imports in 2009 and 2010 is most likely a direct result of the massive economic stimulus programme announced by the Chinese government in late 2008 as a response to the GFC.

<sup>11</sup> Percentage growth in PTB is only rarely used in this section, in contrast to some other sections. This is because the concept does not make sense when a nation changes from being a net importer to exporter, or vice versa, over the period, a situation which is common in these data series.

**Figure 22 Physical trade balance, Asia-Pacific regions and rest of world (1970-2010)**

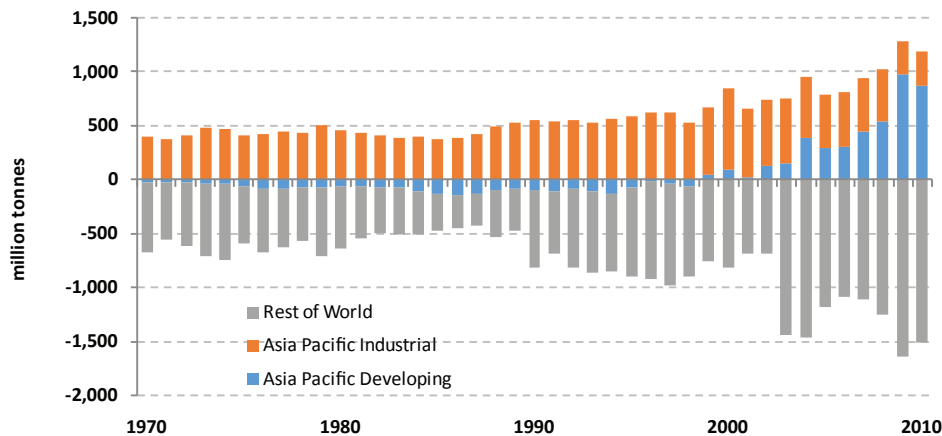
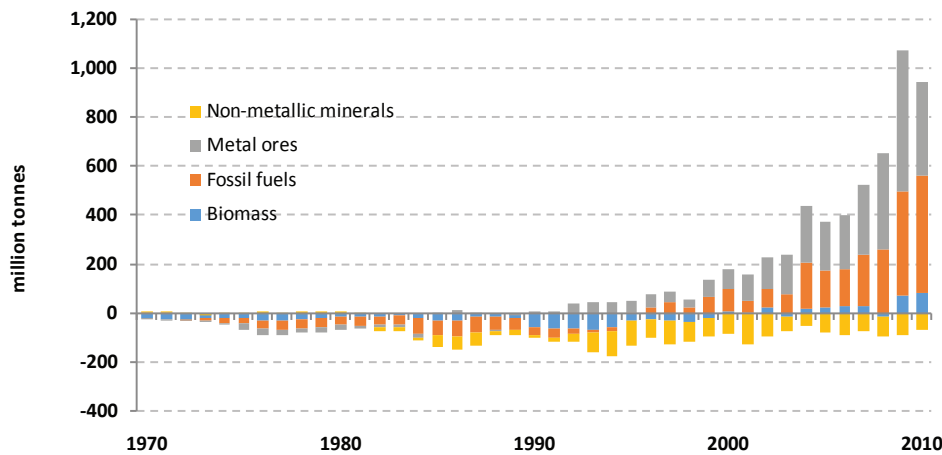


Figure 22 shows that the industrialized countries of the region, taken as a group, have always been net importers, while the Rest of World on average has been a net exporter<sup>12</sup>. The developing group is where the most significant change appears to have taken place, as it changed from near self-sufficiency/ marginal net exporter status to being a major

net importer. Looking back at the detail in Figure 21 we can see that this change in the developing group is largely accounted for by developments in China alone, and that furthermore the developing/industrialized countries groupings do not serve to split net exporters from net importers for the Asia-Pacific region. Of the top two net exporters, one was developing and the other was industrialized (China and Japan), and the situation is the same for the top two net importers (Australia and Indonesia). The decrease in net import tonnages we see for the industrialized countries group, and the growth in tonnage for the developing group, is consistent with what we would expect to see if materials- and energy-intensive processes within the region as a whole were (on average) migrating from the industrialized countries to the developing group. Similarly, net exports from the Rest of World increasing at the same time is also consistent with materials- and energy-intensive processes being transferred at a global level to developing Asia.

**Figure 23 Physical trade balance, Asia-Pacific regions and rest of world (1970-2010)**

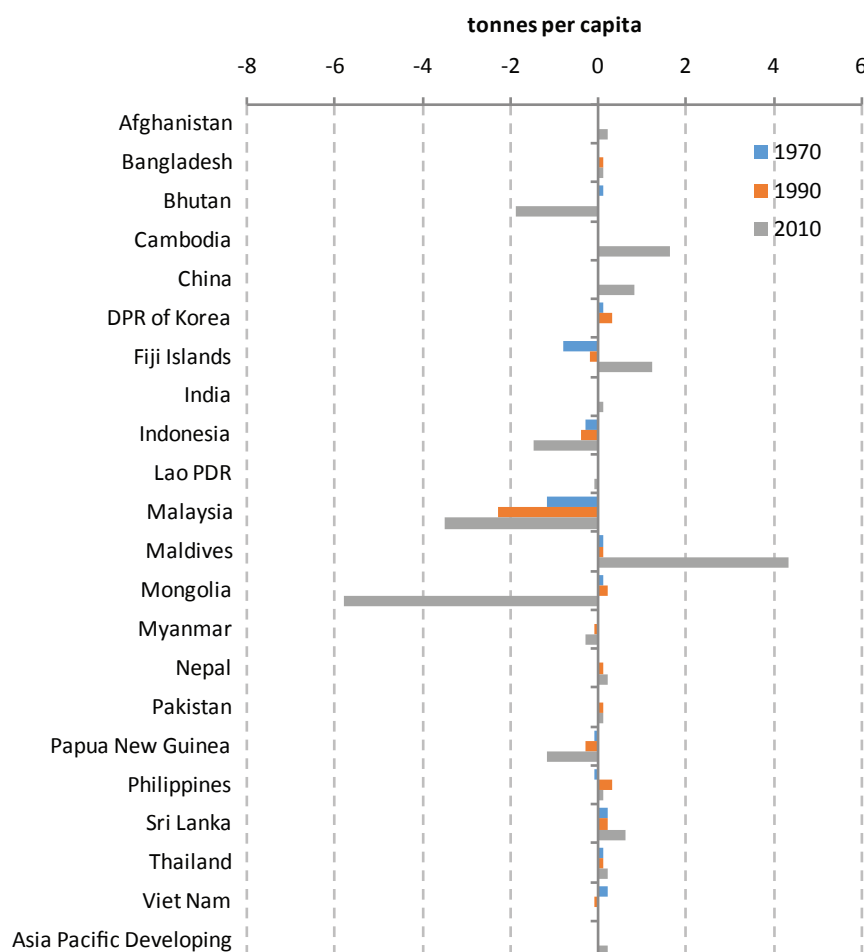


The degree to which the developing group has become increasingly dependent on imports is emphasized in Figure 23. Asia-Pacific developing countries have moved from being self sufficient or marginal net exporters in all products to becoming increasingly reliant on imports of fossil fuels and metal ores. While the total tonnages are modest in comparison to those seen earlier for

DMC, it should be noted that traded tonnages in typical commodities actually embody a much higher concentration of the useful portion of a primary material than an equivalent tonnage of domestic extraction (and so DMC). This comes about due to the concentration of commodities prior to trade, and the phenomenon is particularly pronounced for metal ores, but is also significant for biomass (Schandl and West, 2012). Thus the relative dependency indicated by raw PTB tonnage will usually significantly understate its importance compared to a similar tonnage of raw material trade, a measure which would include the upstream raw material requirement for traded goods.

<sup>12</sup> Net imports and net exports in this graph frequently do not match at the global scale. This due to discrepancies in the base data set i.e. exports do not reconcile exactly with imports in the Comtrade data, on which these PTB accounts are largely based. While these differences are only minor compared to total trade (equal to around 3% of total imports in 2010), the relative importance of any difference gets greatly magnified when viewed in the context of PTB, as the vast bulk of imports and exports cancel each other, but any discrepancy gets fully preserved.

**Figure 24 Physical trade balance per capita, Asia-Pacific developing countries (1970, 1990, 2010)**



The size of China's material flows tends to overwhelm the influence of the other developing group countries in aggregated group statistics, and this is particularly the case for PTB in recent years. The data provided in Figure 24 show that at the individual national level, the overall impression of rapidly growing import dependence does not hold for all. Indeed, the only developing group nations with a population over 25 million to become significant net importers of materials, in actual tonnes per capita terms, was China (0.8 tonnes per capita), by 2010. Both Indonesia and Malaysia, on the other hand, more than doubled their net exports between 1970 and 2010, to 1.5 and 3.5 tonnes per capita in 2010 respectively. Other populous nations, including India, Viet Nam, Thailand and Myanmar, all maintained PTB in the range of -0.3 to 0.3 tonnes per capita,

indicating near self-sufficiency in gross tonnage terms. Cambodia's relatively high net imports of 1.6 tonnes per capita for 2010 appears to be an anomaly, as it was accounted for almost entirely by non-metallic minerals, a category in which it typically imports less than 20% of this level, and was in fact a net exporter for the two years preceding 2010. Given this, a more typical pattern for Cambodia would show low levels of net physical trade, as noted for the bulk of the developing group.

The extremes of PTB per capita, both as net importer and net exporter, are both occupied by nations with small populations. This is largely a result of the impact that individual development projects may have in per capita terms in such nations. In the case of Mongolia the great majority of its net export tonnage can be traced to the commencement of major coal exports (mainly to China, with tonnages quadrupling between 2008 and 2010). In the case of the Maldives, the approximately 70% of the net imports are accounted for by non-metallic minerals (around 2.5 tonnes per capita). Given the Maldives' population of under 350,000 at the time, this equates to imports of less than a million tonnes, which could be accounted for by even a few major construction projects in a country with low availability of local construction minerals.

**Figure 25 Physical trade balance per capita, Asia-Pacific industrialized countries (1970, 1990, 2010)**

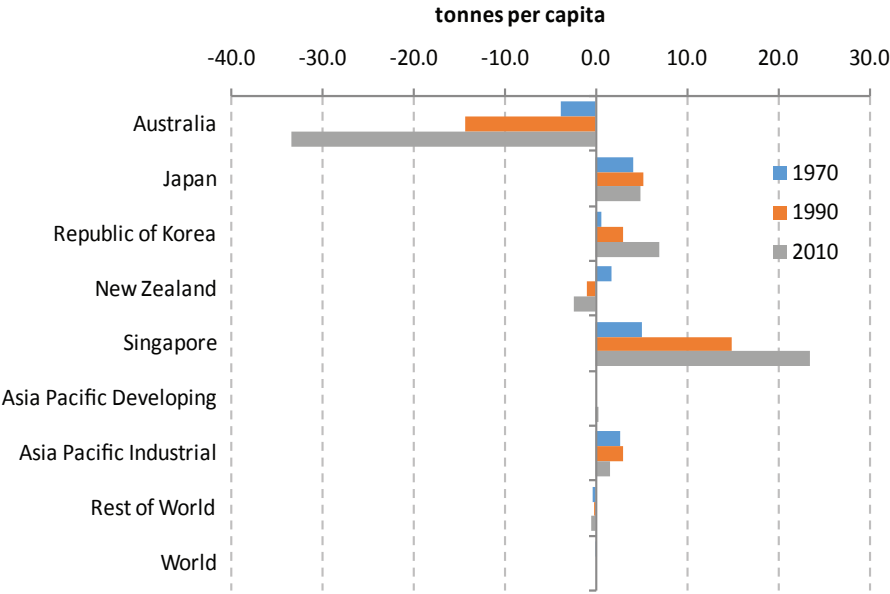


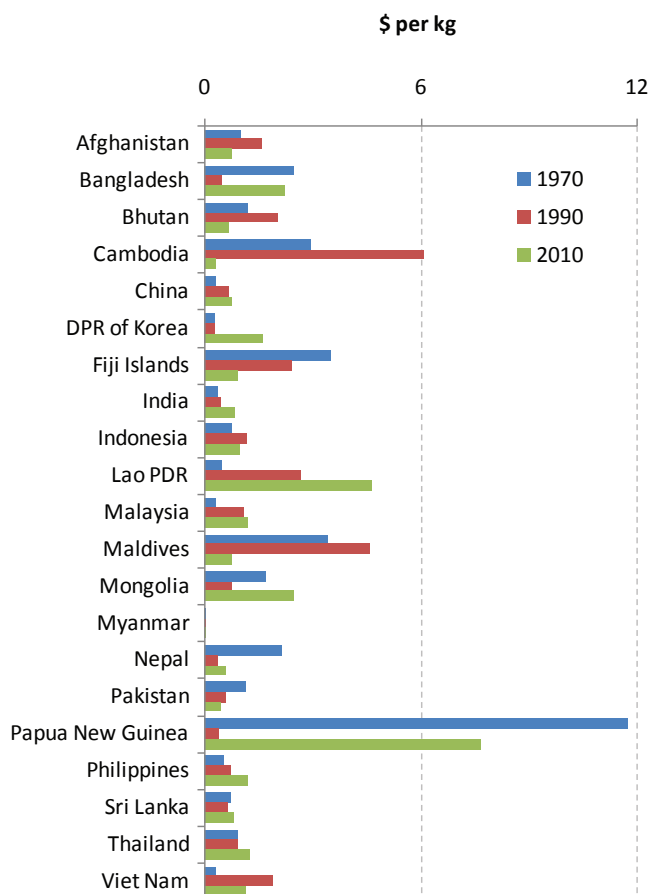
Figure 25 shows that all of the region's industrialized countries were net importers, with the exception of New Zealand (a modest net exporter for 1990 and 2010), and Australia, which has very high net exports which grew rapidly over both periods with per capita levels in 2010 around eight times what they were in 1970. Singapore presents something of a mirror image to Australia, with very strong growth off a high base, with the 1970 level of 5 tonnes more than quadrupling to

over 23 tonnes by 2010. The pattern for the Republic of Korea is similar to Singapore, but coming off a much lower base and ending at around one quarter level (6.9 tonnes per capita by 2010). Japan's level of net imports increased modestly, from 4.0 to 4.9 tonnes per capita, which in 2010 was equal to around one half of Japan's total DMC. As discussed above, the volume of these net imports likely understates their importance to the Japanese economy, due to the effects of concentration of commodities prior to trade. The same concentration effect may explain New Zealand's perhaps surprisingly small net per capita exports. New Zealand is well known as a major exporter of agricultural produce, especially of animal products. This particular category of biomass is particularly subject to concentration prior to trade, especially products sourced from ruminant animals, where the animal product may represent only one or two per cent of the plant biomass used to produce it.

**3.2 Unit price of trade**

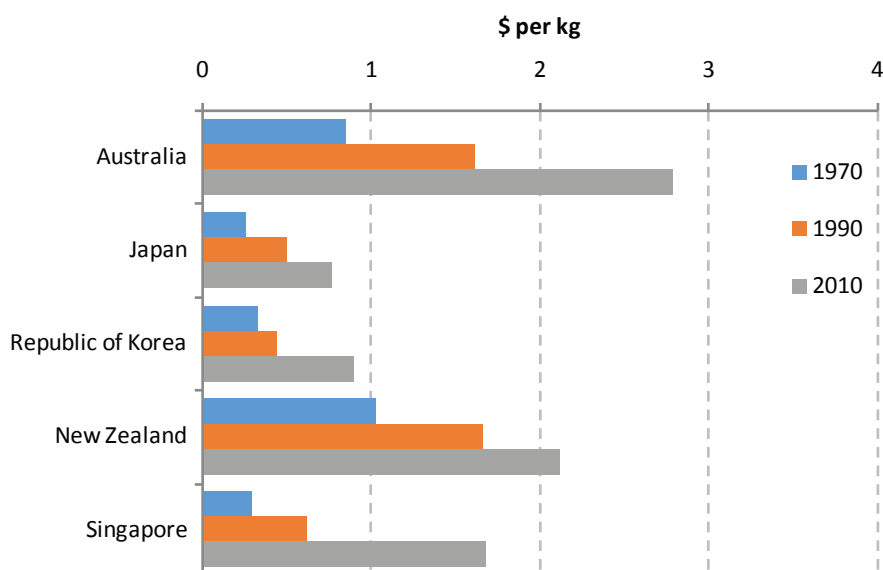
The unit price of trade reports the monetary income (expenditure) a country receives (pays) for each unit mass of exports (imports). A trade pattern of high volume and low value exports and high value low volume imports will result in an unfavourable balance of trade and will limit countries' overall economic prosperity. In the past, countries with large natural resource endowments and a large share of exports have sometimes not been able to effectively use natural resources to grow economically and to support human development. One phenomenon that explains this has been named Dutch disease, a situation where windfall incomes from resource exporting sectors have resulted in an overvalued currency, high economic volatility, and unfavourable conditions for manufacturing and greater income inequality. As the global demand for natural resources is on the rise, countries that have rich endowments will need to put policies in place to combat the unfavourable outcomes described above.

The monetary base used is \$ at constant year 2005 exchange rate value, sourced from UNSD (2015). The actual income (expenditure) value used is the combined figure for exports (imports) of both goods and services. The import and export volumes are the same as those used to calculate PTB in the previous section.

**Figure 26 Unit prices of imports for Asia-Pacific developing countries (1970, 1990, 2010)**

From Figure 26 it is clear that there is no characteristic pattern in unit prices for imports (UPI) which links all countries of the developing group<sup>13</sup>. Countries such as Fiji, Nepal, and Pakistan had all benefited from large falls in the prices they pay for their imports in 2010 compared to 1970, with decreases in their UPI of 73%, 73%, and 61% respectively. Others, such as China, India, Malaysia, and the Philippines saw large increases in UPI, having to pay 137%, 129%, 291%, and 134% more respectively per kilogram of imports. Even within the same country, there is often no stable trend towards increasing/decreasing UPI over the full period, with half of the countries reversing the trend shown from 1970 to 1990 over the following period from 1990 to 2010.

One point of interest is the close similarity between both the absolute values, and the trajectory over time, of the region's two population giants, China and India. Both saw their UPI in 1970 (\$0.32 and \$0.36 per kg respectively) more than double by 2010 (to \$0.77 and \$0.83 per kg). This is perhaps surprising given the divergence in their economic growth and corresponding DMC profiles over the period.

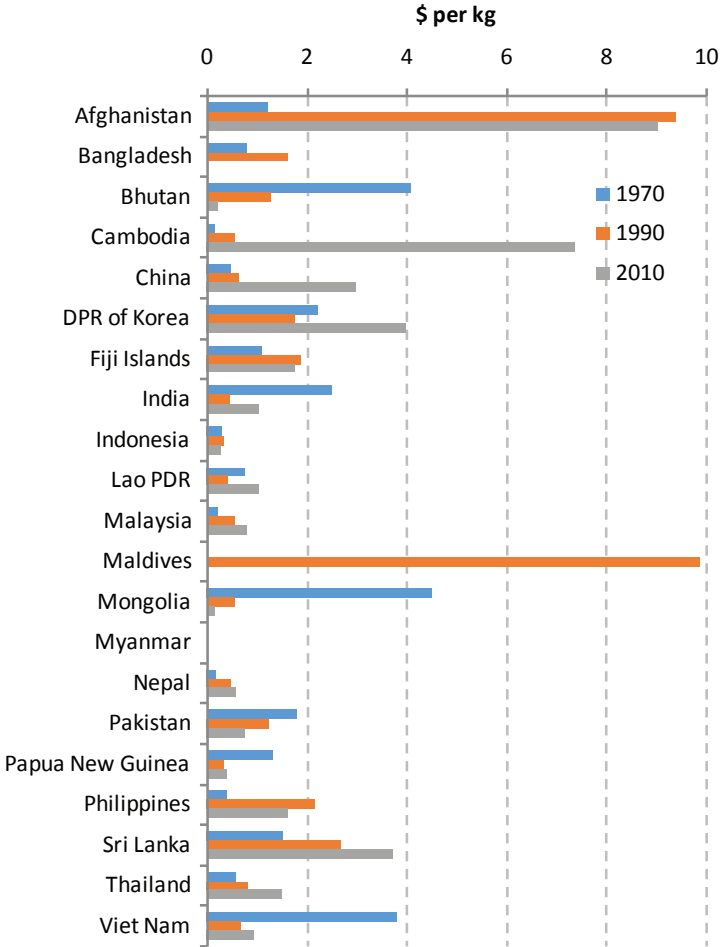
**Figure 27 Unit prices of imports for Asia-Pacific industrialized countries (1970, 1990, 2010)**

<sup>13</sup> For the purposes of this discussion values of greater than \$10.00/kg are ignored, as are those of \$0.05, due to the likelihood that they reflect inadequacies in the base data.



For the industrialized countries, much greater consistency between countries is evident, with Figure 27 showing a steady increase in UPI for all for each successive period. Beyond this similarity in general pattern, there is considerable variation in the actual levels. Australia and New Zealand have consistently paid much higher prices for their imports, although Singapore appeared to be moving into a comparable pricing regime for its imports, after seeing the greatest relative increase in UPI, a more than fivefold increase from \$0.29 to \$1.68 per kg between 1970 and 2010. It is noteworthy that both the trajectories and levels of UPI for Japan and the Republic of Korea are very similar to those seen previously for China (and India) in Figure 26. In the case of China, this likely reflects its transition to a major industrial power, with its import needs largely dictated by the inputs required for mass production of industrial goods for export, the same model followed previously by Japan and the Republic of Korea. Why India also exhibits this pattern is not obvious, indicating that it may just be a chance outcome of aggregation.

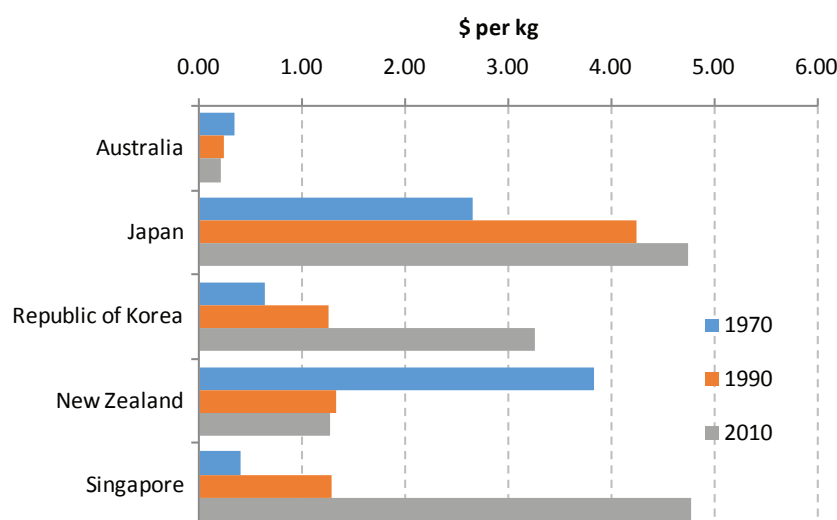
**Figure 28 Unit prices of exports for Asia-Pacific developing countries (1970, 1990, 2010)**



The national trajectories of unit prices of exports (UPE) displayed in Figure 28 displays a similar lack of discernible pattern to Figure 26, with nearly half the of countries reversing trends between periods again, as seen previously for UPI.

There are some interesting features for individual countries. China, for example, achieved a major increase in the UPE relative to UPI between 1970 and 2010. Where a kilogram of imports cost 67% of the value China received for a kilogram of exports in 1970, the relative cost of imports had fallen to 26% by 2010. India has seen the opposite, with a UPI of 15% of UPE in 1970 increasing to 81% in 2010. This suggests that while the UPI is similar for both countries, the ultimate use of those imports in each economy is significantly different. Twelve of the developing nations saw an improvement (decrease) in the ratio of UPI: UPE, while nine saw the ratio increase.

**Figure 29 Unit prices of exports for Asia-Pacific industrialized countries (1970, 1990, 2010)**



In Figure 29, there does not appear to be any of the consistency in general trajectories for UPE in among the industrialized countries that we saw previously for UPI.

One potentially important insight from Figure 29 comes from examining the trajectories of Japan and the Republic of Korea, in conjunction with what we already saw for China. Japan reached a high UPE in 1990 of \$4.25 per kg, at a time when its status as the great manufacturing power of Asia was unrivalled. Its all-time high in fact occurred 1989, when it received \$7.60 per kg. Over the next period Japan's UPE increased only marginally against the 1990 value, and actually fell by around 37% from its 1989 high. The Republic of Korea, in contrast, continued to improve its UPE, rapidly, to \$3.26 per kg. Meanwhile, China's UPE leaped from to \$0.64 in 1990 to \$2.97 per kg, coincident with its rise as a great manufacturing power. It is interesting to speculate what this increasing convergence, and UPE level much lower that Japan received in 1989, may indicate for returns to manufacturing activity in the future.

Australia saw its already very low UPE decline further, to \$0.21 per kg, which is the second lowest of any country (Bhutan received only \$0.20 per kg). New Zealand also saw a marked deterioration in UPE, but from a much higher base. Singapore saw consistent and very strong improvement in its UPE, with a more than sevenfold increase between 1970 and 2010.

नियंत्रण कक्ष



# Resource efficiency

## Headline Indicator 'Resource Efficiency'

- **Natural resource input per unit of economic output (GDP)**
- **Material Intensity** - DMC per unit GDP (tonnes per \$)
- **Energy intensity** - TPES per unit GDP (MJ per \$)
- **GHG intensity** - GHG emissions per unit GDP (kg per \$)
- **Water intensity** - water use per unit GDP (litres per \$)

Land productivity, measured in GDP/land use (\$ per ha or km<sup>2</sup>), would also fit into this indicator domain, but is out of the scope of this report.

Methods for measurement: Combined measure of economic activity and natural resource use based on the set of indicators proposed for natural resource use. The compatibility of natural resource use indicators with the System of National Accounts supports composite productivity indicators. GDP was sourced from UN STAT and refers to 2005 constant prices in US\$.

Data sources: Based on natural resource use indicators and a measure of economic activity; preferably exchange rate based Gross Domestic Product corrected for price effect.

Policy Use: Provides information about relative decoupling which is very important for Asian developing countries which are increasing their resource base to support human development and material standards of living, but would profit from using resources at a slower growth rate than the growth of their economy. This becomes particularly important when Asian economies depend more on natural resource imports and global resource prices are rising.



Resource Efficiency is improving in individual countries in the region, but still lags far behind the rest of the world. Investing in resource efficiency is a necessary strategy to set Asia and the Pacific on a sustainable development path. Well-being and prosperity tomorrow will depend on governments and businesses investing in resource efficiency and waste minimization today.

This chapter presents trends in resource efficiency and compares the evolution of resource and labour productivity over time.

#### 4.1 Material intensity of the economy

The overall material intensity (MI) of an economy refers to the physical mass of materials used to produce a monetary unit of GDP. Another term often used, material productivity, is simply the inverse of MI. Improving efficiency (decreasing MI) or decoupling, is sometimes misunderstood as simply using less and thereby missing out on economic and social benefits that can be derived from resource use. On the contrary, improving efficiency allows an economy to maximize the economic “goods” obtained, i.e. a growing material standard of living and enhanced human well-being, while decreasing economic “bads”, i.e. waste and emissions and their resulting negative environmental impacts. This is often referred to as decoupling economic activity from the use of natural resources, and environmental (and social) impacts from natural resource use.

There are different “types” or reasons behind a trend of increased resource efficiency, or decoupling. The UNEP IRP, in a recent report (UNEP, 2014c) proposed distinguishing between three types of decoupling:

1. Decoupling through maturation. This type of decoupling is a spontaneous process of overcoming outdated and inefficient techniques, of building up of infrastructure, and of actively reducing environmental pollution. This form of decoupling is related to the maturation process as countries shift from extraction- and production-based economies towards service economies. In this process, increasingly more income is earned from economic activities that have lower resource and emissions intensities and hence resource use and emissions grow more slowly than GDP.
2. Decoupling through shifting the material-intensive stages in product life cycles to other countries. If domestic extraction and manufacturing are replaced by imported materials and goods, resource use may decline domestically, but will still occur elsewhere in the world where the more material-intensive, often more polluting, stages in product life cycles are now taking place. This type of decoupling is often labelled as burden shifting, a process by which resource-intensive activities and their environmental impacts are shifted offshore.
3. Decoupling through intentional resource productivity increase. This is what is really needed to reduce pressures on limited resources, on climate, and on the environment in general. It requires investment decisions, technological innovation, and infrastructure conducive to resource efficient and low material intensity manufacturing and living, commensurate changes in technologies and lifestyles, and policies that incentivize such changes to occur.

As Asia-Pacific developing countries industrialize, their overall demand for primary materials will further grow. Using materials more efficiently, however, will help offset some of the growth in material use that would otherwise occur, setting these countries on a more competitive and environmentally sustainable development trajectory. Many countries will earn a dividend of decoupling through maturation, with the exception of major resource exporting countries. Burden shifting is not a current option for many countries developing though increasing their manufacturing capacity and therefore accepting some burden from other countries who buy their products. Improving material efficiency is a necessary but not sufficient strategy to reconcile the continuing need for economic development with satisfactory environmental outcomes in the Asian and Pacific nations. Material efficiency data should ideally be paired with information about the quantity and quality of the resources base for a more complete and coherent picture.



Material intensity in this chapter is defined as domestic material consumption per unit of GDP (DMC per GDP). The monetary base used for GDP is \$ at constant year 2005 exchange rate value, sourced from UNSD (2015). DMC is constructed as described previously in Section 2.1.

**Figure 30 Material intensity for Asia-Pacific and World groupings (1970-2010)**

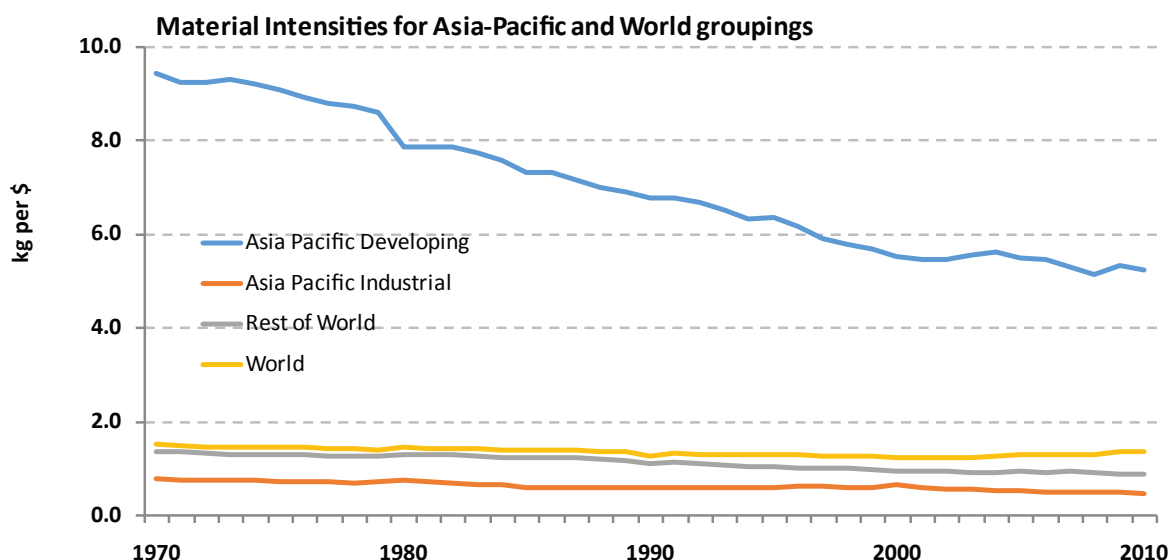
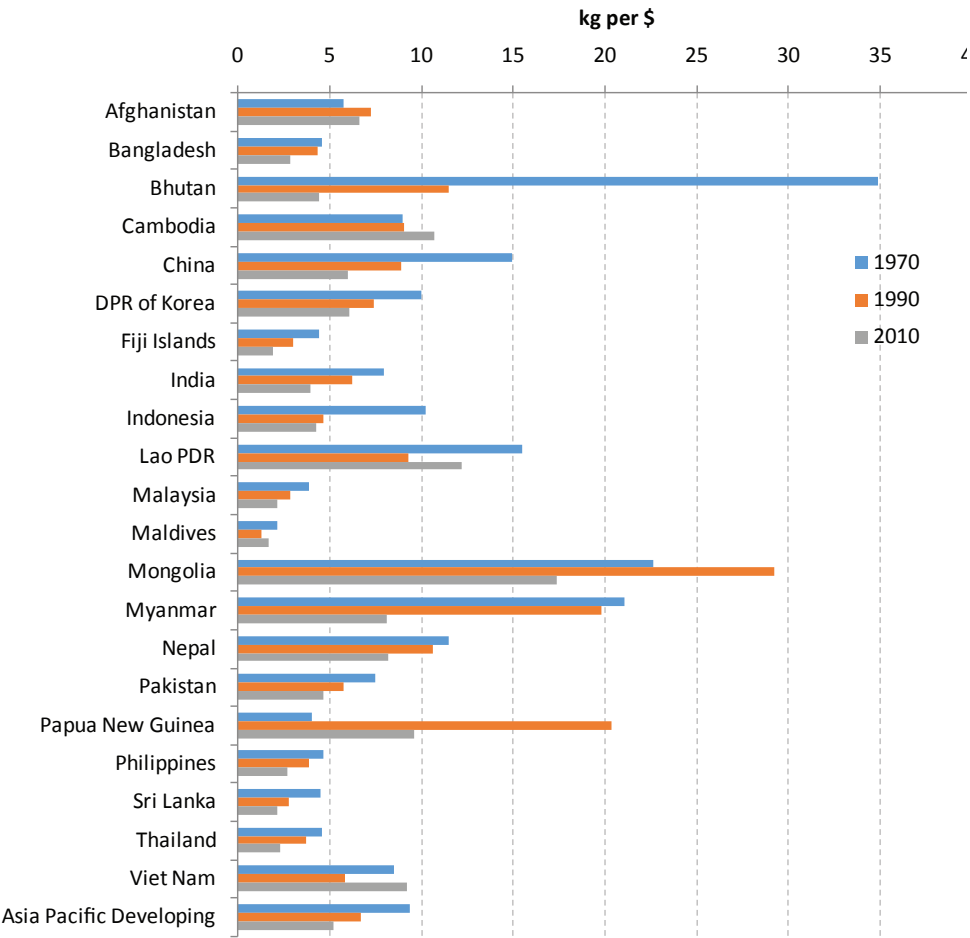


Figure 30 compares the material intensity of the two Asia-Pacific groups to that of the Rest of World, and of the entire World. A salient feature is the very high material intensity of the developing group, on the one hand, and the major reductions achieved over the period on the other. From a very high base in 1970 of 9.4 kg per dollar, the developing group's MI improved at a compounding rate of almost 1.5% p.a., so that by 2010 the group was using 45% less materials per dollar of GDP generated. The rate of improvement for the industrialized countries was almost as good, improving at a rate of 1.3% p.a. for the same period, commencing off a much lower base of 0.76 kg per dollar in 1970. The Rest of World also improved its MI consistently over the full period, reducing MI at a rate of 1.15% p.a. Given this across-the-board consistent improvement in MI at group levels, it is perhaps surprising that MI at the global level only improved slightly for the full period, at 0.30% p.a., and actually deteriorated over the later period, increasing by 0.32% p.a. compounding for the 1990 to 2010 period. This apparent contradiction is explained by the shift in relative shares of economic activity which took place over the period, from the Rest of World (and the Asia-Pacific's industrialized countries), to the developing group. By 2010, a much larger share of the world's economic activity was taking place in the developing group, which, despite having greatly improved its material productivity (lowering its MI), remained at an MI levels much higher than the groupings which had lost share, that is, while MI for the developing group in 2010 was half what it had been in 1970, it was still 6.8 times the average MI for the industrialized countries group back in 1970, and 3.8 times the Rest of World's MI for 1970.

**Figure 31** Material intensity for Asia-Pacific developing countries (1970, 1990, 2010)



The broad trend to improved MI at regional level for the developing group is largely reflected in the individual national level data presented in Figure 31, with 17 of the 21 countries improving their MI between 1970 and 2010, including the four most populous nations (China, India, Indonesia and Pakistan), which posted decreases of 2.3, 1.7, 2.1, and 1.2% p.a. compounding respectively. As with DMC per capita, regional MI levels are largely intermediate between the values for China and India, reflecting their great economic weight relative to other nations in the group. The greatest single individual improvement in MI was for Bhutan, which decreased at a rate of over 5.1% p.a., while the greatest deterioration was for Papua New Guinea, with MI at nearly 2.2% p.a, although the trend there is towards lower MI after an initial massive increase between 1970 and 1990.

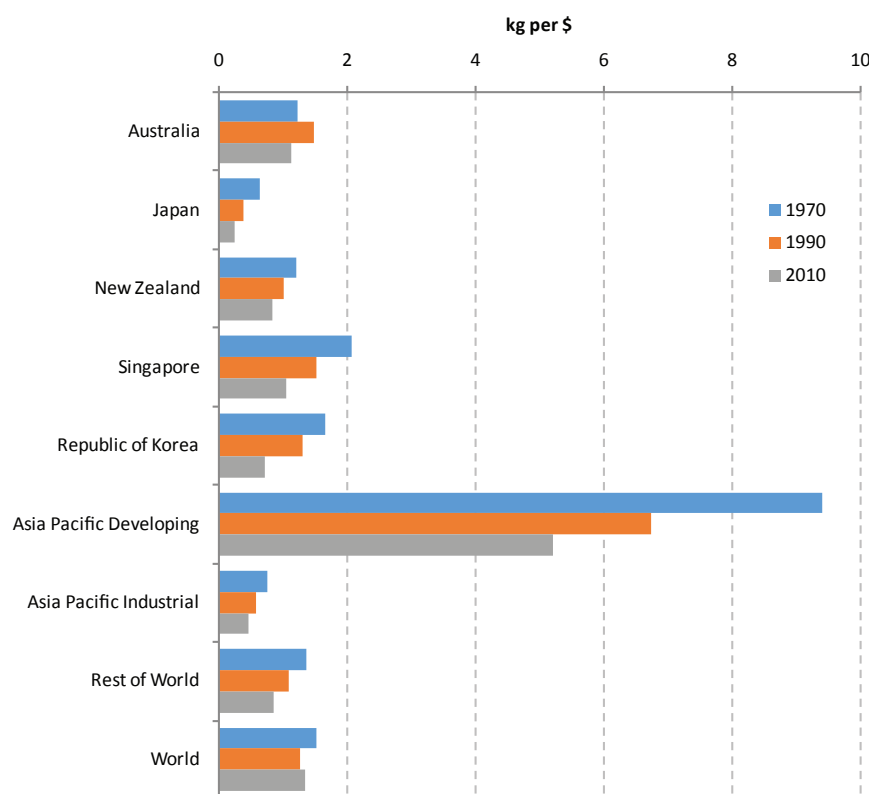
**Figure 32 Material intensity for Asia-Pacific industrialized countries (1970, 1990, 2010)**

Figure 32 shows that all nations in the industrialized countries improved their MI performance between 1970 and 2010, in most cases markedly and consistently. Remarkably, the strongest improvement in relative terms was by Japan, which already had by far the lowest MI of the group in 1970 (0.64 kg per dollar). It subsequently reduced its MI at a compounding rate of 2.3% p.a. Singapore and the Republic of Korea similarly reduced MI by half or more over the period, improving at 1.7% and 2.1% p.a. respectively, while New Zealand decreased its MI by around 30% in total. Australia only improved its MI marginally, after strong deterioration between 1970 and 1990. It is interesting to

view the relative performances of each country here in the context of the unit prices they received for their exports, seen back in Figure 29. While the relationship is not simple, those countries which suffered the greatest declines in unit prices also performed worst in improving their MI.

#### 4.2 Energy intensity of the economy

The overall energy intensity of an economy refers to the amount of energy (in joules) that is used for producing goods and services (measured in \$) which is related to energy efficiency of energy use. Using energy more efficiently reduces costs and is an important factor in achieving a low carbon development path. Similar to materials, energy use in many Asian developing countries will continue to grow over the next couple of decades. Improving efficiency by leapfrogging through the use of energy-efficient technologies in building, transport, heavy industry and manufacturing sectors will allow economic growth to coincide with reduced intensity of energy use and GHG emissions.

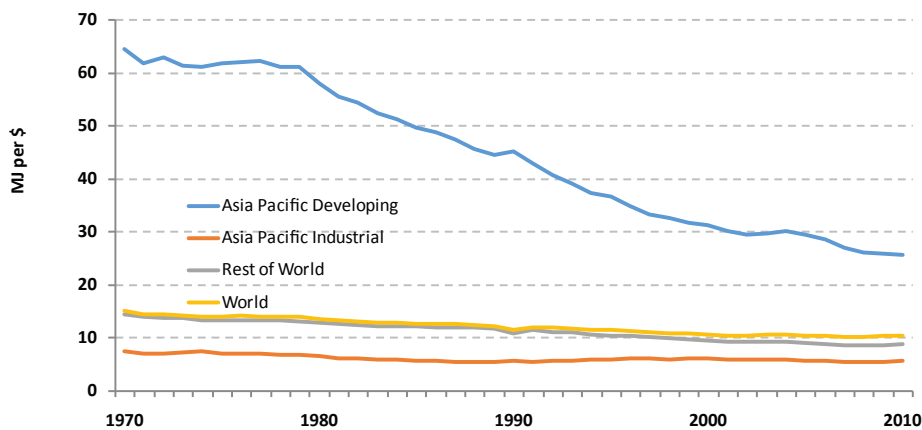
The energy intensity is measured from the perspective of the energy needs of the whole energy system. That is, we refer to total primary energy supply (TPES), which includes all primary forms of energy used directly, for example biomass used for cooking, and those needed to generate secondary forms of energy, for example, electricity or heat. TPES excludes energy embodied in traded goods and services (see Section 6.2 Energy footprint of consumption). Data were obtained from several sources depending on the country (refer to Section 2.2). These were divided by the time series of GDP in constant \$ at 2005<sup>14</sup> for each country, to calculate the energy intensity in megajoules per \$ (MJ per \$)<sup>15</sup>.

14 <http://unstats.un.org/unsd/snaama/dnlist.asp>

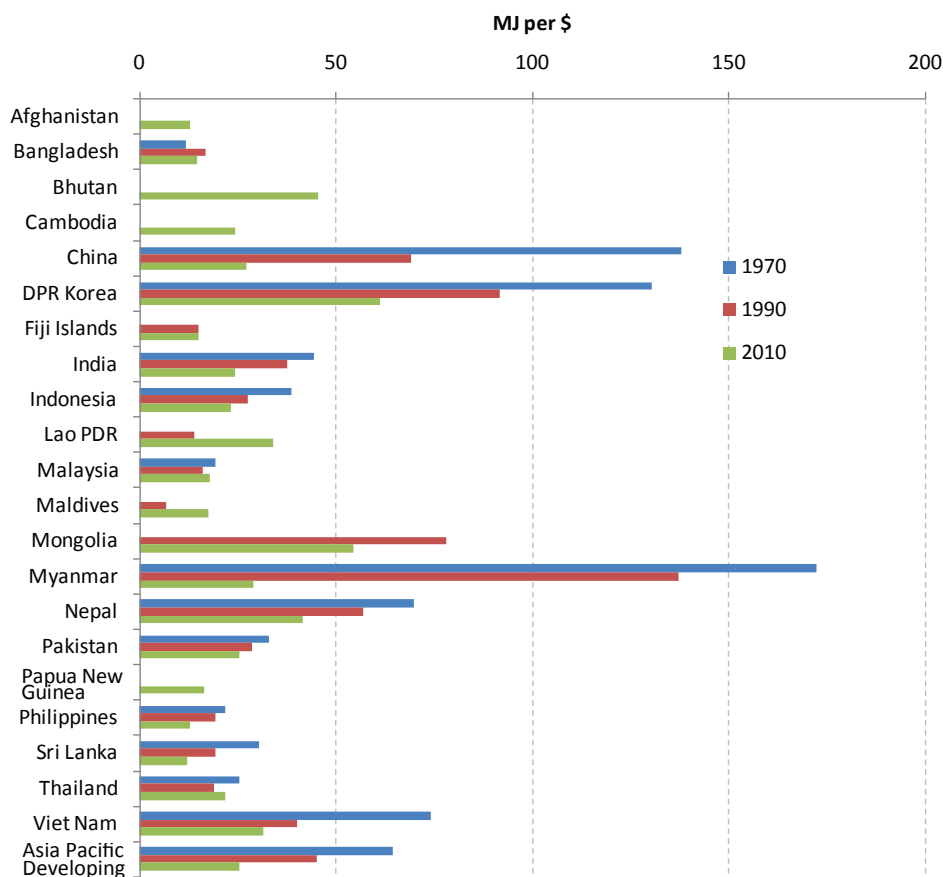
15 1 Megajoules = 0.278 Kilowatt hours =  $23.9 \times 10^6$  tonnes of oil equivalent

As per the material intensity indicator, energy intensity in developing Asia-Pacific countries is characterized as far higher than the rest of the world, but rapidly improving. Since 1970, energy intensity has been steadily decreasing globally by a little over 0.011 MJ per \$ per year. This resulted in an overall global decrease between 1970 and 2010 of 30%. By comparison, the industrialized countries of the Asia-Pacific were half as energy-intensive to begin with but have improved on this trend by reducing their energy intensity by 35% (see Figure 33). While the group of developing Asia-Pacific nations has historically been more profligate in using energy in economic activity, they have reduced their energy intensity by nearly 60%.

**Figure 33 Energy intensity, Asia-Pacific region and World groupings (1970-2010)**



**Figure 34 Energy intensity for Asia-Pacific developing countries (1970, 1990, 2010)**



The analysis of developing nations is limited by the available records that do not have a complete time series for several countries (see Figure 34). What can be shown is a great variety in the experience of developing nations in using energy in production. Factors other than economic structure and technical efficiency that can affect these results include export prices, exchange rates and the international price of fuels. Where the structure and function of economies has remained relatively stable and no great investment in energy efficiency has taken place (for example in Thailand, Malaysia and

Bangladesh) the ratio of TPES to economic output has held its value. Elsewhere in this group there have been significant improvements in energy intensity. There is a common narrative to several countries that have steadily increased the value of economic output while energy needs have also steadily increased, but at a lesser rate. Nepal and Viet Nam serve as examples. Nepal's tourism and services sector now employs more people than industry and agriculture combined and GDP has grown around 4% per year since 1970 while TPES has grown 2.6% per year. In Viet Nam economic growth has been an average of 6.2% per year for 40 years while TPES has only increased 3.8%.

Myanmar and China are conspicuous achievers with similar policy histories, but with very different paths to energy efficiency. Myanmar's energy consumption is mainly in the residential sector and its economic output has historically been dominated by agriculture and strongly coupled to national policies of a centrally controlled economy that was generally closed to international trade. Some similarities can be seen with China's situation up until its 'open door' policies that began in the 1970s. At that time, biomass was still a third of China's TPES and 80% of energy use in Myanmar.

While both countries have grown economically (Myanmar somewhat later than China), Myanmar has not substantially changed the fuel mix of its economy and its TPES grew at only 1.4% per year in our study period. Until the turn of the millennium, Myanmar grew economically at about 4% per year but in the past decade it has reported double-digit growth most likely related to the recent exploitation of gas fields and the expansion of the garment industry<sup>16</sup>.

China's economy has become more service-oriented (services being generally less energy-intensive) and there has been massive investment in new or replacement electricity generation capacity. Additionally, the national government has pursued a number of energy efficiency initiatives over several decades. They have implemented mandatory energy performance standards (MEPS) for high-energy consuming products in the thermal power, steel, non-ferrous metals, building materials and petrochemical industries<sup>17</sup>. China has 11 energy efficiency standards for end-use products in the residential, commercial, and industry sectors.

China's explicit national strategy to improve energy intensity has a highly distributed structure of responsibility, from economy-wide targets down to the shares of the target that must be achieved at the local level. All provinces, municipalities and autonomous regions had a specified goal of reducing local energy consumption per unit of GDP by 20% by 2010 from 2005 levels.

**Figure 35 Energy intensity for Asia-Pacific industrialized countries and regional groupings (1970, 1990, 2010)**

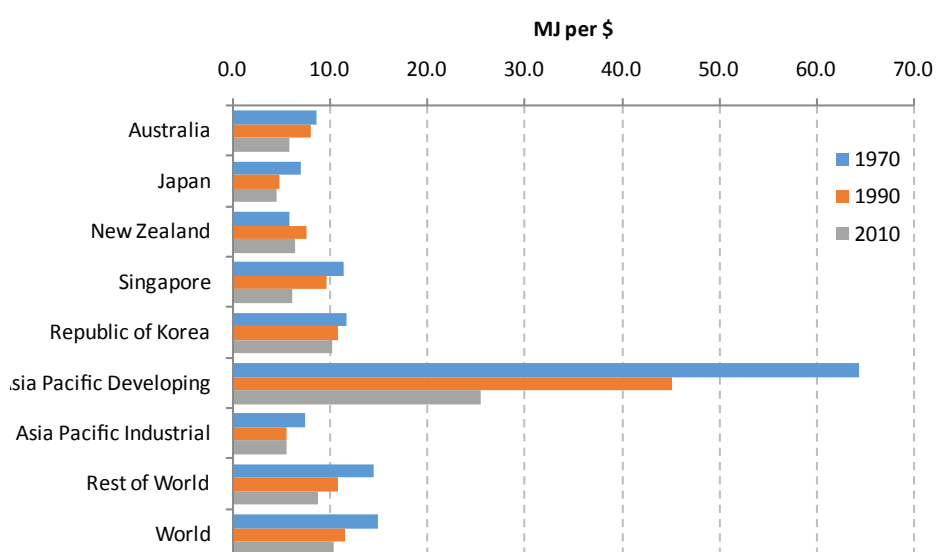


Figure 35 highlights the quantitative difference in both the starting point and the change in energy intensity in Asia-Pacific subregions. While the remainder of the World follows overall global trends, over the past two decades, the gap in energy intensity between Asia-Pacific developing and industrialized countries and the rest of the world has been closing. The most notable long-term change in industrialized countries has been a change in their fuel mix: increased use of gas in Australia

<sup>16</sup> <http://www.ide.go.jp/English/Publish/Download/Dp/pdf/116.pdf>

<sup>17</sup> <http://www.ipeec.org/members.html>



and Singapore and gas and nuclear power in Japan and the Republic of Korea but, as developing nations have increased economic output with fewer energy requirements, the industrialized countries have only reduced their energy intensity by around 1% per year.

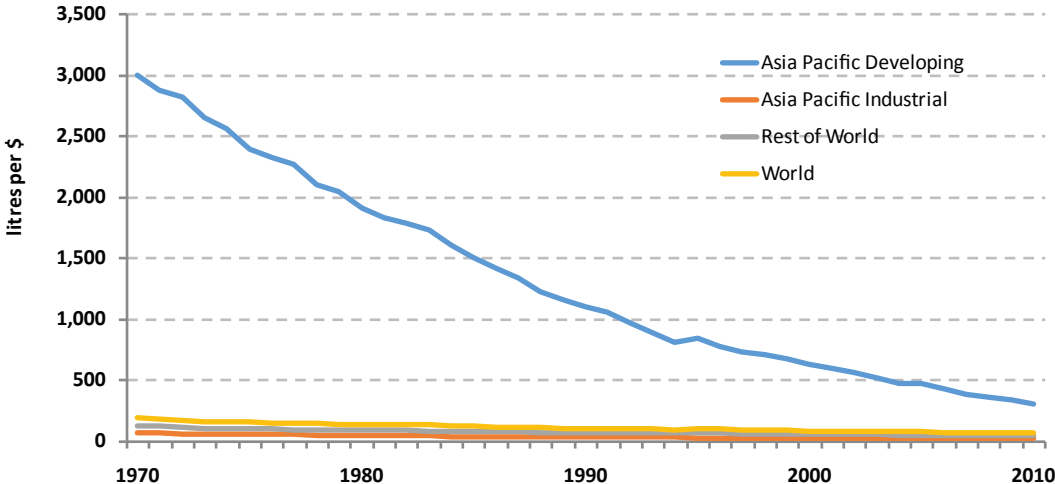
**4.3 Water intensity of the economy**

Water intensity (WI) is conceptually similar to materials intensity, except that the resource measure of interest is simply total water extracted. The reasons for wanting to improve water efficiency are substantially the same as for material efficiency i.e. extracting water and disposing of wastewater post-usage both impose financial and environmental costs. Improving the efficiency with which we can produce economic activity (and its associated social and economic benefits) for each unit of water extracted will reduce the environmental and social costs imposed by water extraction/wastewater disposal, for any given level of economic activity.

Water intensity is defined as total water withdrawals per unit of GDP and measured in litres per dollar.

The measure of water used is total water withdrawals, with base data sourced from FAO (2014), then filled in as outlined previously in Section 2.3 Water use, with the caveats discussed there applying equally here<sup>18</sup>. The monetary base used for GDP is \$ at constant year 2005 exchange rate value, sourced from UNSD (2015).

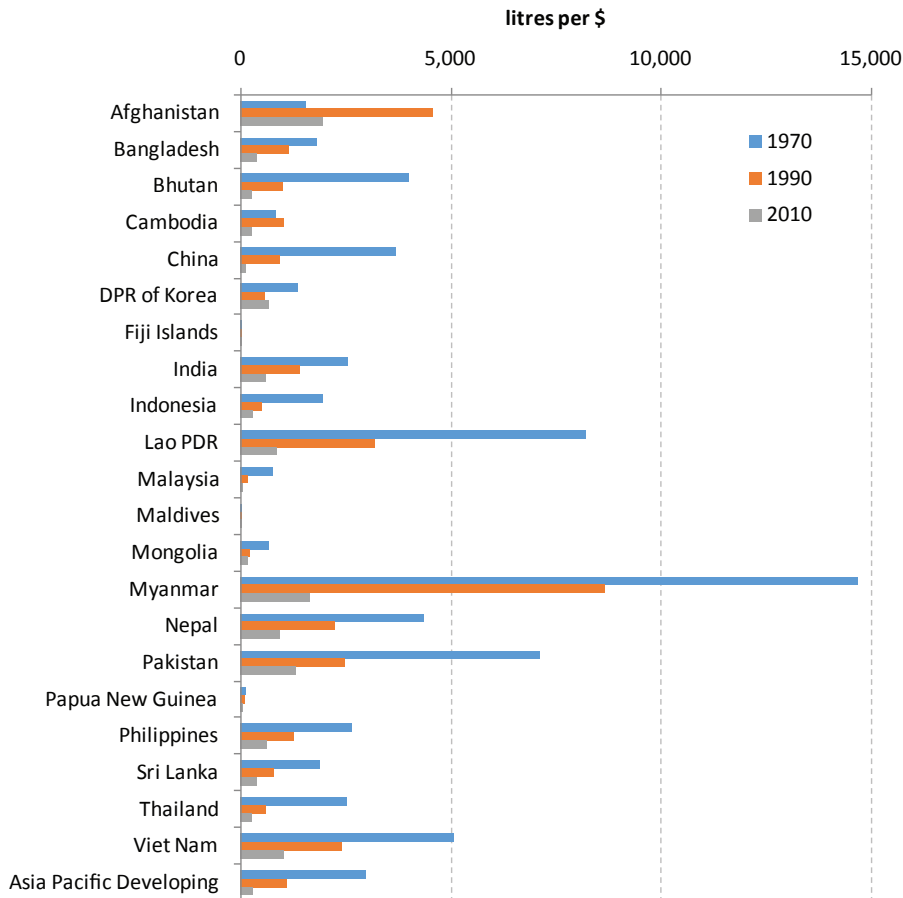
**Figure 36 Water intensity for Asia-Pacific and world groupings (1970-2010)**



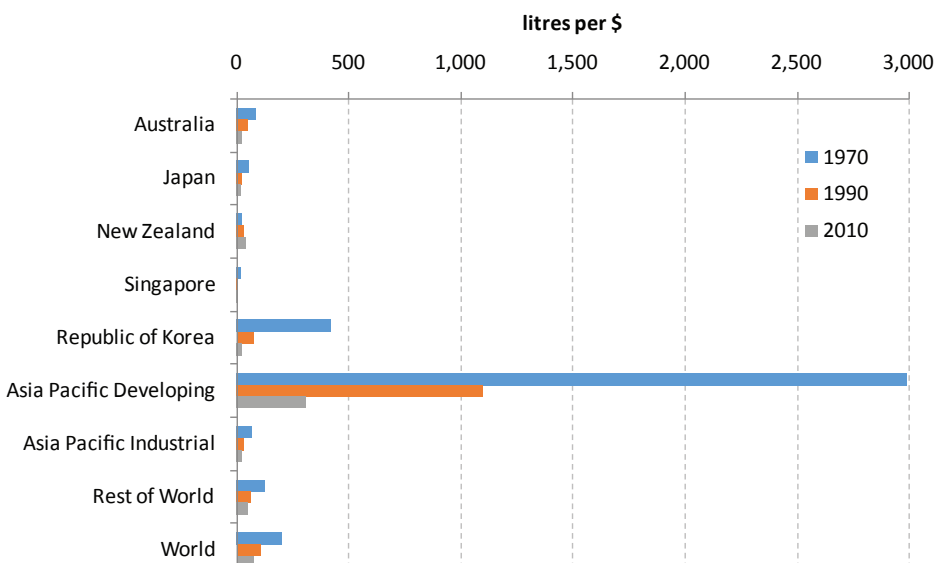
In Figure 36 the extremely water-intensive nature of the developing group is made clear, as are the very rapid improvements made in WI over the period, with an apparent decrease in WI of 5.5% p.a. compounding. This was much faster than the rates seen for the other groupings (3.0 and 2.4% p.a. for the industrialized countries group and Rest of World, respectively). This impressive rate of improvement, while leading to a 90% reduction in the developing group’s water requirement per dollar of GDP, came off such a high initial base that by 2010 the developing group still has WI over four times that the industrialized countries group had attained in 1970, and two and a half times the WI for Rest of World in 1970.

Fortunately, even with the shift of economic activity to the relatively high WI developing group, the rate of improvement was such that WI for the world as a whole improved strongly over the period, at 2.4% p.a. This contrasts with the situation discussed previously for MI.

<sup>18</sup> One important implication of the approach adopted to infilling water data for this report (see 2.3 Water use), is that where we see apparent smooth trends in calculated WI, in many cases this will largely be the expected result of dividing an infrequently updated water figure by a steadily increasing GDP figure.

**Figure 37 Water intensity for Asia-Pacific developing countries (1970, 1990, 2010)**

In Figure 37 we see that WI improved strongly for all but one of the developing group, the sole exception being Afghanistan which saw a marginal increase in WI. China exhibited the greatest decrease in WI, at a compounding rate of 7.8% p.a. over the full 1970 to 2010 period. The other regional giant, India, had a corresponding rate of decrease in WI of 3.5% p.a., and as could be expected, the regional rate is intermediate between the two. Half of all the constituent nations had a rate of improvement better than 3.8% p.a.

**Figure 38 Water intensity for Asia-Pacific industrialized countries (1970, 1990, 2010)**

The Republic of Korea was the only one of the industrialized countries group which ever exhibited a WI approaching the levels seen for the developing group, at over 420 litres per dollar in 1970. From that base it rapidly improved, decreasing WI at 6.8% p.a. compounding for the period to 2010. Remarkably Singapore, which began from a very low base of 19 litres per dollar, achieved the greatest relative reduction in WI, 6.9% p.a., so that by 2010 it required only 1.1 litres per dollar. Both Japan and Australia also achieved strong reductions in WI, with New Zealand the only country in the industrialized countries group to show a deterioration in WI, quite likely a result of that country's huge increases in dairy production for export over the period, with an attendant large increase in irrigation-dependent grazing.

#### 4.4 Emissions intensity of the economy

Emissions intensity refers to the amount of direct greenhouse gas (GHG) emissions produced for every unit of economic output. Whereas aggregate emissions will tell us the scale of emissions that is related to the overall economic activity in different countries, the emissions intensity is a measure of the characteristic efficiency with which economic benefit is achieved in relation to the emissions produced.

The emissions intensity is measured by the ratio of GHG emissions divided by gross domestic product (GDP). Emissions data for 1970 to 2008 came from the European Commission's EDGAR database<sup>19</sup>, which has detail on 55 different sectoral sources for different GHG types. EDGAR reports with the TIER 1 scope as in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Data for 2009 to 2012 were derived from two sources: the World Bank's World Development Indices as updated in September 2014 and the EDGARv4.2 FT2012 time series updated in November 2014 (refer to Section 2.4 Greenhouse gas emissions for more details). These were divided by the time series of GDP in constant \$ at 2005<sup>20</sup> for each country, to calculate the emissions intensity in kilograms of CO<sub>2</sub>-eq per \$ (kg per \$)<sup>21</sup>. This is also how the US Energy Information Administration reports emissions intensity in its International Energy Statistics database<sup>22</sup>.

The global regional trends shown in Figure 39 show a steady decline in emissions intensity both for the World and the part of the World outside the Asia-Pacific region. Although global emissions increased 84% in the same period, global GDP increased 3.4-fold. Comparatively, GHG emissions in the Asia-Pacific increased nearly 250% while aggregate GDP increased 5.5-fold. The net effect is that the World has reduced its emissions intensity of production by 43%; the Asia-Pacific industrialized countries have performed similarly (44%); and Asia-Pacific developing countries have decreased their emissions intensity by 73%.

That the Asia-Pacific industrialized countries share a similar relative change with the Rest of the World is perhaps not surprising given that Japan, the Republic of Korea and Australia have established manufacturing and service sectors in common with other industrialised economies in Europe and North America, which heavily influence the global statistics because of their collective economic size.

That Asia-Pacific developing nations began the study period with much higher emissions intensities is most probably related to their starting point of greater dependence on biomass for fuel, inefficient energy conversion, and outdated technology, for example steam locomotives still in use in China. An important note on our definition of biomass: we have excluded "short cycle" consumption of biomass. That is to say, biomass that regenerates within a year has been excluded from the emissions data and so, when we refer to the use of biomass as an energy source in this section, it is about wood from forests or other biomass that does not replenish itself quickly.

19 <http://edgar.jrc.ec.europa.eu/>

20 <http://unstats.un.org/unsd/snaama/dnllist.asp>

21 One kilogram of CO<sub>2</sub>-eq is a universal way of measuring global warming potential for different GHG gases.

22 <http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=91&pid=46&aid=31>

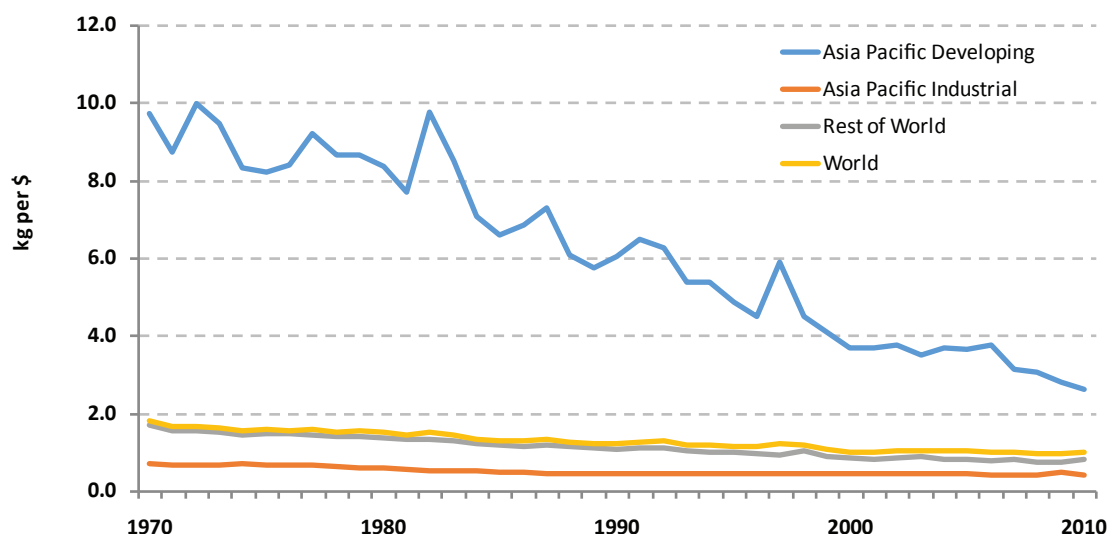
**Figure 39 GHG Emissions intensity for Asia-Pacific and world groupings (1970-2010)**

Figure 40 reveals a general trend in relative decoupling of emissions from GDP in developing Asia-Pacific with Cambodia being the notable exception to the rule. Some key factors that can effect a decrease in emissions intensity include structural change in the economy – from energy-intensive primary or secondary sector production to less energy-intensive tertiary sector dominant economies – and/or a change in the fuel mix.

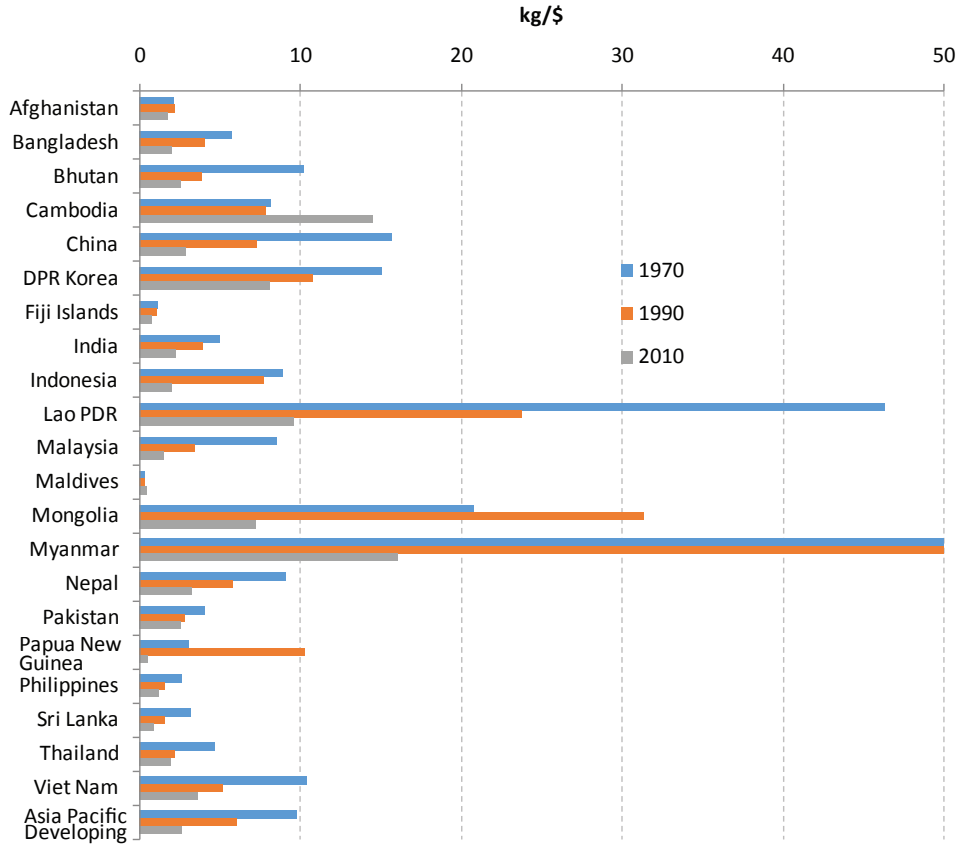
A common trait with several developing countries is an initial state, in 1970, of having agriculture as the most important sector of the economy in terms of emissions. Over 40 years they see a transition: increasing but also diversifying the emissions load to sectors with greater value add, for example, industry, transport and the energy sector. Countries such as Thailand, Viet Nam, Bangladesh, India and Pakistan have different sized economies but share common characteristics in their historical emissions trajectories: increasing emissions but with a faster increase in economic output because of structural change.

Myanmar is conspicuous in Figure 40 though less because of emissions mitigation as much as economic growth. In 1970 Myanmar's GDP was less than either Papua New Guinea or Nepal but by 2000 this had tripled and between 2001 and 2010 it tripled again during a period of sudden economic growth. Thus the denominator (GDP in \$ 2005) in Myanmar's emissions intensity has increased more than tenfold while the numerator (emissions) has maintained a long-term average albeit with great variation due to the effect of forestry and land clearing on its emissions account. In Myanmar there has been the long-term practice of slash and burn cultivation (Taungya), which has been the main cause of forest fires in that country<sup>23</sup>. The subsequent emissions did not yield commensurate economic returns and this contributed to extremely high GHG emissions intensities. Indeed, the variation seen in the Asia-Pacific developing nations trend in Figure 40 can be attributed to emissions from forestry practices, fires and land clearing in Myanmar, Bhutan, Cambodia, Indonesia, Papua New Guinea and Malaysia.

Elsewhere in the developing Asia-Pacific there has been a notable uptake of hydropower, for example in the Lao PDR, and energy efficiency schemes (see the example of China in Section 4.2 Energy intensity of the economy) have reduced emissions intensity by replacing ageing electricity generation technology and reducing the final consumption of energy by the end user.

<sup>23</sup> [http://www.fire.uni-freiburg.de/iffn/country/mm/mm\\_1.htm](http://www.fire.uni-freiburg.de/iffn/country/mm/mm_1.htm)

**Figure 40 GHG Emissions intensity for Asia-Pacific developing countries (1970, 1990, 2010)**



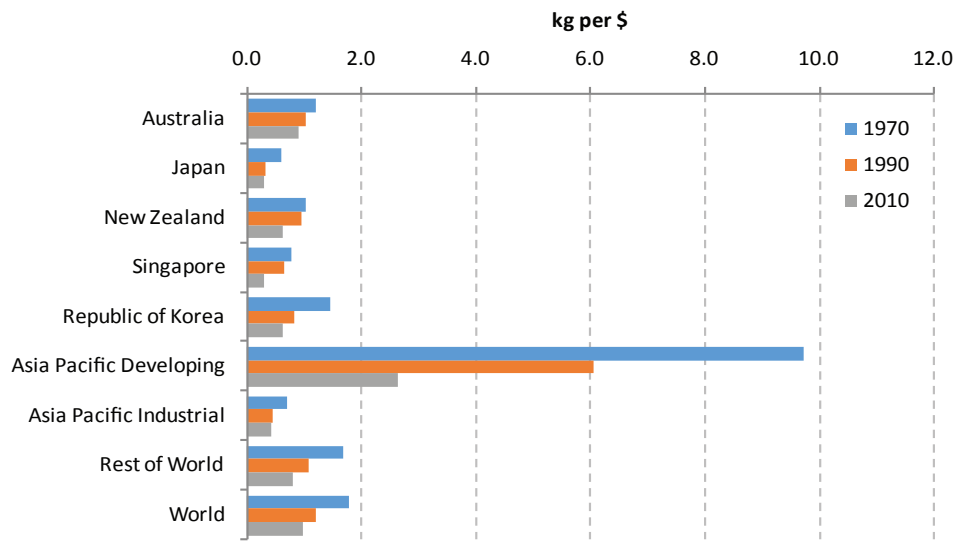
The 1970 and 1990 data for Myanmar has been truncated at 50 kg per \$ to allow readability of the graph. The GHG emissions intensity for Myanmar in 1970 and 1990 was 339 kg per \$ and 267 kg per \$ respectively

The dramatic improvement in emissions intensity of the developing Asia-Pacific has not translated to the industrialized countries because they have retained their basic economic structure throughout the study period, and even with technological change, their energy intensity has decreased only 35% in 40 years.

Industrialized countries have not undergone a transition from an agriculture-dominated emissions account although the Republic of Korea has seen an acceleration of industrialization. What has changed in industrialized countries is their fuel mix. Natural gas has displaced more emissions-intensive coal and petroleum in Australia and Singapore, gas and nuclear power in Japan and the Republic of Korea have reduced the emissions intensity of production, and New Zealand uses a combination of gas, hydropower and non-hydro renewables to provide 60% of its total primary energy needs.



**Figure 41 GHG Emissions intensity for Asia-Pacific industrialized countries and regional groupings (1970, 1990, 2010)**





# Resource use in major sectors

## Headline Indicator 'Eco-Efficiency of Production and Consumption'

- **Total sectoral resource use** (materials, energy, water, GHG emissions, air pollution, land) (tonnes, jouless, m<sup>3</sup>, ha)
- **Resource use per employment** (tonnes per hour; jouless per hour)
- **Sectoral resource productivity** (kg per \$; j per \$; m<sup>3</sup> per \$; ha per \$)
- **Six sectors** – Agriculture and Forestry, Mining and Energy, Manufacturing, Construction, Transport, Services

Methods for measurement: Sectoral accounts of natural resource use attribute resources to those sectors that are using resources and hence attribute responsibility and allow for causation. For material flows and waste there are still unresolved conceptual issues and establishing indicators requires a lot of effort, if they are based on a national physical input-output table showing interdependencies among sectors in physical flows. We have employed sectoral footprints to show the natural resource use per expenditure in sectors.

Data sources: Sectoral data exists for energy use and emissions, and for water to some extent, and can be based on the same data sources used for the national natural resource use indicators. Footprint accounts deliver sectoral disaggregation by expenditure categories for products of major sectors.

Policy Use: Sectoral indicators for eco-efficiency will allow setting targets and establishing policies for different economic activities and will have a much greater steering effect than national targets would have. Because they are close to the activities they would drive innovation and best practice in economic sectors such as agriculture, manufacturing, construction and transport.

The speed and magnitude of growth in productive capacity and infrastructure presents a large challenge and offers great opportunities for innovation. The way we consume and produce food, housing, mobility, energy and water offers huge potential for innovation and much greater resource efficiency.

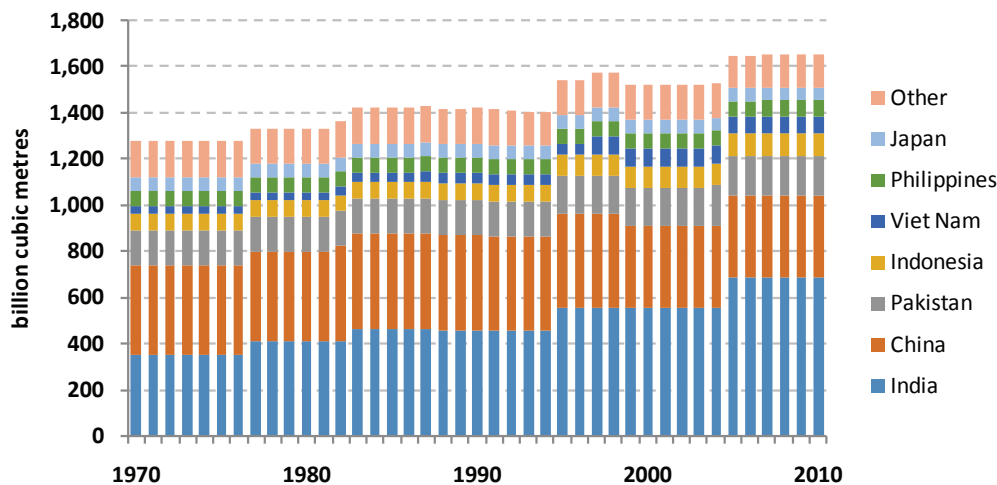
This chapter presents indicators for major economic activities and links systems of provision to resource use.

### 5.1 Water use in agriculture

Agriculture is by far the biggest user of water, often using 70% to 80% of all water resources. A viable agricultural sector also underpins food security and export opportunity in many Asian developing countries.

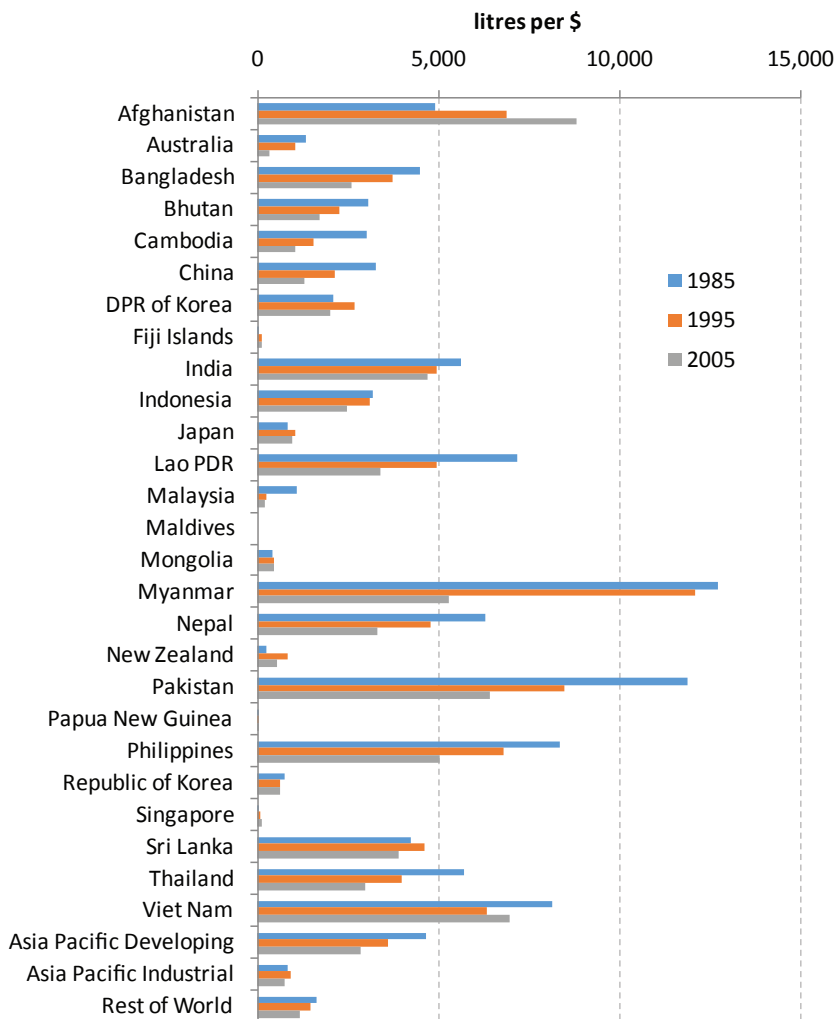
The measure of water used is “agricultural water withdrawal”, with base data drawn from FAO (2014), and missing data filled in using the same method as outlined previously for the total water withdrawals measure used previously in Section 2.3 Water use and Section 4.3 Water intensity of the economy, with the caveats discussed there applying equally here. The monetary base used for water intensity in agriculture is the “Agriculture, hunting, forestry, fishing (ISIC A–B)” category sourced from UNSD (2015) which is denominated in \$ at constant year 2005 exchange rate value. Data on employment in agriculture were sourced from World Bank (2014).

**Figure 42 Agricultural water withdrawal, Asia-Pacific region (1970-2010)**



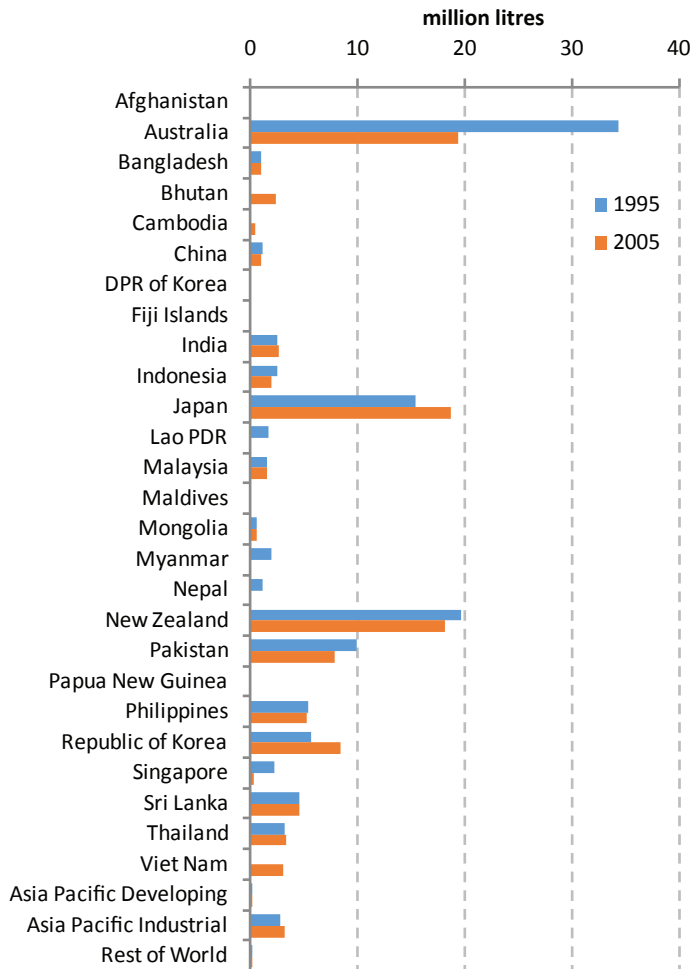
The seven countries with the highest agricultural water withdrawals in the Asia-Pacific region in 2010, shown in Figure 42, accounted for almost 89% of the regional total of 1,706 billion m<sup>3</sup>. The national patterns of use, and growth in use, seen for agricultural water withdrawals are very similar to those seen previously for the total water

withdrawals, discussed in Section 2.3. This is unsurprising due to the dominance of agricultural water withdrawals over all other uses of water in nearly all large economies.

**Figure 43 Water intensity in the Agricultural sector, Asia-Pacific region (1985, 1995, 2005)**

In Figure 43 we see that agricultural water intensity improved for 19 of the 26 countries examined, and for both of the Asia-Pacific groups (developing and industrialized countries), as well as for the Rest of World. The improvements seen in water intensity for the agricultural sector are much less than seen in Section 4.3 Water intensity of the economy for water intensity for the full economy. This quite likely reflects physical limits on the real efficiencies that can be achieved in the water efficiency with which plants can be grown, and output increased. The centrality of large quantities of water to the core agricultural process of biomass production does not apply to anywhere near the same extent in manufacturing or services. That said, half of all the constituent Asia-Pacific nations had a rate of improvement better than 1.9% p.a. on average between 1985 and 2005, while rates of improvement over the same period for the developing group, industrialized countries group, and Rest of World were 2.2%, 0.5%, and 1.3% p.a. respectively.

**Figure 44 Water used per employee in the agricultural sector, Asia-Pacific region (1995, 2005)**



In Figure 44, the years examined were restricted to 1995 and 2005 due to the sparsity of data available on agricultural labour force for the earlier years. A salient feature of Figure 44 is the relatively high levels of water used per agricultural employee in the industrialized countries group compared to most in the developing group<sup>24</sup>. This is consistent with what we would expect as a by-product of the socio-metabolic transition. A key feature of industrialization is the increased mechanization of agriculture, in effect substituting energy for labour, with the remaining labour force consequently able to produce much greater quantities of biomass per employee. The physical requirements of growing biomass ensure that the inputs per employee, of which water is a key one, grow correspondingly.

## 5.2 Emissions of the energy sector

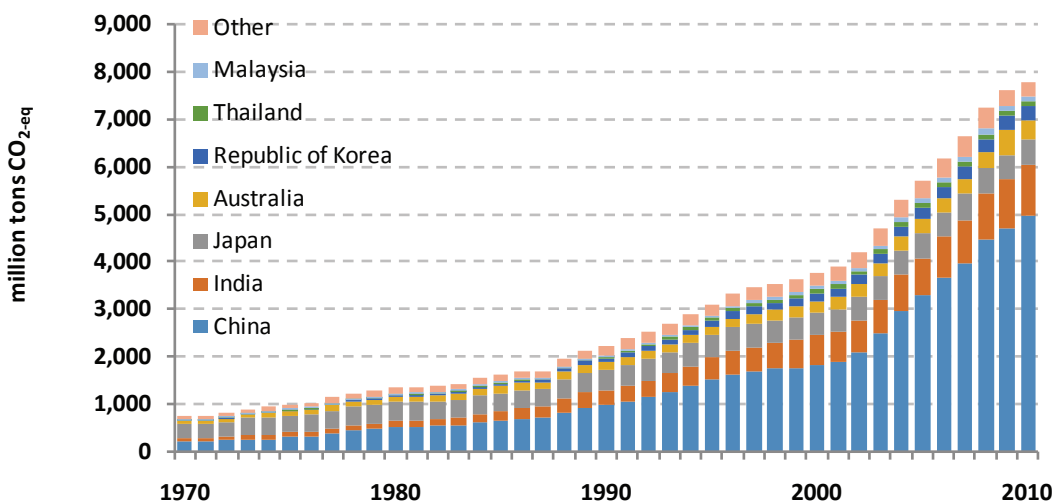
Direct GHG emissions that are produced in the generation and transmission of energy are a relevant indicator of both the carbon efficiency with which energy services are provided, and the scale of the energy needs of a society. The scale aspect of energy production and consumption has been discussed in Section 2.2, but this section looks at the environmental impacts from the perspective of climate change. While many countries in the Asia-Pacific region have reduced their energy intensity in terms of megajoules per unit of GDP, a great deal of this energy transition has come about through new coal-fired power. This investment may even replace more emissions-intensive technology but the total emissions produced from the energy sector are due to a combination of the carbon intensity of energy production, the consumption of energy per capita and the population growth.

<sup>24</sup> Singapore is disregarded in this, as it is effectively a city state with extremely restricted land supply and with very little agriculture as a consequence.



Emissions data were sourced for all countries from the European Commission's EDGAR database<sup>25</sup>, which has detail on 55 different sectoral sources for each of the GHG gas types. EDGAR reports with the TIER 1 scope as in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories<sup>26</sup>. Other details on these data are outlined in the UNEP Emissions Gap Report (UNEP, 2014b) and in Section 2.4 Greenhouse gas emissions. These data represent the emissions associated with the local production and direct consumption of energy. Since 1970 emissions from the energy sector in the Asia-Pacific region have increased nearly tenfold, mainly through the expanding energy needs of China, India, the Republic of Korea and Australia. While the total regional primary energy supply (TPES) has increased fourfold, there has been a relatively greater increase in the emissions-intensive, non-transport component of TPES. More than half of the Asia-Pacific's TPES is directly consumed in China where coal-fired power dominates electricity generation (see Section 2.2 Energy Use). The emissions intensity of energy production in China in 2010 was 47 thousand tonnes of CO<sub>2</sub>-eq for every petajoules of TPES (KtCO<sub>2</sub>-eq per PJ). For comparison, the emissions intensity of TPES in the USA was 60 KtCO<sub>2</sub>-eq per PJ. Of the significant countries in Figure 45, China, Australia and India all have comparably high energy emissions intensities and are among the top four countries of the region. Australia produces 75 KtCO<sub>2</sub>-eq per PJ of energy, India has 36 KtCO<sub>2</sub>-eq per PJ and Mongolia has an intensity of 59 KtCO<sub>2</sub>-eq per PJ. The small population and relatively low-energy lifestyle in Mongolia means that it does not feature in the emissions totals of Figure 45 but Australia, still with a relatively small population, uses the most energy per capita of any nation in the Asia-Pacific and has the highest emissions intensity of energy production. Japan has an energy related emissions intensity of 25 KtCO<sub>2</sub>-eq per PJ and, despite a large population, is notable for having had very low annual increase in energy related emissions since 1970 (1.2%). This may be attributed to its uptake of nuclear power and less emissions-intensive gas power.

**Figure 45 GHG Emissions of the energy sector, Asia-Pacific region (1970-2010)**



<sup>25</sup> <http://edgar.jrc.ec.europa.eu/>

<sup>26</sup> <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>

**Figure 46 GHG Emissions of the energy sector, Asia-Pacific developing countries (1970, 1990, 2010)**

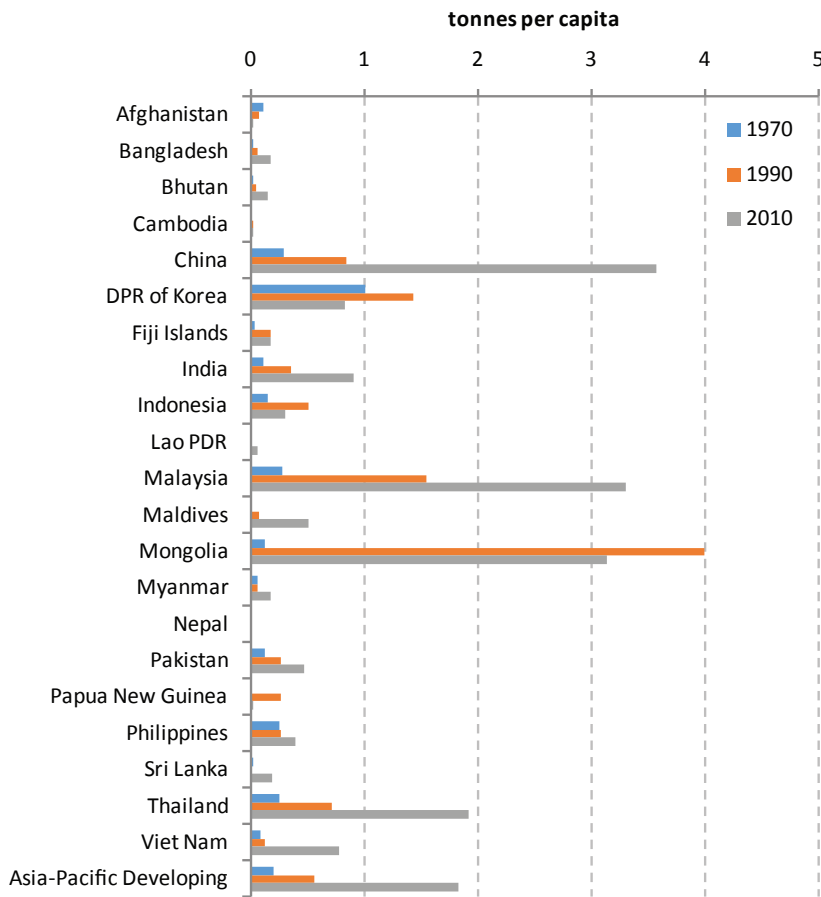


Figure 46 shows the generally low levels of per capita emissions from the energy sector in the Asia-Pacific. Recent fast economic growth (and manyfold increases in energy use) has seen large changes in annual per capita energy emissions in: Thailand (6.5% per year), Viet Nam (7.6% per year), Malaysia (9% per year) and China (7.6%). The latter weighs heavily on the overall average for developing nations in the region (6.8% per year). Mongolia operates on a smaller scale but stands out in Figure 46 as it holds approximately 10% of the known global coal reserves and has been particularly expanding the extraction and consumption of this energy resource since the mid-1980s. While its overall emissions profile is dominated by land-use change, the steady urbanization in Ulaan Baator has demanded the

provision of more electricity and an expansion of coal-fired powered electricity generation.

**Figure 47 GHG Emissions of the energy sector, Asia-Pacific industrialized countries and regional groupings (1970, 1990, 2010)**

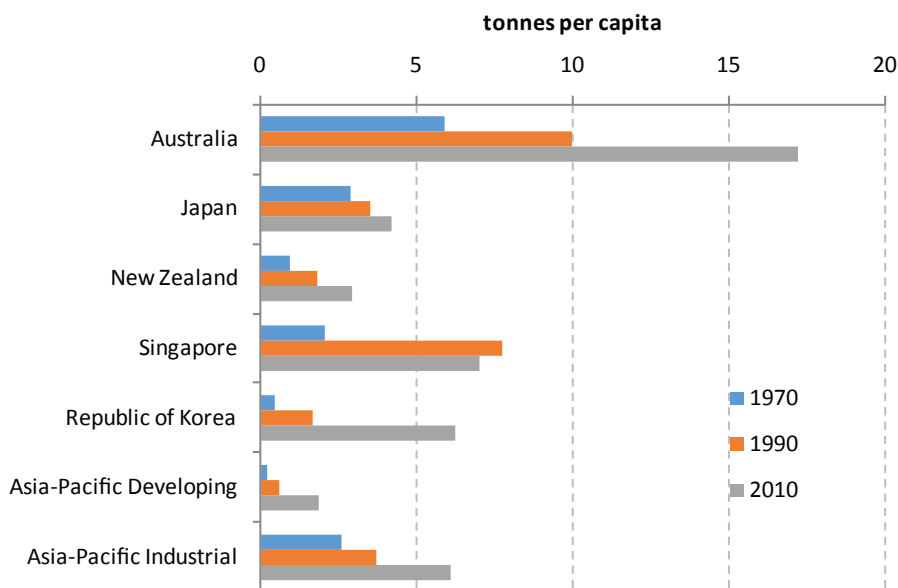


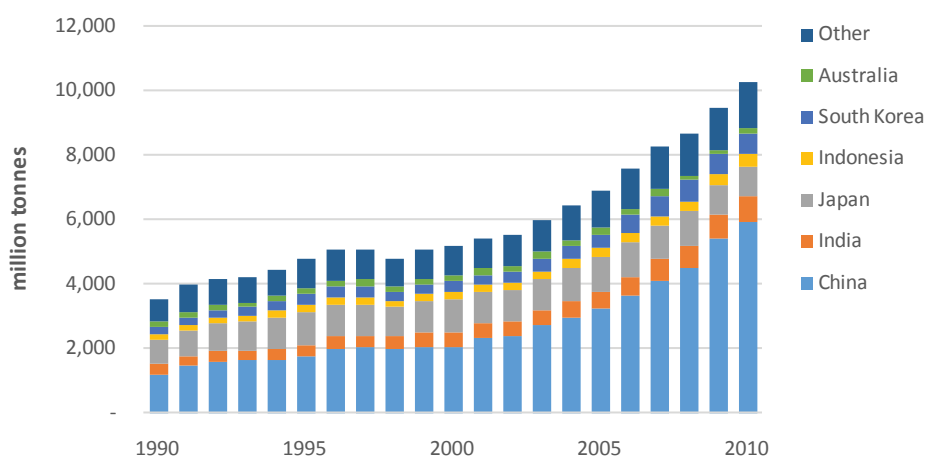
Figure 47 highlights the large relative difference between the developing and industrialized countries of the Asia-Pacific and in particular the increasing per capita emissions intensity of energy in the Republic of Korea and Australia. Australia has steadily increased emissions in its energy sector by 3.4% while population has only increased at 1.4% per year. The compound effect of the 2% difference leads to a 2.2-fold increase in emissions per capita for the Australian energy sector over the last four decades. With the exceptions of Afghanistan and DPR of Korea, all countries have seen at least a doubling in their total energy related emissions between 1970 and 2010, with 13 out of the 26 countries experiencing more than a tenfold increase. With the exceptions of Afghanistan, DPR of Korea and Nepal, all countries in the region saw an increase in their per capita energy related emissions and for the vast majority (17 countries) this tripled or more between 1970 and 2010. For both metrics, the Maldives far exceeded all other nations in the region with a 140-fold increase in total energy related emissions and increasing per capita energy emissions nearly 50-fold. This is very likely because of the extremely low access to electricity in 1970 in contrast to the recent widespread development of electricity generation capacity powered by liquid fossil fuels<sup>27</sup>.

### 5.3 Material use for manufacturing

The manufacturing sector is an important user of materials and also has great potential for using materials more efficiently through eco-innovation. This indicator measures the material footprint of manufacturing by attributing global material extraction to final demand of the manufacturing sector<sup>28</sup>. Global material extraction is attributed to expenditure by households and governments for consumer goods, services and capital investment using a global, multi-regional input-output framework.

The consumption of manufactured goods in Asia and the Pacific has a large material footprint across the whole supply chain and includes many different materials. Over the past two decades, but especially from 2000 onwards, new middle-class consumers have increased consumption of all kinds of manufactured goods including cars, furniture and household appliances. In 2010, 60% of the total footprint for the consumption of manufactured goods came from China, which has also seen the fastest growth at an average of 8.3% yearly over the past two decades. The second biggest consumption footprint of manufacturing goods has occurred in Japan (about 10% of total manufacturing footprint) but with very modest growth of 1% per year.

**Figure 48 Material footprint of manufacturing, Asia-Pacific region (1990-2010)**



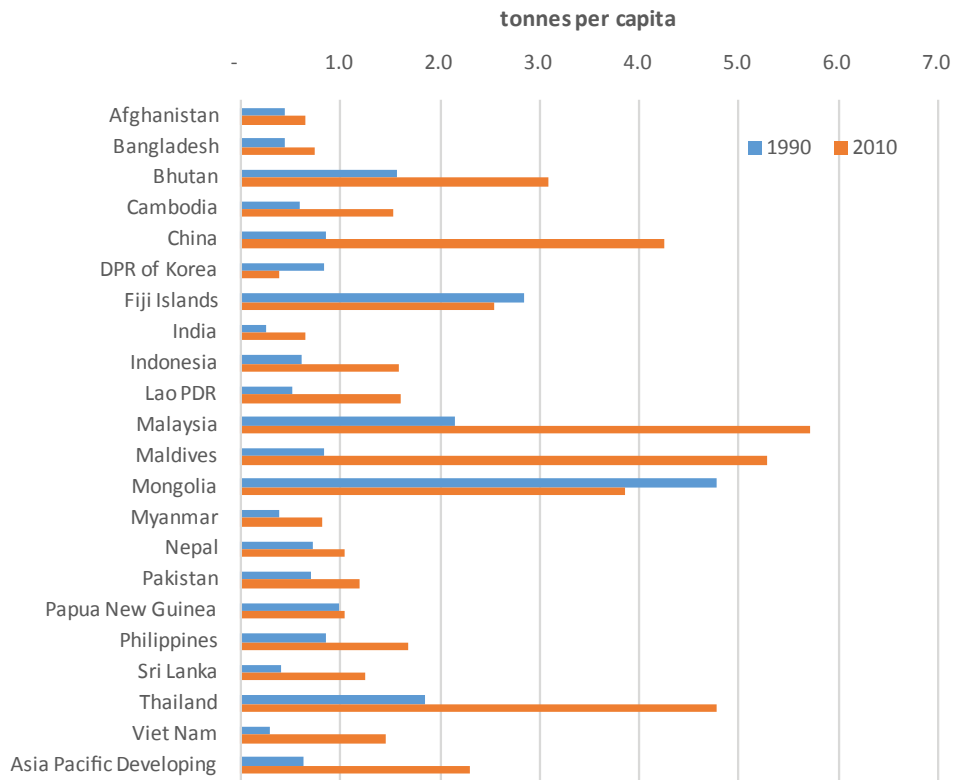
The per capita material footprint of manufactured goods has grown in most Asian and the Pacific developing countries over the past two decades with the only exceptions being Fiji, Mongolia and PDR of Korea. Growth was most accentuated in China, Malaysia, and Thailand which are also among the largest in material footprint for the consumption of goods

from the manufacturing sector. The Maldives also show a very large per capita footprint which is mostly due to the tourism industry and the large amount of accommodation equipped with modern appliances.

<sup>27</sup> <http://www.stelco.com.mv/history.php>

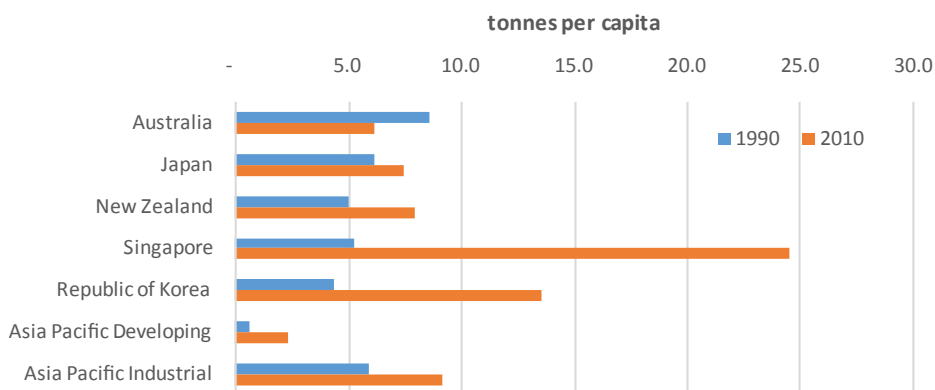
<sup>28</sup> The concept of the material footprint will be explained in more detail in the following chapter.

**Figure 49 Material footprint per capita of manufacturing, Asia-Pacific developing countries (1990, 2010)**



In comparison to industrialized countries in the region the consumption of manufactured goods is still comparably low in Asia-Pacific developing countries and hence the related material footprint is on average also much lower. Growth rates in Asia-Pacific developing countries have, however, been much larger than in industrialized countries of the region, which is evidence of the speed at which the material standard of living in developing countries has improved during the last two decades.

**Figure 50 Material footprint per capita of manufacturing, Asia-Pacific industrialized countries (1990, 2010)**



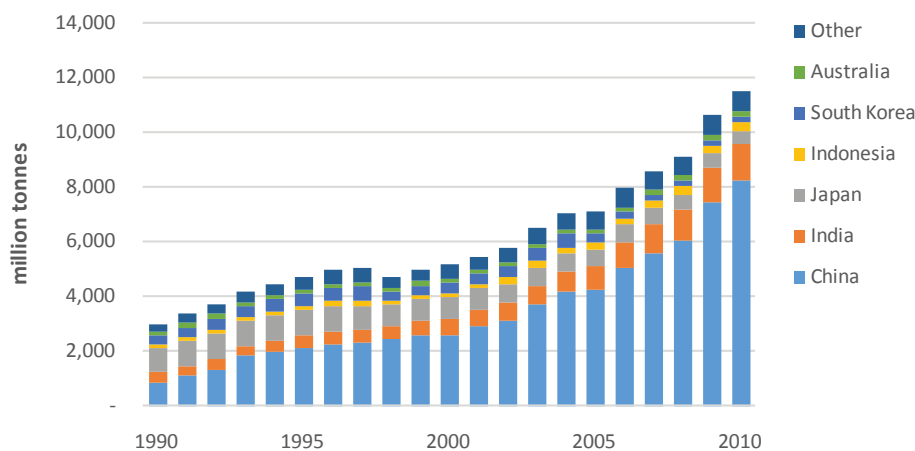
## 5.4 Material use for construction

Fast-growing demand for residential and commercial buildings and for transport infrastructure in cities relies on large amounts of non-metallic minerals (cement, sand and gravel) and metals (iron and steel, copper). This indicator reports the material footprint of the construction sector in each country by attributing the global extraction of non-metallic minerals and metal ores, as well as other minor inputs to the construction sector, to final demand from the construction sector. Global material extraction is attributed to expenditure by households and governments for a consumer goods, services and capital investment using a global, multi-regional input-output framework.

Expenditure for products of the construction sector is another large component – approximately of similar size to manufacturing – of material footprint in the region. This involves mostly construction materials (cement and concrete), metals (iron and steel, copper), timber and glass for new residential and commercial buildings as well as transport infrastructure. More than three quarters of material footprint of construction in 2010 occurred in China, which has seen an extraordinary 11.7% of yearly average growth in construction expenditure related footprint. This immense upstream material requirement of construction activity in China is related to exponential urban growth and also to the establishment of modern transport infrastructure including roads, ports, airports and high speed rail. While this large investment has had an important multiplier effect for the Chinese economy it has also relied on a very large amount of materials.

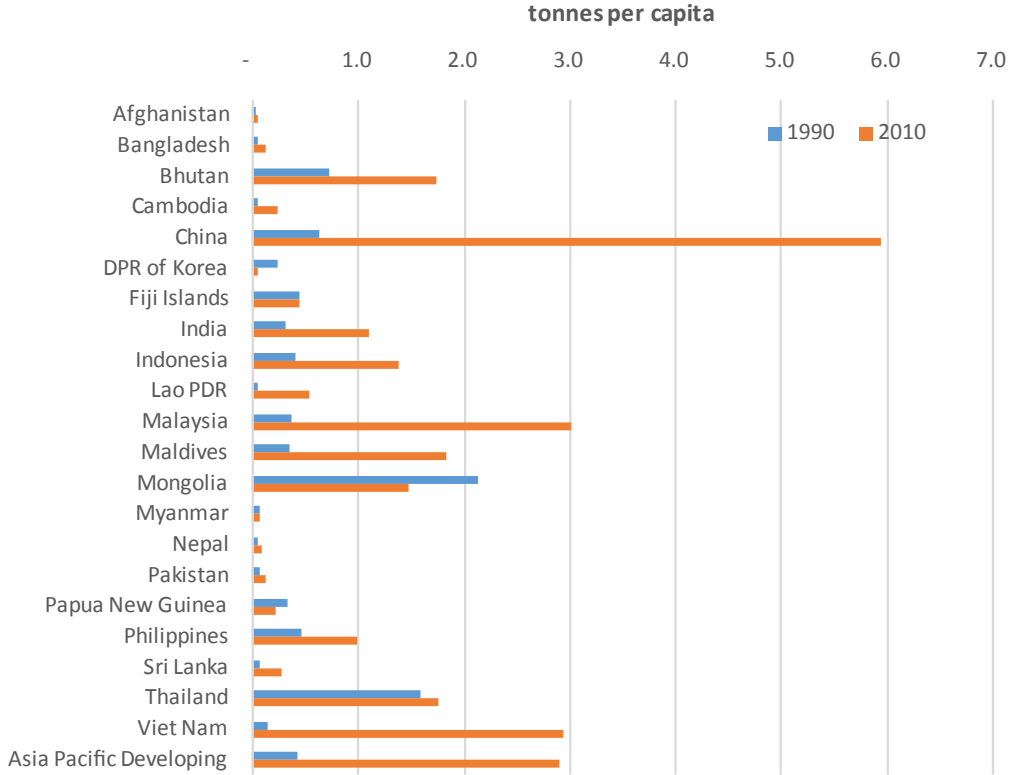
India was second in material footprint of construction expenditure and also showed the second-highest average growth at a yearly 6.5%. In Japan and the Republic of Korea, by comparison, construction expenditure and related material footprint declined over the past two decades by an average of –2.9% in Japan and of –2.7% in the Republic of Korea.

**Figure 51 Material footprint of construction, Asia-Pacific region (1990-2010)**



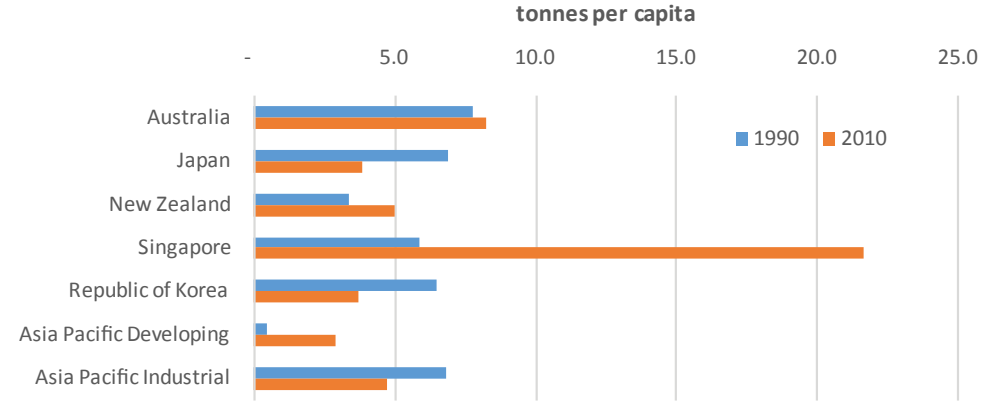
In 2010, China had by far the largest material footprint of construction expenditure of the whole region at 6 tonnes per capita, up from less than one tonne per capita in 1990. Viet Nam has experienced similar impressive growth in construction expenditure related material footprint to China.

**Figure 52 Material footprint per capita of construction, Asia-Pacific developing countries (1990-2010)**



Despite such enormous growth in many developing countries in the region, Asia-Pacific industrialized countries still have a larger per capita material footprint for construction expenditure. The growing trend in developing countries and declining amounts in industrialized countries may well converge to a similar level of per capita material footprint of construction over the next decade.

**Figure 53 Material footprint per capita of construction, Asia-Pacific industrialized countries (1990-2010)**





## 5.5 Emissions of transport

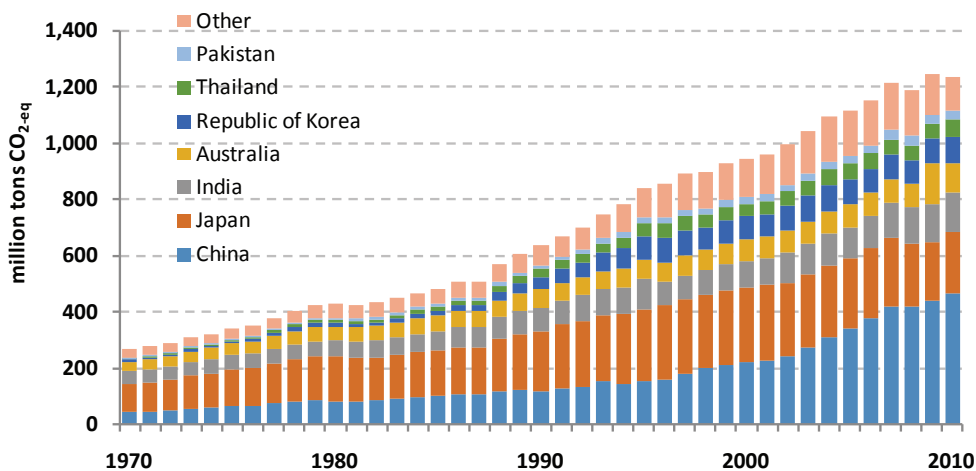
Direct GHG emissions from the transport sector indicate both the carbon efficiency with which motorized mobility is enabled and the overall mobilization of society. The availability of different transport options is important and there has been a growing trend across the region in private vehicle ownership. This section looks at the environmental impacts of the transport sector from the perspective of climate change.

Emissions data were sourced for all countries from the European Commission's EDGAR database<sup>29</sup>, which has detail on 55 different sectoral sources for each of the GHG gas types. EDGAR reports with the TIER 1 scope as in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories<sup>30</sup>. Other details on these data are outlined in the UNEP Emissions Gap Report (2014) and in Section 2.4 Greenhouse gas emissions. These data represent the emissions associated with the local production and direct consumption of energy, by industry and from land-use change. From this we have selected those direct GHG emissions attributed to the transport sector for each country. In the figures that follow we have retained the metric of tonnes of CO<sub>2</sub>-eq for consistency across sections although the great majority of emissions due to transport are CO<sub>2</sub>.

Transport data discussed in this section comes from the Millennium Cities Database for Sustainable Transport and the Mobility in Cities Database both from the International Union of Public Transport (UITP)<sup>31</sup>.

In Figure 54 the aggregate emissions from the seven most significant countries and the rest of the Asia-Pacific region are shown. Even as the total regional emissions have increased just under sixfold, it is worthwhile noting that, approximately, the overall impact from transport has only recently exceeded the regional emissions from the energy sector in 1970. Emissions from transport have grown relatively more slowly than emissions from stationary energy production and use (4.5% per year). The changes in transport related emissions in the region over 40 years have been influenced by different countries at different times.

**Figure 54 GHG emissions of the transport sector, Asia-Pacific Region (1970-2010)**



China and Japan combined have always been responsible for more than half of regional transport emissions (52% in 1970, and 54% in 2010) but they have exchanged places in their relative importance. Japan's rapid post-WWII growth saw industrialization and, subsequent to that, increases in income per capita, car ownership and personal mobility. Between 1970 and 1995 there was a 176% increase in transport emissions. However, from the turn of the millennium, Japan has consciously sought energy efficiency in public and private transport (such as micro-cars and "Shinkansen" inter-city trains) resulting in a decline in national transport emissions. Since 1970, China has undergone a later but faster economic transition and, proportionally, China has increased its regional contribution from 17% to 37% of Asia-Pacific transport emissions.

<sup>29</sup> <http://edgar.jrc.ec.europa.eu/>

<sup>30</sup> <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>

<sup>31</sup> <http://www.uitp.org/>

Part of this can be attributed to greater ownership of private automobiles. In 1995, car ownership in major Chinese cities was around 26 cars per 1,000 people and motorcycle ownership had more than double this incidence (56 per 1,000 people). In Beijing the average per capita, car passenger transport task was 814 passenger kilometres per year. By 2010, the incidence of private automobile ownership had multiplied more than fourfold and the annual passenger task had increased to 1,365 passenger kilometres per year. This 68% per capita increase was also multiplied by the near doubling of Beijing's population in the same period.

**Figure 55 GHG emissions of the transport sector, Asia-Pacific developing nations (1970, 1990, 2010)**

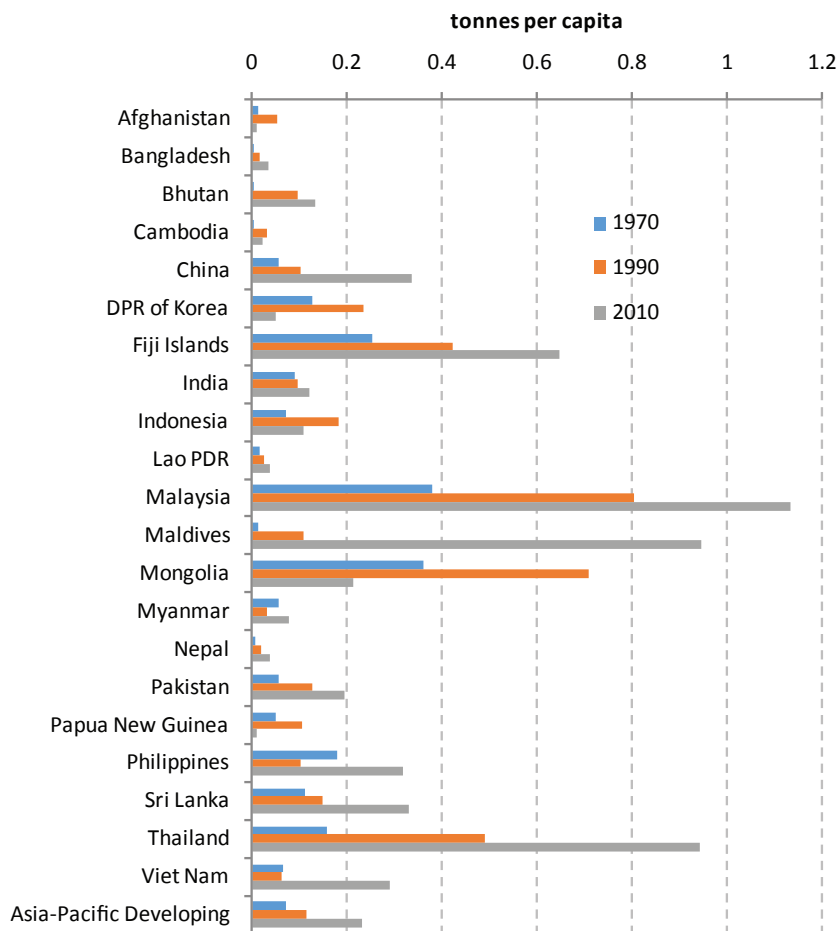


Figure 55 shows that although some southern Asian nations (for example, Malaysia and Thailand) have more than tripled their per capita transport emissions, there is a more general trend exemplified by Viet Nam, Sri Lanka, the Philippines, Pakistan and China of raising per capita transport emissions to between 0.2 and 0.3 tonnes per person, and within this range is the average for Asia-Pacific developing nations as a group.

The Maldives may be considered exceptional as the relatively small population rely on transport as part of their expanding tourism industry that is the most significant part of their economy. This is also the case to a lesser extent for Fiji.

**Figure 56 GHG emissions of the transport sector, Asia-Pacific industrialized countries (1970, 1990, 2010)**

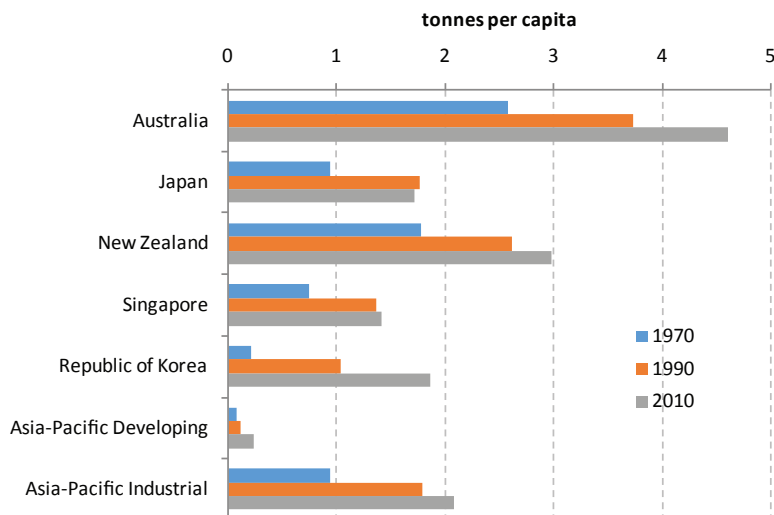


Figure 56 highlights the order-of-magnitude relative difference between the developing and industrialized countries of the Asia-Pacific. Japan's efforts on reducing energy use in transport have levelled out their per capita transport emissions and Singapore shows similar characteristics, while Australia, New Zealand and the Republic of Korea have all substantially increased their per capita emissions.

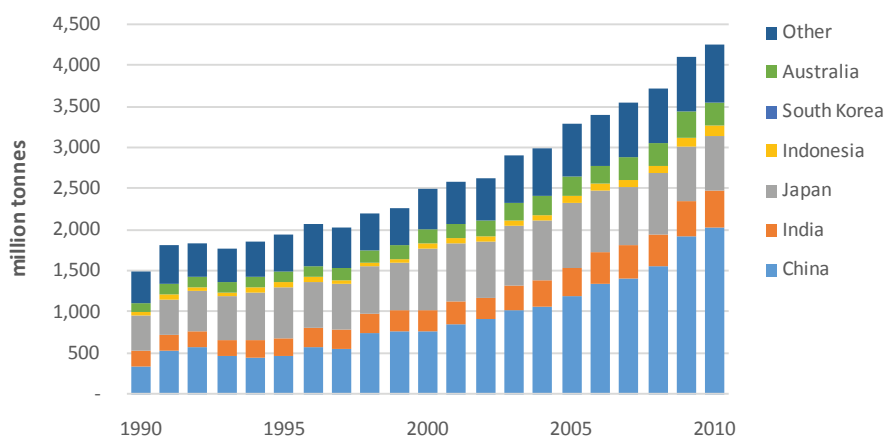
In Australia, private passenger vehicles dominate the transport task and some basic statistics substantiate the observed increase in transport emissions. Australian private car ownership has increased from 307 cars per 1,000 people in 1971 to 551 cars per 1,000 people in 2010 and this is broadly concurrent with the corresponding increase in the total passenger kilometres (km) travelled from 100 billion passenger-km to 260 billion passenger-km (BITRE, 2012). According to the Australian Bureau of Statistics (ABS, 2013), the average passenger vehicle fuel economy remains between 10 and 11 litres of petrol per 100 km, which is approximately the same fuel economy as a new car bought in the 1980s<sup>32</sup>.

## 5.6 Material footprint of services

As economies in Asia and the Pacific mature they undergo structural changes. Employment and added value in agriculture, forestry and fishing declines at the cost of growth in manufacturing and service industries. The growing service sector offers a range of opportunities at very different income levels but usually has a lower environmental footprint per unit of output compared to other sectors of the economy. This indicator measures the material footprint of the service sector by attributing global material extraction to final demand of the service sector. Global material extraction is attributed to expenditure by households and governments for consumer goods, services and capital investment using a global, multi-regional input-output framework.

Consumption in the service sector has also grown rapidly but because of the much lower material intensity of services the overall material footprint has been comparably low although expenditure now surpasses other expenditure categories in many countries. In 2010, almost half of the material footprint for all kinds of materials related to the consumption of services has occurred in China, with around 15% in Japan, 10% in India and 7% in Australia. China has seen the fastest yearly growth at an average of 9.3%, followed by Indonesia, and Australia's material footprint of consumption of services has grown at over 5% yearly.

**Figure 57** Material footprint of services, Asia-Pacific Region (1990-2010)



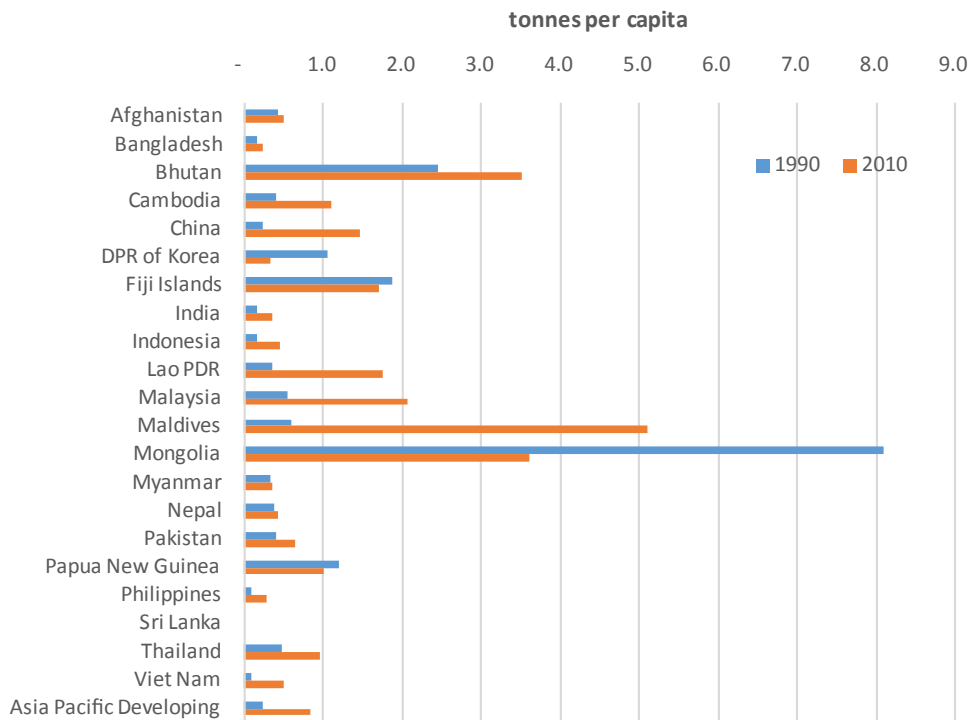
The largest per capita material footprint related to the consumption of services has occurred in Bhutan, the Maldives and Mongolia for different reasons. Countries with a large tourism industry (such as the Maldives) would show a considerably higher service-related consumption footprint as would countries that have a large share of mining activity, and not much manufacturing, but a high

number of well-paid services related to the mining sector such as is the case in Mongolia.

In many countries the overall expenditure for services has grown over the past two decades. This, however, very often involved low paid services that also have very low material intensity. This has meant that per capita levels of footprint have grown much more slowly than for other consumption activities.

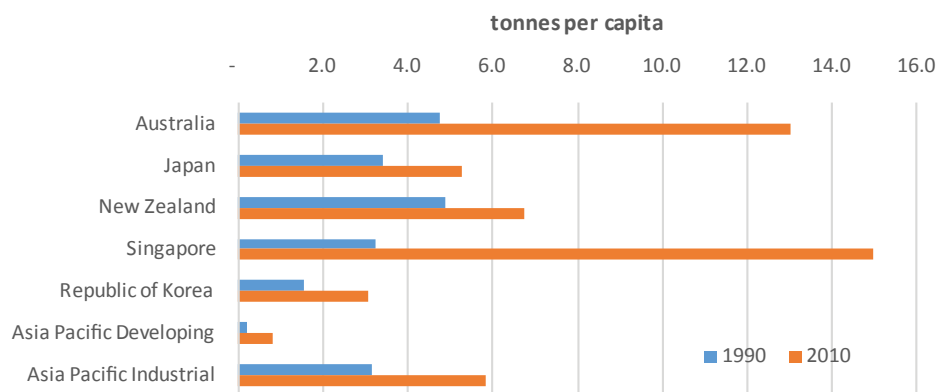
<sup>32</sup> [https://www.bitre.gov.au/publications/2009/files/is\\_030.pdf](https://www.bitre.gov.au/publications/2009/files/is_030.pdf)

**Figure 58 Material footprint per capita of services, Asia-Pacific developing countries (1990, 2010)**



Comparing the material requirement for services in industrialized countries and developing countries in Asia and Pacific, the difference between the two is more accentuated than for other sectors and growth in industrialized countries has been similar to growth in developing countries, signalling a great reliance of consumers in Japan, the Republic of Korea, Australia, New Zealand and Singapore on often material intensive services.

**Figure 59 Material footprint per capita of services, Asia-Pacific industrialized countries (1990, 2010)**









# Consumption-based indicators for natural resource use

## Headline Indicator 'Consumption'

- **Natural Resource Footprint** – Attribution of natural resource use to final consumption in a country
- **Material Footprint** (tonnes; tonnes per capita)
- **Energy Footprint** (joules; joules per capita)
- **Water Footprint** (cubic metres, cubic meters per capita)
- **Carbon Footprint** (tonnes; tonnes per capita)

Land Use Footprint (ha; ha/capita) would also be a recommended indicator for this domain, however it is outside the scope of this report.

Method of measurement: Conceptually a relatively new indicator based on a combination of global data for natural resource use (with country by country detail) and a multi-regional, global input-output representation of the world economy. A seminal contribution in the *Proceedings of the National Academy of Sciences* (Wiedmann et al., 2013) has set a standard that was followed in this report.

Data sources: Data was produced based on natural resource use data and MRIO capability. We employed the Eora MRIO framework for attributing natural resources and emissions to final consumption and capital expenditure.

Policy Use: This indicator attributes natural resource use to final consumption in countries and offers a very important additional perspective to that provided by territorial indicators such as DMC and TPES because it corrects for the upstream requirements of imports and exports. For high importing and exporting countries this will allow an 'equal playing field' regardless of economic structure and role in the global economy.

This indicator set will also be important for communication with the public and key stakeholders.

## Resource use for consumption and capital investment is still below direct resource use in production because of Asia's focus on manufacturing for exports.

This chapter presents an overview of trends in natural resource use – materials, energy and water – and trends in emissions using a consumption approach and covering the past four decades. This chapter complements Chapter 4 and presents a comparison between direct and footprint indicators.

### 6.1 Material footprint of consumption

The material footprint of consumption indicator attributes global material extraction to final demand including final consumption of households and governments and capital investment. In doing so it provides information on the primary material demand of an economy by eliminating the distortion that occurs through the trade system. When economies mature they replace a significant share of the domestic production of final goods and the extractive activities it relies on by importing final goods. The upstream primary material requirements to produce those goods and the related environmental impact stays in the producing country. This process of outsourcing material intensive activities to third countries has allowed wealthy economies to reduce their domestic environmental pressure and impact at the cost of exporting countries. This indicator reports the true amount of primary materials consumption and capital investment in a country relies upon independently from where the material extraction has occurred in the global economy.

Material footprints give valuable information on the often counter-intuitive concept how much one country's lifestyle in fact depends on materials that have been extracted outside that country's borders. Some of these supply chains are obvious. For example, South Africa is a large coal exporter and it is obvious that the electricity supply in countries that purchase this coal depends on the coal extracted in South Africa. But the vast majority of global material dependencies are highly complex and counter-intuitive, and the location of the material extraction is often geographically far removed from the country of final consumption.

Moran et al. (2014), for example, examined the path that coltan takes in its journey from the point of extraction to the final product. They identified that coltan from Central Africa is processed into derived products several times and at different locations before it is finally used as part of the microprocessor within entertainment devices that are sold on the US market. The mining of the coltan has had severe ecological impacts and led to a catastrophic drop in the population numbers of several endangered species within the mining area. Using the same techniques that are presented within this report, this causal chain of events was identified, and legislation was put in place to ensure that the consumption of entertainment devices within the US does not indirectly drive biodiversity threats in Africa.

The material footprint accounts were calculated using the Eora global, multi-regional input-output framework developed by the University of Sydney (Lenzen et al., 2013a) and a new global material extraction satellite data set detailing 48 material extraction categories for every country in the world for the 1990–2010 period. Standard input-output analytical procedures based on the conceptual framework developed by Leontief (1974) were applied.

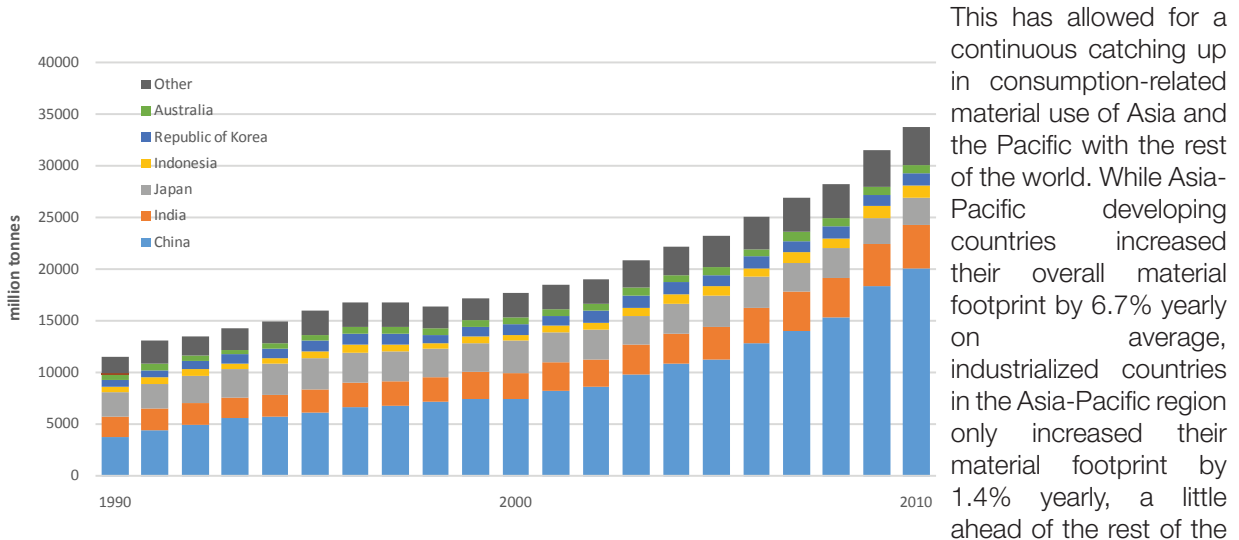
Calculating these material footprints requires the processing of large amounts of data on economic activities as well as on material extraction. Two key data types must be merged into a unified database to allow for material footprint calculations such as those presented in this section. The first data type is economic transaction data. These data are published by national and international statistical agencies in the form of input-output tables (IO tables). IO tables implicitly hold detailed information about the structure of an economy, the interdependencies between different economic actors, and ultimately the supply chains as they occur within this economy. IO tables are usually published for individual nations or specific regions only. Hence, published IO tables do not provide information about supply chains that span the entire globe.

In order to understand global supply chains, individual IO tables must be merged into a single, global IO database. The IO tables in a global database are referred to as multi-regional IO tables (MRIO tables). While global MRIO databases had already been envisaged from the 1950 onwards, only recent developments in high-performance computing and data availability have allowed researchers to attempt the compilation of such databases. The Eora database (Lenzen et al., 2012 and Lenzen et al., 2013b), which was used for the calculations presented in this chapter, is the currently largest and most detailed global MRIO database.

With the information on global supply chains being readily available within the Eora database, the second key type of data must be linked to the economic MRIO database: data on material extraction for each country. Linking these data to the Eora model allows researchers to identify how consumption behaviour in one particular country requires material extractions within all other countries. This technique is called environmentally-extended input-output analysis. Thanks to the global MRIO database, billions of supply chains connecting the final consumer and the material extraction can be considered. The result of this analysis is the allocation of all globally extracted raw material to the final consumers within a specific country – the so-called material footprint.

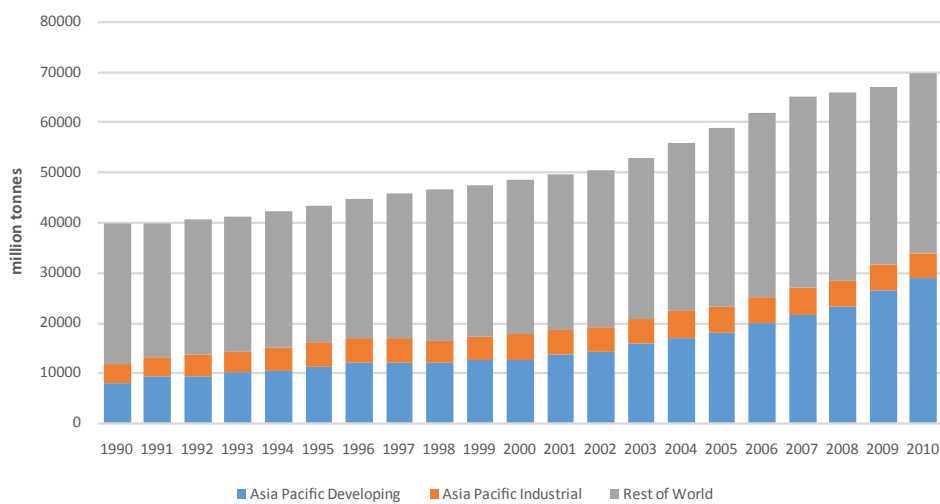
The material footprint of consumption has grown rapidly in Asia and the Pacific, especially in China, with a yearly average growth rate of 8.7% reflecting China’s tremendous growth in GDP and to a lesser extent that of India (yearly growth of 3.9%) but also in the region overall which grew from 11.5 billion tonnes in 1990 to 33.1 billion tonnes in 2010 (yearly growth of 6.7%). Very fast growth in material footprint was also experienced in Viet Nam (10.7% yearly, surpassing China’s growth), the Lao PDR and Singapore (7.6% yearly). This meant that the Asia-Pacific region increased from one quarter of global material use to one half of global material use related to final consumption and capital investment. Initial growth in the early 1990s come to a halt during the Asian financial crisis in the late 1990s but since 2002 the region has been on a renewed growth trend which was not at all interrupted by the global financial crisis of 2008–2009, mainly because of the capacity of the region to invest during the economic down cycle.

**Figure 60 Material footprint, Asia-Pacific region (1990-2010)**



world which was growing by 1.3%. Most of the growth dynamic in material footprint, similar to domestic material consumption, originated in growing final consumption and capital investment in Asia-Pacific developing countries. These have been the “motor” of the world economy in terms of manufacturing growth, enabling growth in household and government consumption based on higher incomes and tax earnings.

**Figure 61 Material footprint, Asia-Pacific region and rest of world (1990-2010)**

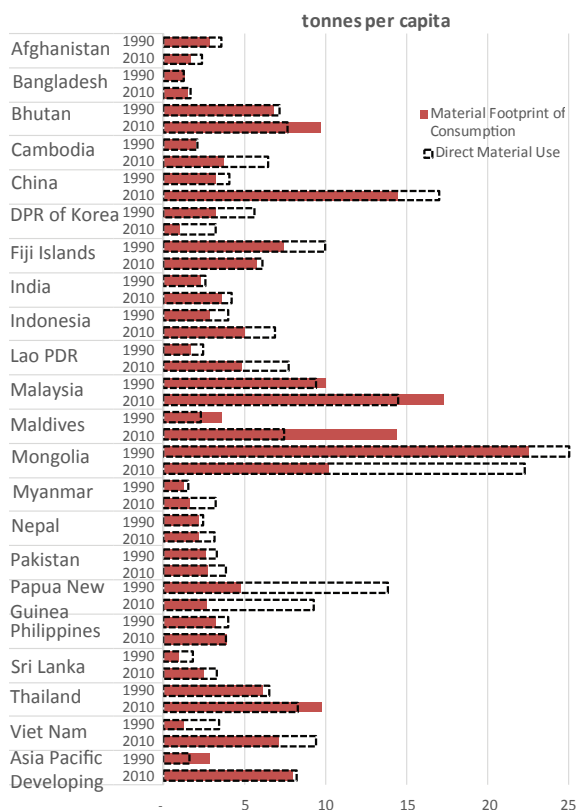


Per capita material footprints in Asian developing countries have been low in general at less than 5 tonnes, reflecting a relatively low material standard of living and low investments in built infrastructure and productive capital. This has, however, changed in a number of countries over the past two decades, most notably in China (due to raising households out of

poverty and increasing living standards in economic centres and cities), in Thailand and Viet Nam (for similar reasons – a growing middle class based on new opportunities and higher incomes in growing cities) and in the Maldives because of the sizeable tourism industry. Material standards of living are lower than those of industrial countries in Asia and the Pacific, whose material footprint is three times as large as in the developing economies of the region. It should be emphasized here that similar to the DMC data, footprint data is measured at an average scale, and does not reflect equitable distribution.

In 1990, for most Asian developing countries' per capita material footprint was lower than per capita direct material use with the exception of Malaysia and the Maldives suggesting a comparably high standard of living for the former and the large influence of the tourism sector for the latter. In 2010, there continued to be a gap between footprint and direct use of materials in most countries but Thailand and Bhutan have now joined Malaysia and the Maldives with a material footprint of consumption higher than the direct use of materials.

**Figure 62 Material footprint per capita compared to Domestic material consumption per capita, Asia-Pacific developing countries (1990, 2010)**



All industrialized countries in Asia and the Pacific have continued to increase their material footprint, indicating that there is no level of income at which material use has saturated in the region yet although the growth in per capita footprint in Japan has been very small. The average rate of growth in Asia-Pacific industrialized countries was 0.9%. Per capita material footprint has not grown in the rest of the world over the past two decades, mainly because of the breakdown in household consumption and government spending during the global financial crisis and the years of recession that have followed in many parts of the world economy.

Japan, Singapore and the Republic of Korea have higher material footprints compared to direct material use demonstrating the extent to which they have outsourced material intensive processes to other economies. The gap between the two had become very large for Singapore by 2010; Singapore now depends to a very large extent on a resource base outside of the country. Australia and New Zealand show the opposite picture with the consumption material footprint quite a bit lower, especially for Australia, than direct use which reflects Australia's role as a major exporter of natural resources.

**Figure 63 Material footprint per capita compared to Domestic material consumption per capita, Asia-Pacific industrialized countries (1990, 2010)**

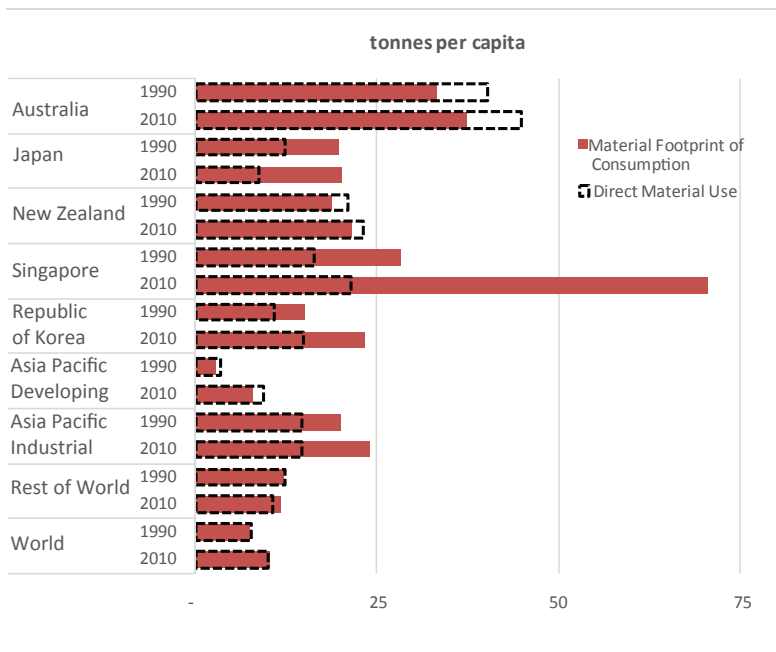
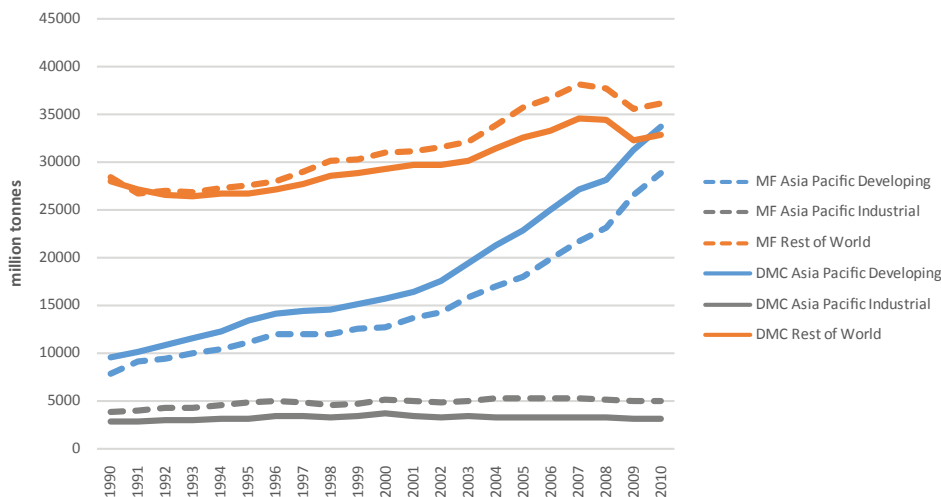


Figure 64 compares the two indicators direct material use (DMC) and material footprint (MF) for Asia-Pacific developing countries, Asia-Pacific industrialized countries and the rest of the world. Over the past two decades, the gap in global primary materials use for final consumption between Asia-Pacific and the rest of the world has been closing, meaning that also, per capita, Asia-Pacific has been catching up with the rest of the world.

**Figure 64 Material footprint compared to Domestic material consumption, Asia-Pacific and rest of world (1990-2010)**



The contribution of Asia and the Pacific region to the material standard of living of the rest of the world has, however, also increased which is demonstrated by the widening gap between territorial material use and material use for consumption in the Asia-Pacific region. The opposite trend is visible in the rest of the world, which has profited from manufacturing products for the Asia-Pacific region.

Material footprints can provide valuable input for policymaking. Often, the local environmental effects of material extraction (for example due to mining) are very well researched and understood. Impacts on local communities

and the environment often result in negative effects on quality of life, biodiversity, and ecosystems. Costs associated with these direct effects are often passed on to local communities and/or governments. Due to the complexity of the global trading system, the final consumer might be aware of the negative effects that the extraction of raw materials has locally, but it might be impossible to realize that one's consumption behaviour is the indirect cause of these effects. Using material footprints of consumption allows policymakers to develop legislation that lets the final consumer of the extracted material take a share of these costs to take the burden off local communities and governments.

## 6.2 Energy footprint of consumption

The energy footprint of consumption indicator attributes global energy production to total final demand including final consumption of households and governments and capital investment.

Unlike the total primary energy supply (TPES) indicator, the energy footprint includes indirect energy needs embodied in goods and services traded. TPES records direct use of energy by households, governments and by industry in production within a specific territory. The energy footprint does not report direct energy consumption by industry but records the energy embodied in products of industry, which may be ultimately consumed by (and attributed to) households and governments anywhere in the World. The difference effectively allows us to observe the direct needs of countries and regions as producers (TPES) in the World economy and compare this to their impact as consumers of all goods and services including those in international trade (energy footprint).

The energy footprint accounts were calculated using the Eora global, multi-regional input-output framework developed by the University of Sydney<sup>33</sup> and the same data sources for energy used in Section 2.2 Energy Use were incorporated into this analysis. These sources were used to create an energy satellite account with the Eora multi-region input-output tables, for 187 countries, for the 1990 – 2010 period. Standard input-output analytical procedures based on the conceptual framework developed by Leontief were applied (Lenzen et al., 2010, Lenzen et al., 2012).

The energy footprint of consumption has grown rapidly in Asia and the Pacific, and especially in China, with a regional yearly average growth rate of 5% (7.5% in China). While China's increasing purchasing power drives much of the growth in the regional energy footprint, India, Thailand, Singapore and Malaysia have also enlarged their energy footprints by 5% or more between 1990 and 2010 (see Figure 67).

That developing Asia-Pacific nations have increased their energy footprint may be attributed to the increasing direct use of energy in the regional economy. The annual overall rate of growth in energy footprint in Asia and the Pacific is, however, slightly more than the annual growth in TPES (4%). This suggests that the rise of new affluence in the Asia-Pacific has increasingly purchased embodied energy through internationally traded goods and services. Although the supply of energy to the Asia-Pacific region is 38% of the global total, its energy footprint is 29% of the World footprint (see Figure 65). This suggests that overall the region is a net exporter of energy either in raw form or embodied in internationally traded goods.

It was noted in Section 2.2 that China has accelerated in terms of its direct TPES. This has translated to its overall energy footprint. Between 1990 and 2000 its energy footprint increased a little over 4% per year but nearly 11% per year over the subsequent decade (see Figure 65). While the direct use of energy in China has increased and influenced the increase in energy footprint, it should be noted that the annual rate of growth in TPES was less than for the footprint. Between 2000 and 2010 this difference was about 3% less, and the compound effect of that difference in annual growth over 10 years means that 34% of the change in energy footprint over that period was due to purchases of goods and services in China. India also experienced an acceleration in the latter 10 years but not as obviously as in China, and on a smaller scale, Cambodia has seen a rapid increase in energy footprint over the past 20 years (16% per year) and Viet Nam has also experienced double-digit growth in its footprint (11% per year).

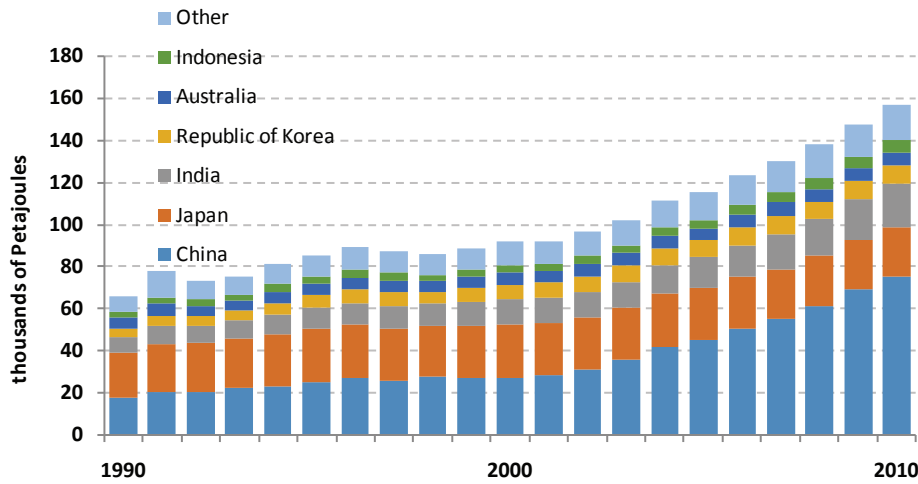
Despite reported increases in GDP, Myanmar has not commensurately increased its energy footprint, which is at odds with the economic development history of nations in the region where energy use and economic growth are often correlated. The Lao PDR has experienced lower than the regional average growth in its energy

<sup>33</sup> <http://worldmrio.com/>

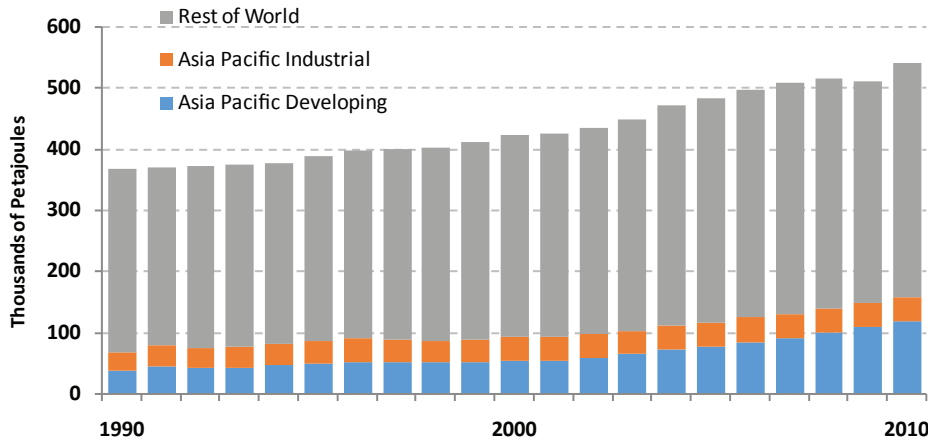


footprint (2% per year) and several countries have seen negative changes to their energy footprint between 1990 and 2010, for a variety of reasons: North Korea (-4.5% per year) has very limited international trade; Afghanistan (-4% per year) has been almost continuously involved in internal conflict, and the Fiji Islands (-3%) underwent a peak and at 2010 were in a trough, most probably due to the latent effects of the global financial crisis on their tourism industry. Mongolia, Papua New Guinea and Bhutan also recorded negative changes to their energy footprint.

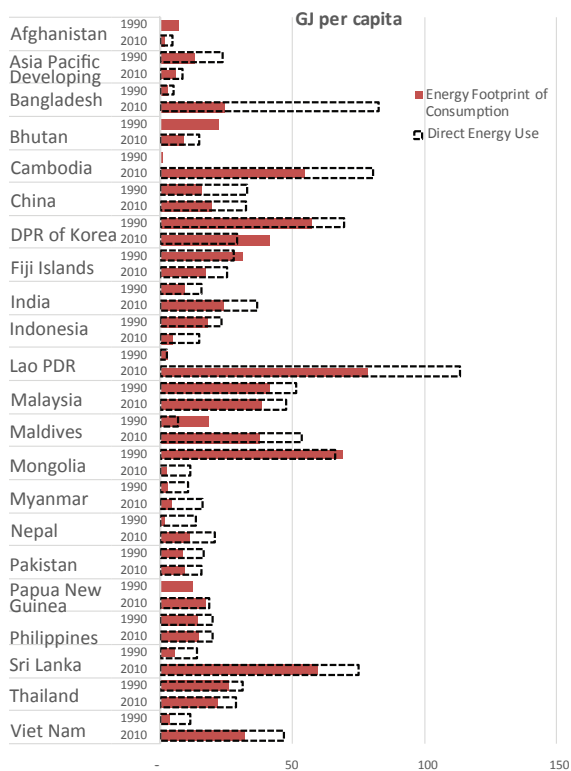
**Figure 65 Energy footprint, Asia-Pacific region (1990-2010)**



**Figure 66 Energy footprint, Asia-Pacific region and rest of world (1990-2010)**



**Figure 67 Energy footprint per capita compared to Energy use per capita, Asia-Pacific developing countries (1990, 2010)**



Asia-Pacific developing countries have a low energy footprint, on average, compared with the rest of the world (31 MJ per \$ compared with 64 MJ per \$ at 2010) reflecting relatively low energy intensive lifestyles and low levels of consumption (refer to Figure 68). Despite the population growth in the Asia and Pacific region, the aggregate results on energy footprint have generally translated to the per capita results. China, India, Sri Lanka, Thailand and Malaysia all show growth both in their aggregate energy footprint and the footprint per capita (Figure 67). Viet Nam and Cambodia have notable increases though the results for Nepal and the Maldives may be heavily influenced by the consumption of goods and services involved in the tourism industry there rather than consumption by local residents.

Overall, the per capita results indicate a growing fraction of the population is receiving higher incomes and spending that on more domestic and imported goods, or purchasing more energy-intensive goods and services, or possibly both of these effects at the same time. Direct energy use by households has increased with urbanization in the region but the additional energy per household does not serve the same number of people per household as in the past (in both rural and urban areas of India and China)<sup>34</sup>.

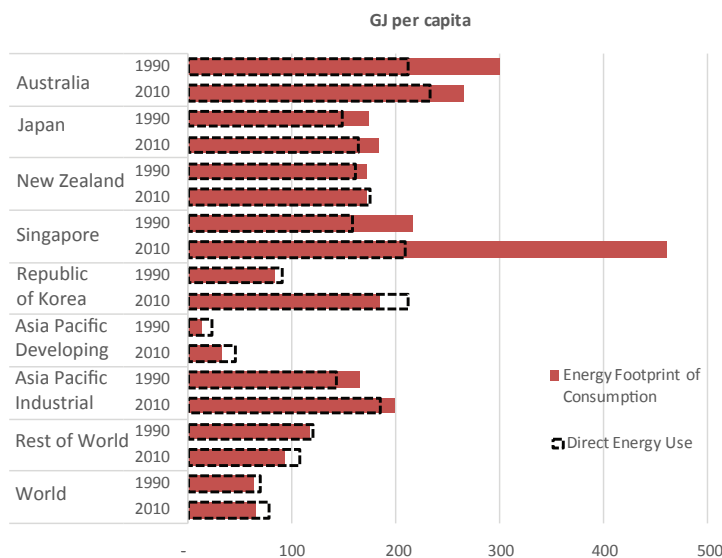
This also pushes up the energy footprint per capita.

For most countries, the energy footprint of consumption was quite a bit lower than their direct energy use in 1990 and 2010. The manufacturing industries in Asian developing countries produce a large amount of goods that embody energy, which does not contribute to the material standard of living in the producing country but rather abroad, with only a few exceptions.

The comparison with the rest of the World (Figure 68) shows that the developing Asia-Pacific has a long way to go before we can claim that its energy footprint represents affluence. Standards of living are still lagging industrialized countries in Asia and the Pacific whose average energy footprint (200 GJ per cap) is six and a half times as large as in the developing economies of the region. Though there is certainly a polarization of income inequality both across and within many countries of the Asia-Pacific (including the industrialized countries). The per capita results reflect an aggregate alleviation of poverty and increasing material welfare in many developing nations. This is often enacted in economic centres and cities.

34 <http://www.rba.gov.au/publications/bulletin/2014/mar/pdf/bu-0314-7.pdf>

**Figure 68 Energy footprint per capita compared to Energy use per capita, Asia-Pacific industrialized countries (1990, 2010)**



Whereas the per capita energy footprints for Japan and New Zealand have remained stable and Australia's per capita footprint has even declined, the Republic of Korea and Singapore have both seen a doubling of their per capita footprint between 1990 and 2010. Both direct energy use and affluence have influenced this sharp change. In the Republic of Korea, TPES per capita also doubled over the same period (see Section 2.2 ) while GDP increased by 83% or 3% per year. Singapore had the converse situation where per capita TPES increased only 1.4% per year but GDP increased by two and half times over 20 years. Undoubtedly, the increase in GDP in both countries has led to greater purchasing power and lead to a rise in per capita energy footprint, but increasing affluence has been more important in Singapore.

All industrial countries in Asia rely on energy from abroad, with the exception of the Republic of Korea and New Zealand in 2010. This dependence is most accentuated in Singapore and Australia, with both countries depending to a very large extent on consumer goods produced abroad in the absence of their own manufacturing sectors satisfying domestic demand.

Figure 69 compares TPES used directly in production and households, and the energy footprint for Asia-Pacific developing countries, Asia-Pacific industrialized countries and the rest of the world over the past two decades. Although a great deal of energy is traded directly as well as embodied in products, there appear to be three clear trends:

- TPES and energy footprint ('EF' in the figure) have increased in the Asia-Pacific developing nations and the Rest of the World and, within those subregions, at roughly the same rate.
- Although TPES and EF have both increased there is a consistent gap where Asia-Pacific developing nations have a lesser EF than TPES and the Rest of the World has a greater EF than TPES.
- There has been little growth in energy footprint, and only a small TPES/EF gap, for the Asia-Pacific industrialized countries.

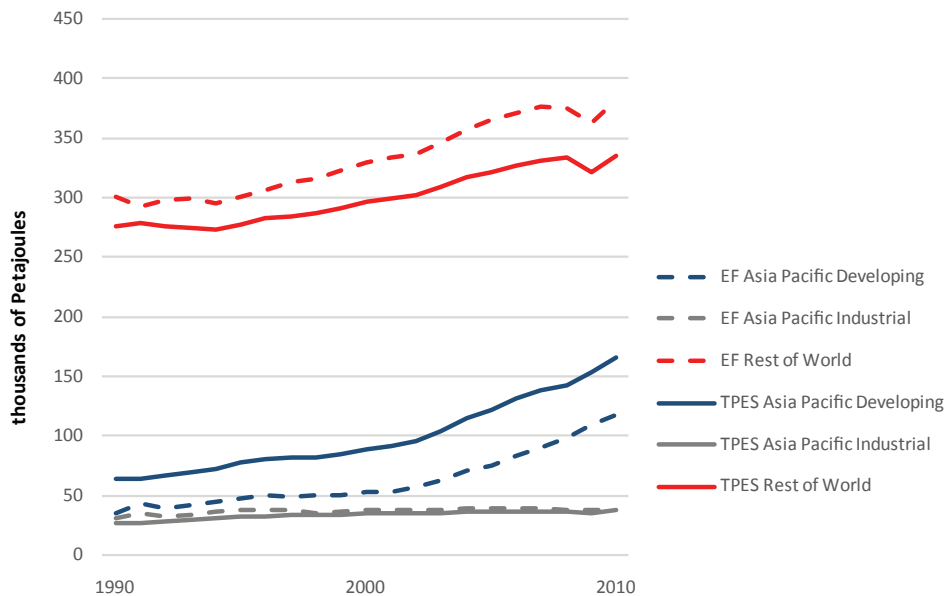
Developing Asia-Pacific countries have seen an increase in both TPES and energy footprint but their domestic energy production has been in excess of their needs as energy consumers (both in the direct and indirect sense).

Whereas the developing Asia-Pacific are clearly net energy exporters (in both the direct and embodied sense), the Rest of the World are net energy importers and a great deal of this is embodied in the exports from China (Liu et al., 2010).

The Asia-Pacific industrialized countries have grown in population and economic size but not substantially increased their aggregate or per capita TPES, a feat achieved either through production or end-use efficiencies. It would also appear that the industrialized countries have also restrained growth in their collective EF through less energy-intensive consumption.

It is worth noting that a dip occurs in the trend for the Rest of the World in both TPES and energy footprint showing the effect of the global financial crisis on the economy outside the Asia-Pacific. Many Asia-Pacific nations such as Cambodia and Australia were not heavily exposed to this event and their financial systems and industrial activity displayed resilience in the face of the global economic downturn.

**Figure 69 Energy footprint compared to Total Primary Energy Supply, Asia-Pacific and rest of world (1990-2010)**



Unlike goods, energy is much harder to transport over large distances. Hence, the energy used within each step of a supply chain is often generated nearby. Depending on the technology used for energy generation, this can have severe negative impacts on the nearby environment. Over the past 20 years China has risen to become the country where the largest amount of goods is manufactured. Large parts of China's power stations are coal-fired, resulting in dramatic declines in air quality in some parts of China.

A large proportion of the goods manufactured in China are consumed within other countries. One could argue that these countries benefit from China taking the burden of poor air quality – and hence should contribute to the costs associated with the poor air quality. Energy footprints of final consumption deliver the information that is required to develop and implement such a scheme.

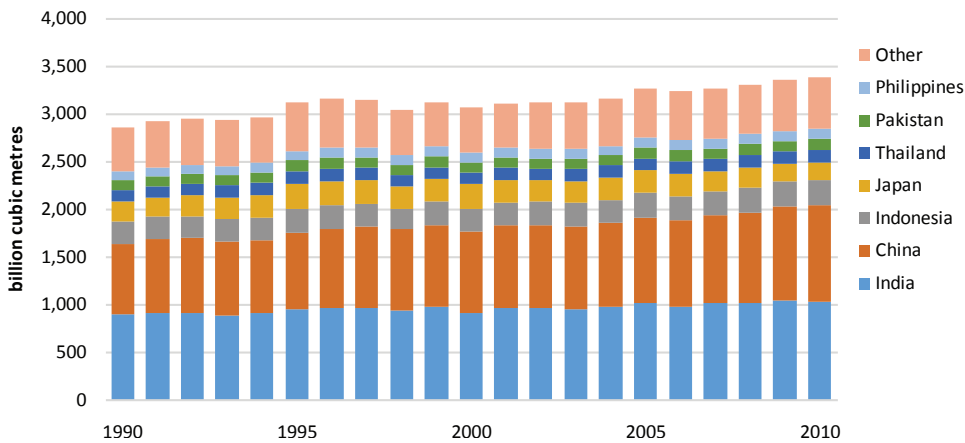
### 6.3 Water footprint of consumption

The water footprint of consumption indicator attributes global water extraction to final demand including final consumption of households and governments and capital investment. In common with the other footprint indicators, this means that water embodied in a product will be accounted for in the jurisdiction of its final consumption, rather than where it was initially input in creating the product.

The water footprint accounts were calculated using the Eora global, multi-regional input-output framework developed by the University of Sydney (Lenzen et al., 2013a). A detailed account of the derivation of water footprint is given in Lenzen et al. (2013b).

It is important to note at the outset that there is no close accounting relationship between the total water withdrawals used in Section 2.3 Water use and Section 4.3 Water intensity of the economy, and water footprint here. This contrasts with the relationship between material footprint and DMC, where the global totals of each must be equal. The calculation of water footprint uses actual process modelling, such as the demand for water by crops, in determining water use. These models implicitly include much water (mainly direct rain feed) that is not counted in the total water withdrawals metric. The water footprint values here are typically over twice the total water withdrawals given previously.

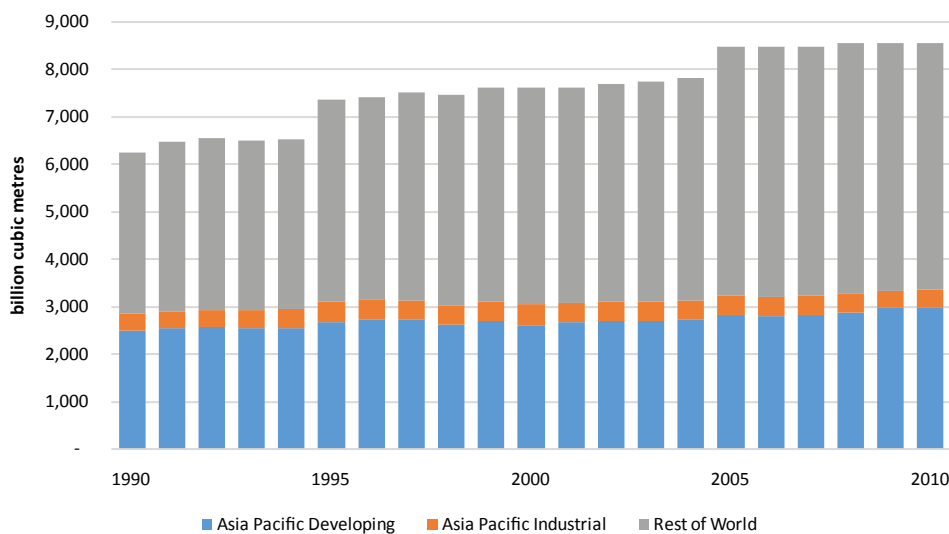
**Figure 70 Water footprint, Asia-Pacific region (1990-2010)**



In Figure 70 the top seven water consumers in the Asia-Pacific region are displayed individually. Despite the fundamentally different nature of water footprint to the basic total water withdrawals metric used previously in Sections 2.3 Water use and 4.3 Water intensity of the

economy, Figure 70 shows that the pattern of consumption is very similar to that seen for total water withdrawals, with six of the seven top consumers remaining the same, with slightly changed ordering. Only Thailand is a new addition, displacing Viet Nam. India is still the largest consumer, although its water footprint is only 5% higher than China's in 2010, as compared to the 37% margin seen for water withdrawals. Fifteen of the 24 countries for which there were data increased their water footprint between 1990 and 2010, including all of the four most populous countries (China, India, Indonesia, and Pakistan with total increases over the full period of 37%, 14%, 16%, and 4% respectively). Of the top seven consumers, all except one also increased their water footprint, the exception being Japan, which saw a fall of 15% over the period.

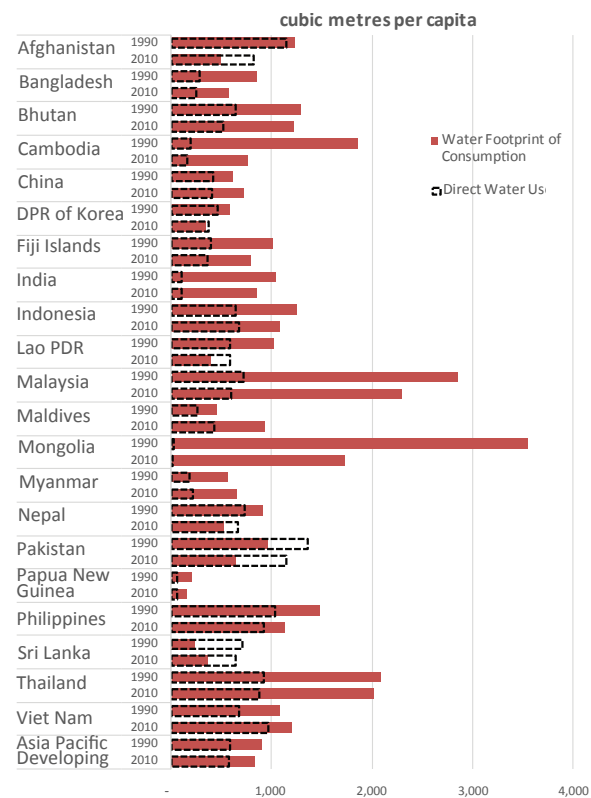
**Figure 71 Water footprint, Asia-Pacific region and rest of world (1990-2010)**



In Figure 71 we see that the water footprint of the Asia-Pacific region is much smaller in comparison to the rest of the world than it was for total withdrawals, with both the developing country and industrialized countries groups combined constituting 39% of global water footprint in 2010, compared to 55% of water withdrawals. The ratio of the water footprint of the industrialized

countries compared to the developing group has also increased markedly, with the former group consuming over 11% of the Asia-Pacific regional total, as compared to less than 7% for water withdrawals. This is what we expect to see for an indicator which reallocates embodied water use to the end consumer, with wealthier countries having a disproportionate level of imports, all of which embody water to some extent.

**Figure 72 Water footprint per capita compared to Water use per capita, Asia-Pacific developing countries (1990, 2010)**



In Figure 72 we can see that China's per capita water footprint increased between 1990 and 2010, in contrast to the per capita decrease seen in Section 2.3 Water use for water withdrawals. This may be a result of the huge increase in per capita incomes experienced by China over that period, and the corresponding ability to import more water-intensive imports. This inference is not, however, straightforward, as many countries which saw large increases in affluence saw falling per capita water footprint, e.g. Malaysia, Thailand. These latter cases may provide examples of the effect of the crop process models embodied in the footprint calculations. A very large effect on water footprint can occur from a change in crop types, *including changes made on unirrigated land*. This is unlike water withdrawals, which do not take direct consumption of rain into account.

It is noteworthy that while China's water footprint per capita grew relative to India's, India's footprint remained higher despite that country's much lower level of affluence. Comparing Figure 72 to Figure 13 reveals a closer correspondence between national levels of affluence and water footprint, so that the high relative levels of water withdrawals seen previously for countries like Pakistan and Afghanistan are greatly reduced relative to Malaysia and Thailand on a water footprint basis. The degree of reallocation seen between water withdrawals and in

water footprint appears to considerably less than the corresponding reallocation between DMC and material footprint. One factor likely to explain this is the relatively higher dependence of poor countries on biomass, the main consumer of water resources, most of which is both produced and consumed locally.

**Figure 73 Water footprint per capita compared to Water use per capita, Asia-Pacific industrialised countries (1990, 2010)**

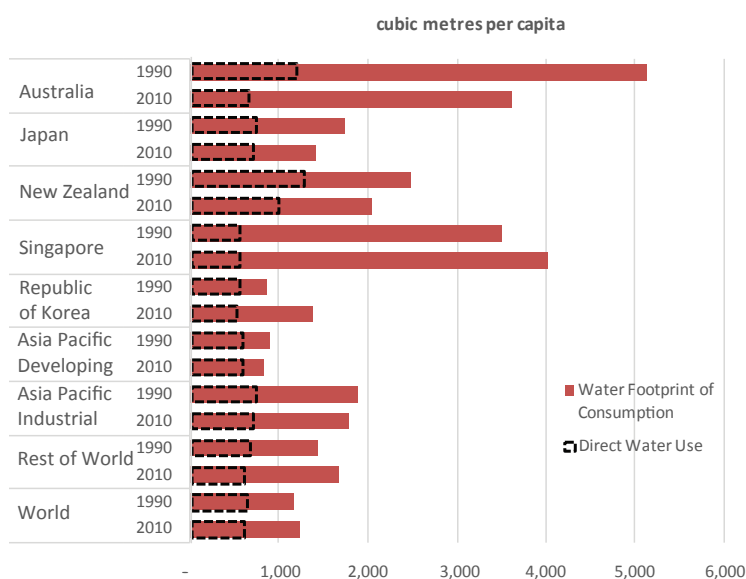


Figure 73 provides further insight into the differences that the crop production process models used for water footprints introduce over straight water withdrawal information. The water footprint per capita of Australia is much higher than those for both Japan and New Zealand for both years considered, over two to three times the level of Japan and at least 75% higher than New Zealand.

This is not the case for water withdrawals, where both Japan and New Zealand's per capita withdrawals exceed Australia's in the later years. This might in large part be attributed to the large areas of broadacre, rain-fed cropping and grazing in Australia, none of which is accounted for in water withdrawals. Singapore's increase to the highest per capita water footprint of the

group obviously cannot be explained by agricultural activity there, and so must be related to the change in imports and/or industrial composition of the economy over the period. Where Singapore's per capita water



withdrawals for recent years were within 40% of both the Republic of Korea's and Japan's, its water footprint is over double that of either. While the water footprint per capita for both Asia-Pacific groupings decreased between 1990 and 2010, that for the Rest of World increased by 16% in total.

#### 6.4 GHG emission footprint of consumption

The GHG footprint of consumption indicator attributes global emissions to total final demand including final consumption of households and governments and capital investment.

In Section 2.4 Greenhouse gas emissions we presented data on direct GHG emissions from within the borders of the countries reported. This included emissions from local land-use change, production and other economic activity. The GHG footprint presented here attributes emissions embodied in the products of that activity (goods and services traded around the world) to the place of final consumption. The data in Section 2.4 Greenhouse gas emissions records direct emissions by households, governments and by industry in production within a specific territory.

The GHG footprint does not report direct emissions by industry but records the emissions embodied in products of industry, which may be ultimately consumed by households and governments anywhere in the world. In this way the emissions of production are indirectly attributed to the place of consumption and at the global level the aggregate territorial emissions and emissions footprint should be equal. A comparison illuminates the direct emissions impact of countries and regions as producers with respect to their impact as consumers of all goods and services including those in international trade (GHG footprint).

The GHG footprint accounts were calculated using the Eora global, multi-regional input-output framework developed by the University of Sydney<sup>35</sup> and the same data sources for GHG emissions used in Section 2.4 Greenhouse gas emissions were incorporated in this analysis. These sources were used to create an emissions satellite account with the Eora multi-region input-output tables, for 187 countries, for the 1990–2010 period. Standard input-output analytical procedures based on the conceptual framework developed by Leontief were applied (Lenzen et al., 2010, Lenzen et al., 2012).

The GHG footprint of consumption has generally increased in the Asia-Pacific between 1990 and 2010 though an apparent plateau in the trend for many nations in the late 1990s was followed by a step change in the annual rate of increase in their GHG footprint. China's GHG footprint has enlarged by 5.7% per year over the 20 years and India's by 3.7% but between 2000 and 2010 the growth was 8.7 % and 4.2%, respectively. The smaller economies of Viet Nam, the Republic of Korea and Singapore experienced over 4% per annum growth in their footprints. Most countries had annual increases in their GHG footprint less than 3% but DPR of Korea, Japan and Australia all declined (see Figure 74 and Figure 76). Data for the Lao PDR, Mongolia and Papua New Guinea are possibly incomplete as all three appeared to have declined significantly in the last years of the time series while having had emissions levels at much higher levels in the record prior to 2008.

The relative significance of the region's developing nations to the world increased and, indeed, substantially drove global emissions upward from 2000 to 2010. Asia-Pacific developing countries accounted for 18% of the global footprint in 1990 and by 2010 this had grown to 32% of the total (Figure 75).

<sup>35</sup> <http://worldmrio.com/>

Figure 74 GHG footprint, Asia-Pacific region (1990-2010)

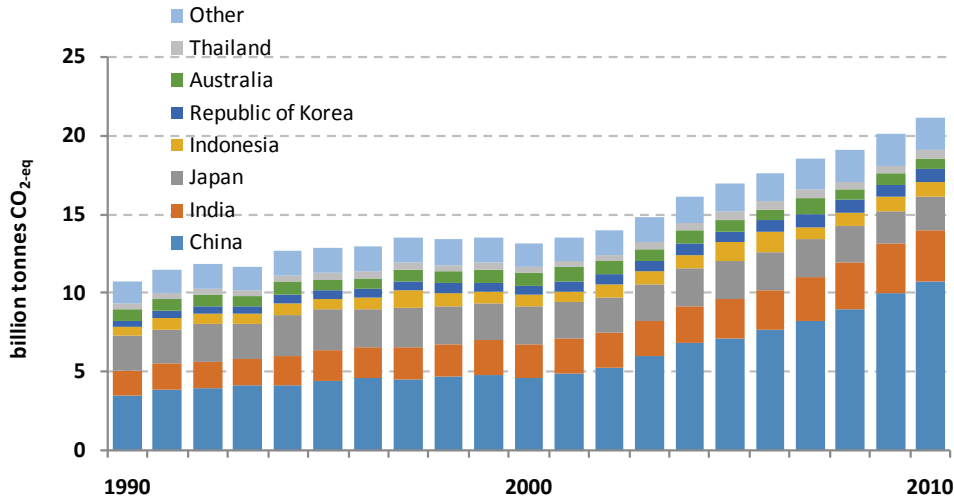
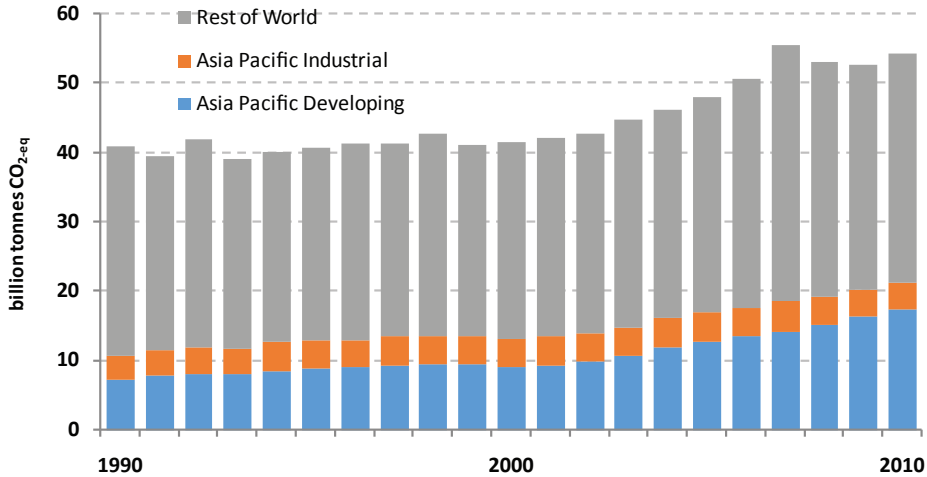
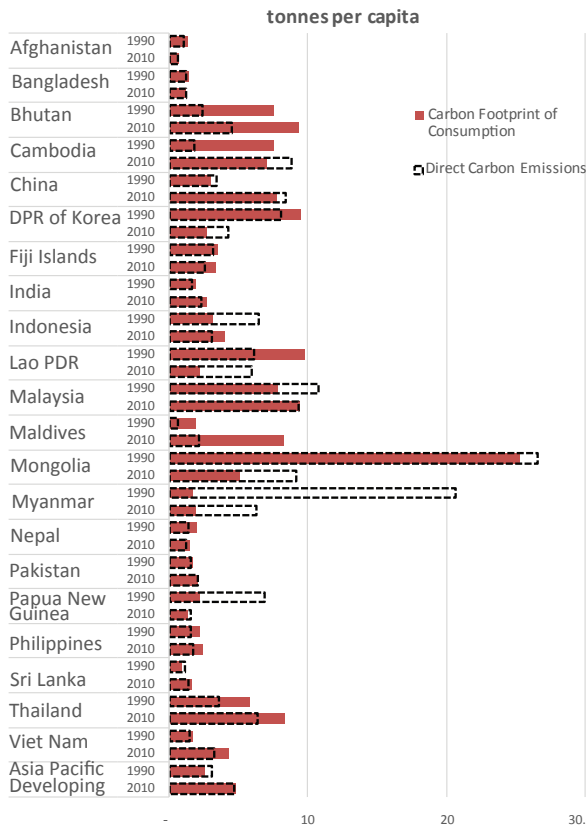


Figure 75 GHG footprint, Asia-Pacific region and rest of world (1990-2010)



**Figure 76 GHG footprint per capita compared to direct GHG emissions per capita, Asia-Pacific developing countries (1990, 2010)**

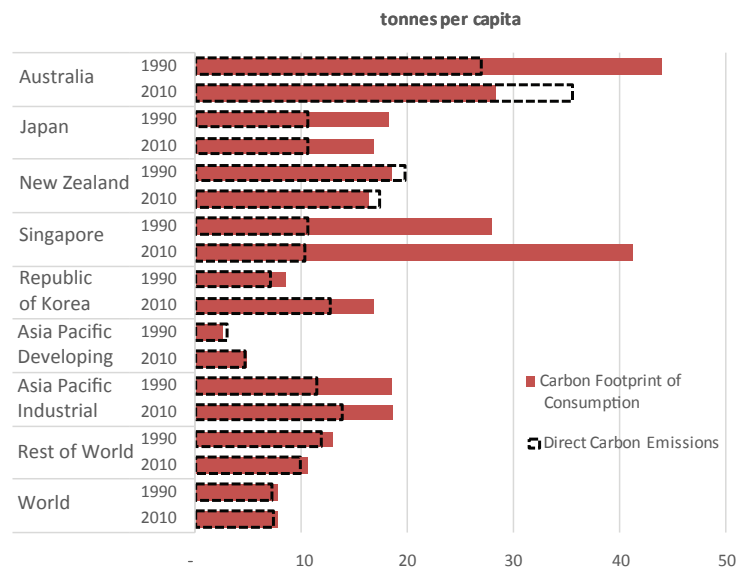


For some south Asian nations there is an approximate similarity in the magnitude and pattern of change between territorial GHG emissions and their GHG footprint, for example, Nepal, Afghanistan, Thailand, Viet Nam, Sri Lanka, Bangladesh, and Pakistan. This indicates these countries have likely retained a characteristic economic production that aligns with the consumption characteristic of the resident population and government.

Where there is divergence between the territorial and footprint indicators, there is likely to be some difference between the local emissions intensity of consumption and the goods and services actually produced by that nation. This is the case with Indonesia, Myanmar, Malaysia and Cambodia where emissions-intensive land-use change and resource extraction are important parts of the local economy. Malaysia's territorial emissions per capita have remained constant compared to its increasing GHG footprint per capita (see Figure 76). One of the key industries in Malaysia has been (and continues to be) oil and gas extraction; refining and exporting these products has effectively exported the GHG footprint to other, consuming nations. As Malaysia's affluence has grown, these energy- and emissions-intensive products have traded more on the domestic market and Malaysia has also consumed more of other goods and services.

The emissions of Malaysia's industry have not changed as much as the GHG footprint of its consumption lifestyle. Conversely, Cambodia's territorial emissions have increased dramatically with land-use change but the emissions embedded in the products of that change do not appear to have been consumed locally as the GHG footprint declined between 1990 and 2010.

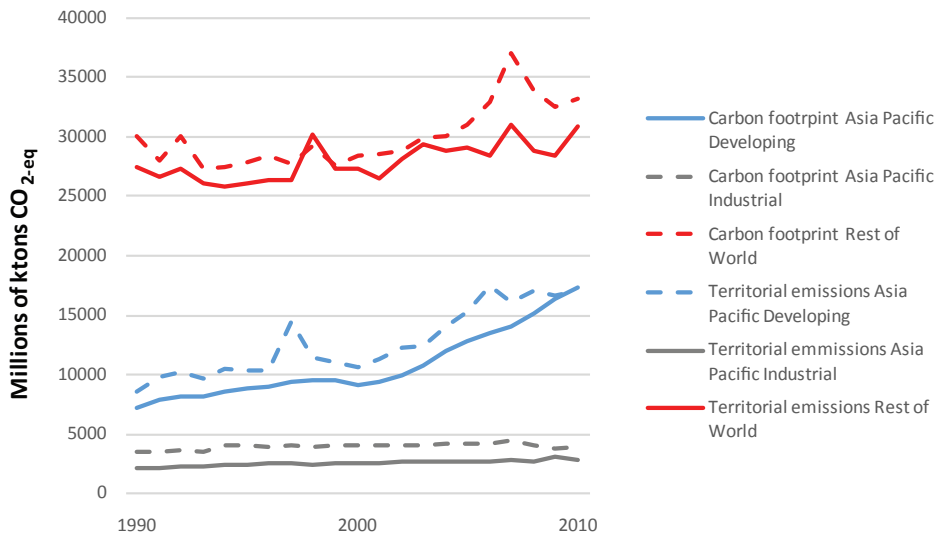
**Figure 77 GHG footprint per capita compared to direct GHG emissions per capita, Asia-Pacific industrialized countries (1990, 2010)**



Asia-Pacific industrialised countries appear, on aggregate, to have generally held steady in their emissions footprint but that is a combination of two subgroups within the industrialized countries having quite different trends: decreases in Japan and Australia and very low annual growth (0.6% per year) in New Zealand are counteracted by growth in Singapore (4.7% per year) and the Republic of Korea (4.1% per year) – refer to Figure 77. Although the industrialized countries are, in aggregate, maintaining the same per capita emissions footprint in 2010 as in 1990, this is still more than three times the average emissions per capita footprint of developing Asia-Pacific nations in 2010.

Figure 78 compares the time series of territorial emissions from Section 2.4 Greenhouse gas emissions and the GHG emissions footprint discussed here for global subregions. The general observations made earlier about the difference between territorial emissions and the GHG emissions footprint (GHGF) of developing Asia-Pacific nations is borne out here as well. The territorial emissions show the year-to-year variation due to land-use change and fire events and are consistently greater than the less variable GHGF. This indicates a general structure of production activities that is less emissions-intensive than the aggregate economic consumption. By contrast, results for both the Asia-Pacific industrialized countries and the Rest of the World present a consumption-based GHGF greater than their territorial emissions. In particular, both these subregions show GHGF that peaks towards 2008 and a subsequent trough immediately after this date. This suggests that the industrialised economies in these subregions were consuming more leading up to the global financial crisis of 2008 and far less thereafter. That the Asia-Pacific developing nations show no such peak in their GHGF reflects the disconnection between their income and consumption and the global financial sector.

**Figure 78 GHG footprint compared to direct energy emissions, Asia-Pacific and rest of world (1990-2010)**



The phenomenon of outsourcing carbon-intensive industries in order to shift the burden of GHG emissions to other countries has been well-observed since the introduction of the Kyoto Protocol. Lenzen et al. (2010b) for example showed that the UK's footprint – despite being reported to be declining according to territorial emissions standards – is actually growing if a consumer-based accounting approach is used.

The information gathered from GHG emissions footprints of consumption is indispensable to creating regulations for global GHG accounting. Follow-up agreements to the Kyoto Protocol must consider consumer-based accounting concepts such as GHG emissions footprints of consumption to ensure that effects like outsourcing of GHG-intensive industries are appropriately addressed.





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### The TARA EcoKiln

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#### PRODUCTION ECONOMICS SHEET

Useful information for the EcoKiln operator to monitor the performance of the kiln. The sheet is to be filled in daily and submitted to the TARA Regional Office. The sheet is to be filled in daily and submitted to the TARA Regional Office.

Parameter	Unit	Value
Production	Bricks	
Energy	kg	
Water	liters	
Electricity	kWh	
Gas	liters	
Oil	liters	
Coal	kg	
Other		





# Resource efficiency revisited

Headline Indicator '**Adjusted Resource Efficiency**'

## **Natural resource consumption per unit of economic output (GDP)**

- **Adjusted material intensity** – Material Footprint per GDP (tonnes per \$)
- **Adjusted energy intensity** – Energy Footprint per GDP (MJ per \$)
- **Adjusted GHG emission intensity** – Carbon Footprint per GDP (kg per \$)
- **Adjusted water intensity** – Water Footprint per GDP (litres per \$)

Method of measurement: Combined measure of economic activity and natural resource consumption based on the set of indicators for natural resource consumption (footprints).

Data sources: Based on natural resource consumption indicators and a measure of economic activity. Exchange rate based Gross Domestic Product corrected for price effect was used for this report.

Policy Use: Provides adjusted information about relative decoupling and demonstrates real gains in resource efficiency based on final resource consumption in countries.

## When using consumption-based indicators resource efficiency appears improved for the developing nations group. But do efficiency gains reach far enough to keep pace with growth in population and consumption to avoid significant resource depletion and climate change?

This chapter revisits resource productivity based on the footprint indicators and includes a discussion on the different policy implications of direct and footprint accounts.

### 7.1 Material intensity adjusted for trade

The adjusted material intensity (AMI) indicator provides an alternative measure for material intensity based on the material footprint of consumption per unit of economic output. A reason for using material footprint rather than DMC is that it provides a complementary allocation of materials to where end consumption takes place. It avoids the effects of the concentration in trade, to which DMC based measures are subject (discussed previously in Section 2.1 ), giving a much clearer idea of the total resource inputs required, including extraterritorial resource inputs, to support a nation's economy.

The material footprint data were sourced from the Eora global, multi-regional input-output framework developed by the University of Sydney (Lenzen et al., 2013a), as discussed above in Section 6.1 Material footprint of consumption. The monetary base used for GDP is \$ at constant year 2005 exchange rate value, sourced from UNSD (2015). The time series here only cover 1990 to 2010 rather than 1970 to 2010 as was the case for DMC based measures, reflecting the shorter time series available for material footprint data.

**Figure 79 Material footprint intensity for Asia-Pacific and World groupings (1990-2010)**

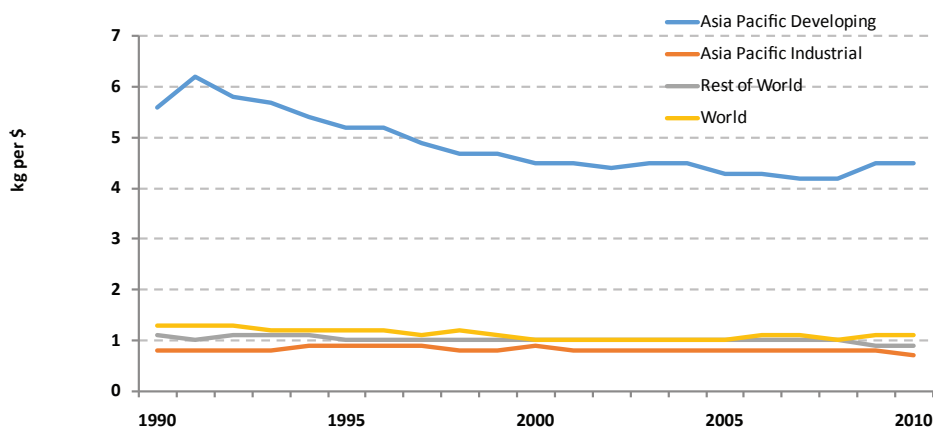


Figure 79 has similarities with the corresponding conventional MI based figure in Section 4.1 Material intensity of the economy, with the Asia-Pacific developing countries group displaying the highest AMI and the industrialized countries group having the lowest AMI, which is much closer to the Rest of World than developing Asia. There are however

important differences in detail. The developing group has a considerably lower AMI than MI (10% to 20% lower over the full time series 1990 to 2010), while the reverse is the case for the industrialized countries group (40% to 70% higher over the period 1990 to 2010). There is a similar but slightly more pronounced levelling off in the rate of improvement in AMI from 2000 onward for the developing group.

**Figure 80 Material footprint intensity, Asia-Pacific developing countries (1990, 2010)**

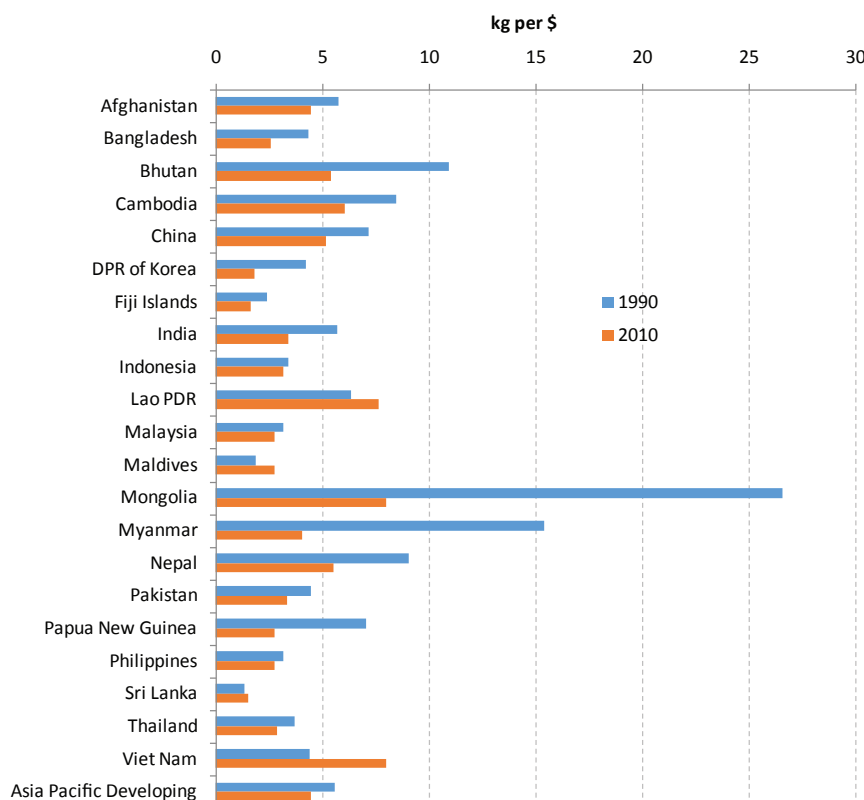
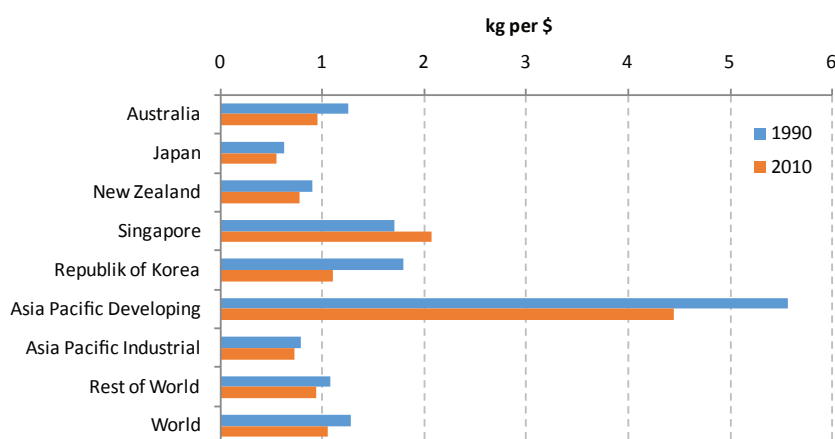


Figure 80 shows that 17 of 21 countries in the developing group reduced their AMI between 1990 and 2010, including all of the most populous nations (China, India, Indonesia and Pakistan), which posted decreases of 1.6, 2.5, 0.3, and 1.4% p.a. compounding respectively), yielding a rate of improvement for the developing group as a whole of 1.1% p.a. The most populous nation not to record an improvement in AMI was Viet Nam, which saw AMI increase by 3.1% p.a. If we compare Figure 80 to its conventional MI counterpart in Section 4.1 Material intensity of the economy, 16 of 21 countries show a reduction in AMI compared to MI for 2010, including all of the most populous nations, and the group average AMI for 2010 is 13% lower than MI for the same year.

**Figure 81 Material footprint intensity, Asia-Pacific industrialized countries (1990, 2010)**



A comparison of Figure 81 with its conventional DMC based counterpart in Section 4.1 Material intensity of the economy illustrates clearly the degree to which material footprint based indicators overcome concentration in trade effects. The best illustration comes in comparing the MI and AMI for Australia and Japan. Australia still has a markedly higher AMI than Japan, with Australia requiring nearly 75% more materials input per unit of GDP generated than Japan in 2010.

This compares, however, with a 380% difference using conventional MI. Another major difference can be seen in that Singapore's AMI deteriorates sharply, increasing by 21%, compared to a 43% decrease when using conventional MI. Also apparent is the change in rankings in this group using AMI, with Singapore and the Republik of Korea becoming the most materials-intensive economies, whereas using conventional MI Australia and New Zealand are rated the most materials intensive (in 2010). Where AMI relative to MI for 2010 was 15% less for Australia, Singapore's AMI was 95% higher than MI. Similarly, New Zealand's AMI was 7% lower, while

the Republic of Korea's was 53% higher. Due to its large economic size, Japan's re-rating (an increase of 120% in AMI compared to MI), had proportionally the largest effect on re-rating the industrialized countries group as a whole, which had a group AMI 57% higher than MI in 2010.

**Figure 82 Material footprint intensity compared to direct material intensity, Asia-Pacific and Rest of World (1990-2010)**

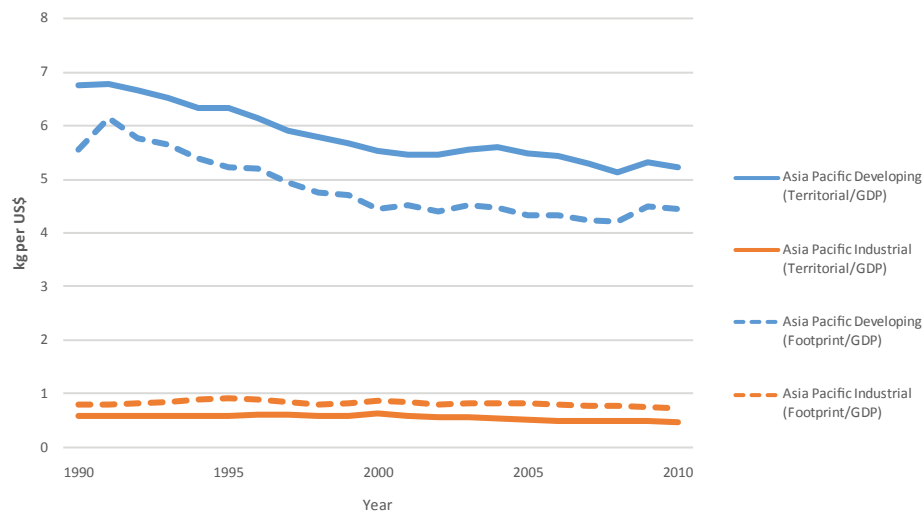


Figure 82 makes clear an overall trend for AMI to re-attribute resources use from developing countries to developed countries. This is evident from the decrease in AMI relative to MI for the developed group, and the increase in AMI relative to MI for the industrialized countries. It is important to note, however, that this trend is in large part linked to the role of many developing countries as resource providers, or

lower value added manufacturers. As we saw above, when a developed country develops a large primary resources for export sector, e.g. Australia and New Zealand, then its AMI will similarly decline relative to MI. The re-rating reflects the main economic activities performed by a country as much or more than its level of affluence/level of development.

## 7.2 Energy intensity adjusted for trade

Adjusted energy intensity refers to the amount of direct and indirect energy from final consumption by government and households. Whereas direct energy will tell us about the energy efficiency characteristic of production, the indicator presented here relates to the impact of energy embedded in goods and services consumed within a given country. The changes in the consumption-based energy footprint intensity tell us about the emissions arising from affluence and spending rather than those due to local production and income. Energy intensity is measured by the ratio of the calculated energy footprint divided by gross domestic product (GDP). Energy footprints were calculated using the Eora global, multi-regional input-output (MRIO) framework developed by the University of Sydney<sup>36</sup> and the same data sources for direct total primary energy supply (TPES) used in Section 2.2 .

These sources were used to create an energy satellite account with the Eora multi-region input-output tables, for 187 countries, for the 1990 to 2010 period. More detail on the treatment of the raw data to produce energy footprints is in Section 6.2 Energy footprint of consumption. The energy footprint for each country between 1990 and 2010 was divided by the time series of GDP in constant \$ at 2005<sup>37</sup>, to calculate the energy intensity in megajoules per \$.

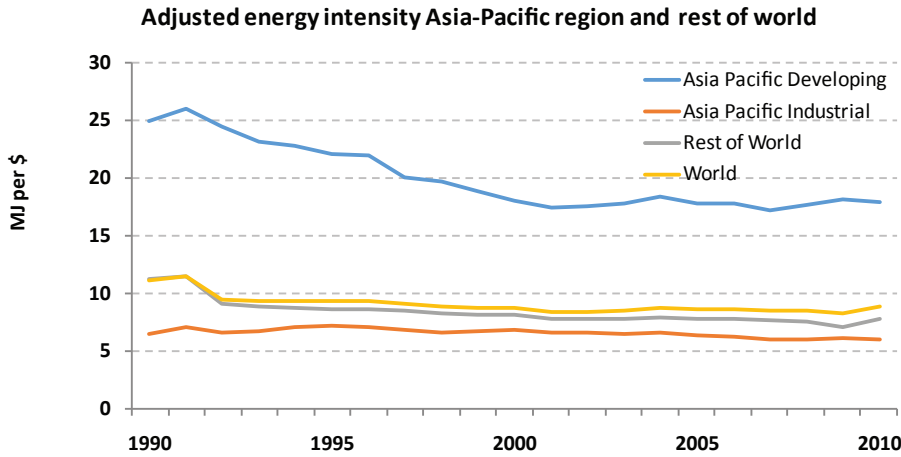
The per capita results of Section 6.2 Energy footprint of consumption illustrated the general (though not universal) experience was of increasing energy footprint per capita in the Asia-Pacific. In contrast, the general result for energy intensity per GDP (in \$ 2005) is one of decreasing energy footprint intensity (see Figure 84). This implies that although more energy is being consumed directly and indirectly per person in the region, this is being used as that population's income (GDP) increases faster than their energy footprint. Asia-Pacific industrialized countries have declined their energy footprint intensity relatively less than developing nations indicating a stable but modestly improving relationship between their energy footprint of consumption to their

<sup>36</sup> <http://worldmrio.com/>

<sup>37</sup> <http://unstats.un.org/unsd/snaama/dnllist.asp>

GDP. Developing nations reduced their energy footprint intensity by nearly 15% over 20 years reflecting that their income (GDP) has increased proportionally more than the energy intensity of the goods and services that they have purchased with that income.

**Figure 83 Energy footprint intensity, Asia-Pacific and World groupings (1990-2010)**

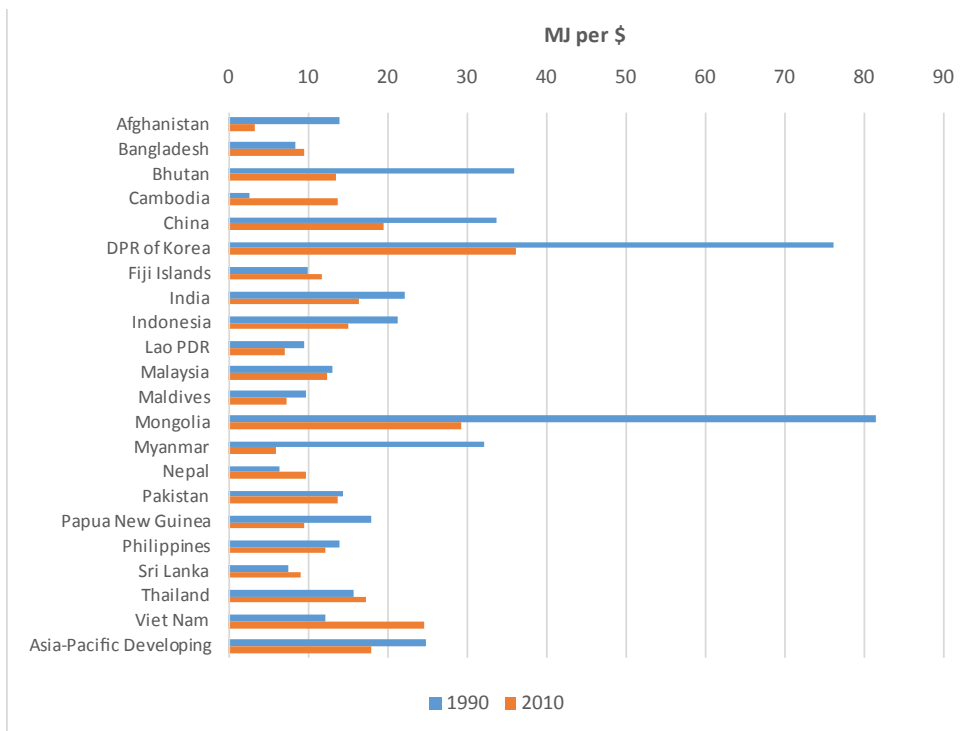


The exceptions to this are roughly the same countries identified in Section 6.4 GHG emission footprint of consumption as having similar territorial and footprint emissions: Bangladesh, Cambodia, Nepal, Sri Lanka, Thailand and Viet Nam (see Figure 84). The implication here, as in the preceding commentary, is that these nations have a closer alignment than most between their consumption

patterns and domestic production. Thus, a change in energy and emissions relating to their territorial production, translates to the energy and emissions intensity of domestic consumption.

China's dominance in the energy footprint of the region means that its own 42% reduction in emissions footprint per \$ has strongly influenced the overall reduction in Asia-Pacific developing nations. Figure 85 shows that lesser reductions have occurred across the Asia-Pacific industrialized countries and the Rest of the World.

**Figure 84 Energy footprint intensity, Asia-Pacific developing countries (1990, 2010)**



**Figure 85 Energy footprint intensity, Asia-Pacific industrialized countries (1990, 2010)**

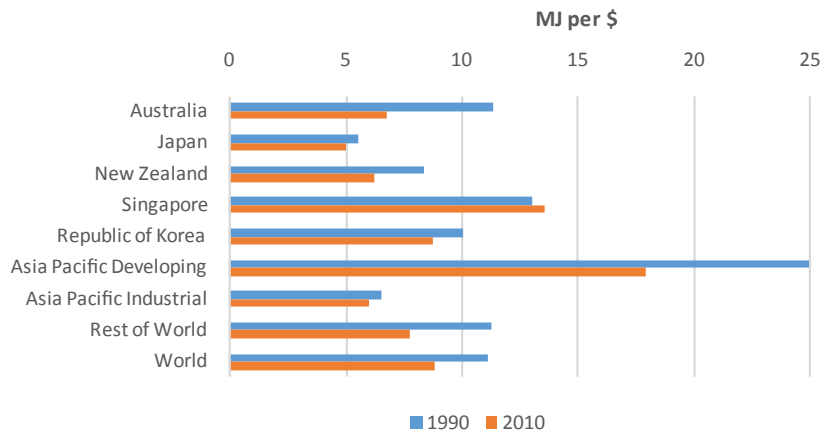


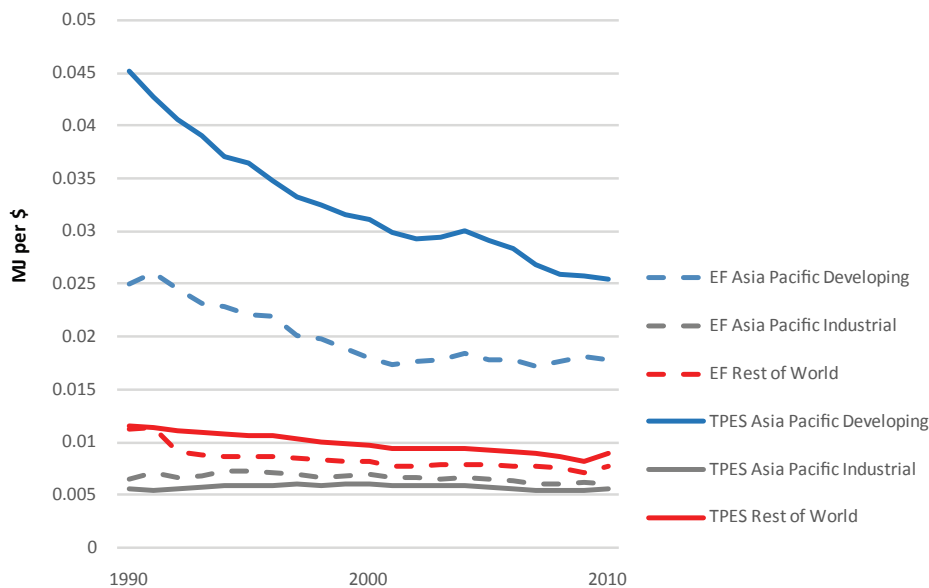
Figure 86 shows the decline in the territorial (TPES) and energy footprint (EF) intensity of production in global regions. Evidently, Asia-Pacific developing countries reduced their territorial energy intensity by 44% while the intensity of their energy footprint declined by 28% between 1990 and 2010.

It is notable that the energy intensity of production in developing Asia-Pacific is greater than that for consumption indicating that the products of this subregion are not consumed locally. The residents and governments of the developing nations either consume less or consume less energy-intensive goods and services than they produce.

By comparison the level of the energy intensity footprint and the territorial energy intensity of industrialized countries is lower and more stable. This suggests that their products have higher value (and/or require much less energy to produce) and that these countries consume goods and services that are much more aligned to those that they produce themselves.

The global regional trends shown in Figure 86 show a steady decline in energy intensity both for the World and the part of the World outside the Asia-Pacific region. The consumption-based EF intensity for the Asia-Pacific developing group of countries has decreased by approximately the same relative amount as that of the Rest of the World (30% between 1990 and 2010).

**Figure 86 Energy footprint intensity compared to Direct energy use, Asia-Pacific and world groupings (1990-2010)**



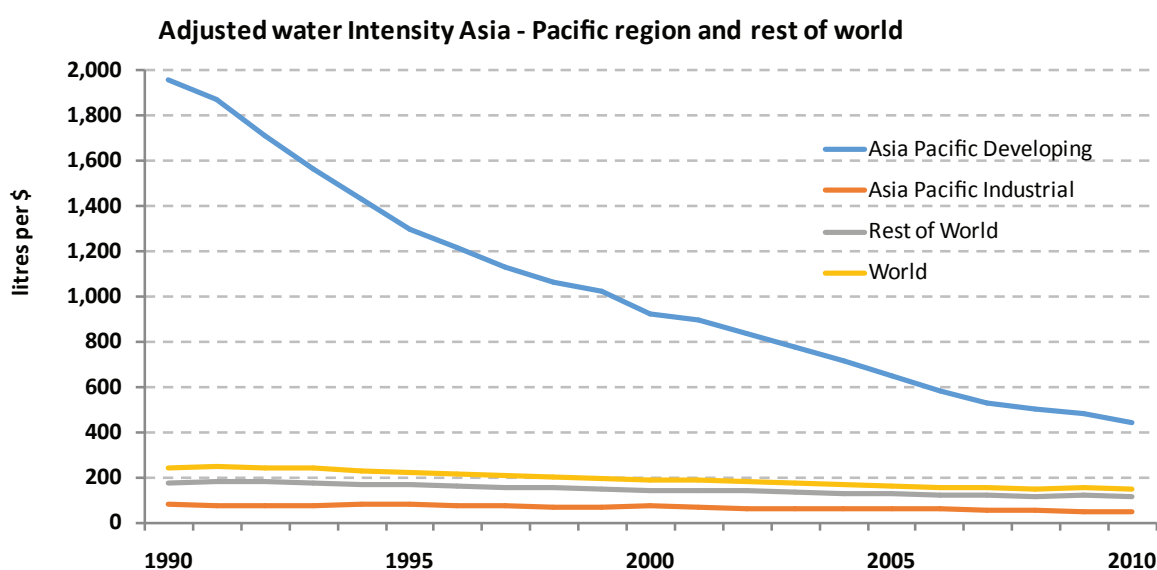


### 7.3 Water intensity adjusted for trade

The adjusted water intensity (AWI) indicator provides an alternative measure for water intensity based on the water footprint of consumption per unit of economic output.

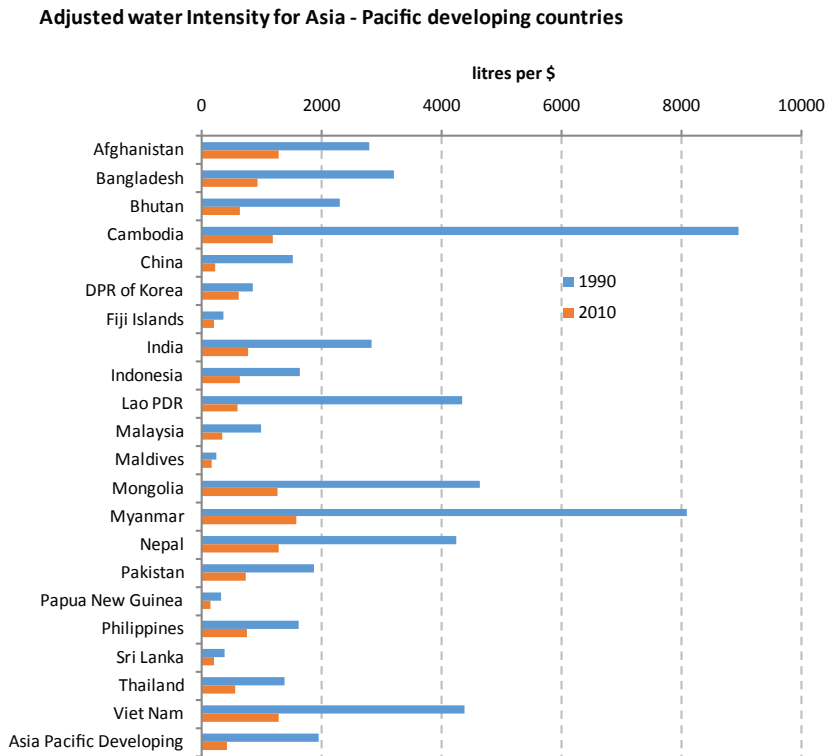
The water footprint data was sourced from the Eora global, multi-regional input-output framework developed by the University of Sydney, as discussed above in Section 6.3 Water footprint of consumption. The specific calculation of water footprint is described in detail in Lenzen et al. (2013b). The monetary base used for GDP is \$ at constant year 2005 exchange rate value, sourced from UNSD (2015). The time series here only covers 1990 to 2010 rather than 1970 to 2010 as was the case for DMC based measures, reflecting the shorter time series available for material footprint data. As discussed in Section 6.3 Water footprint of consumption, unlike other footprints there is no close accounting relationship between water footprint and the territorial measure of water withdrawals, with the world total water footprint in 2010 being approximately double total withdrawals.

**Figure 87 Water footprint intensity, Asia-Pacific and World groupings (1990-2010)**



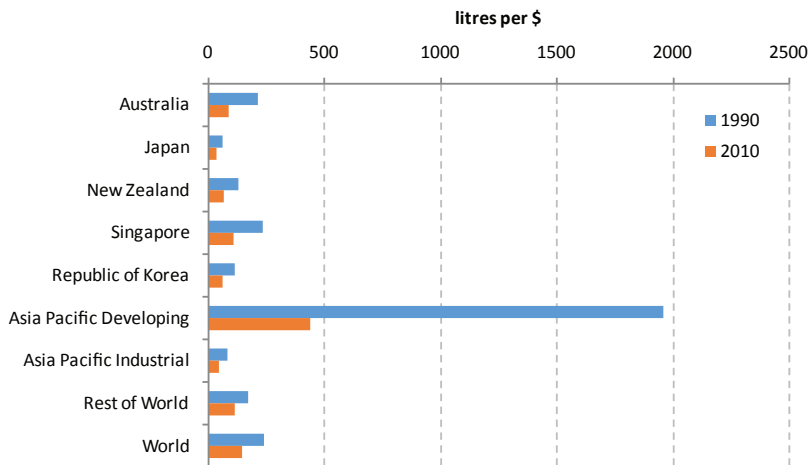
In rough accordance with the higher global total for water footprint, if we compare Figure 87 to Figure 36 we see that AWI for the developing group began the period between 78% and 180% higher than WI for each group, with the smallest difference for the developing group and the largest for the industrialized countries group. This is what we expect for a footprint metric which reallocates water usage based on final consumption. The corresponding range by 2010 was AWI from 44% to 152% higher than WI. All groupings improved their AWI over the period, with the strongest relative improvement for the developing group, which reduced AWI by 7.2% compounding p.a., off a very high initial base of 1960 litres per \$. The industrialized countries group improved at 2.5% p.a., and the Rest of World at 2.0% p.a. but this came of a much higher base and so resulted in a much higher absolute improvement in AWI.

**Figure 88 Water footprint intensity, Asia-Pacific developing countries (1990, 2010)**



In Figure 88 all individual nations and the developing group as a whole show improvement in AWI over the period. The most populous nations all experienced rapid decreases of 8.8%, 6.3% 4.5%, and 4.5% p.a. compounding for China, India, Indonesia, and Pakistan respectively. The greatest relative rates of improvement were for Cambodia and the Lao PDR, at 9.6 % and 9.5% respectively, with Cambodia also experiencing the largest absolute improvement, with the volume of water required to produce a \$ of GDP decreasing by 7768 litres between 1990 and 2010.

**Figure 89 Water footprint intensity, Asia-Pacific industrialized countries (1990, 2010)**



The levels of AWI seen for the industrialized countries group, in Figure 89, are all much lower than seen for any of the developing group in the corresponding years. All nations in the industrialized countries group also saw their AWI improve, in by between 2.5% and 4.4% p.a. compounding, with a group aggregated average of 2.5% p.a. (compared to 7.2% p.a. for the developing group). On the AWI metric, Singapore becomes the most water-intense economy in the industrialized countries

group, using 112 litres per \$ of GDP in 2010. This contrasts with it being the most efficient economy in the group if we use the WI metric, as seen in Figure 38. Also noteworthy is the strong improvement in AWI for New Zealand, in marked contrast to the deterioration seen using the WI metric. This would be consistent with New Zealand's increased WI being largely a result of expanding agricultural exports.

## 7.4 Emissions intensity adjusted for trade

Adjusted emissions intensity refers to the amount of direct and indirect greenhouse gas (GHG) emissions from final consumption by government and households. Whereas direct emissions will tell us about the characteristic efficiency of production, the indicator presented here describes the intensity of GHG emissions embedded in goods and services consumed within a given territory, in relation to that territory's GDP.

The emissions or "carbon" intensity is measured by the ratio of GHG emissions footprint divided by gross domestic product (GDP). Emissions were calculated using the Eora global, multi-regional input-output framework developed by the University of Sydney<sup>38</sup> and the same data sources for GHG emissions used in Section 2.4 Greenhouse gas emissions with one important exception: forest fires, peat fires and peat decay were not included. This substantially underestimates some results for Indonesia and Cambodia.

These sources were used to create an emissions satellite account with the Eora multi-region input-output tables, for 187 countries, for the 1990–2010 period. More detail on the treatment of the raw data to produce GHG emissions footprints are in Section 6.2 Energy footprint of consumption. The GHG emissions footprint for each country between 1990 and 2010 was divided by the time series data for GDP in constant \$ at 2005<sup>39</sup>, to calculate the emissions intensity in kilograms of CO<sub>2</sub>-eq per \$ (kg per \$)<sup>40</sup>.

**Figure 90 GHG Emissions footprint intensity, Asia-Pacific and World groupings (1990-2010)**

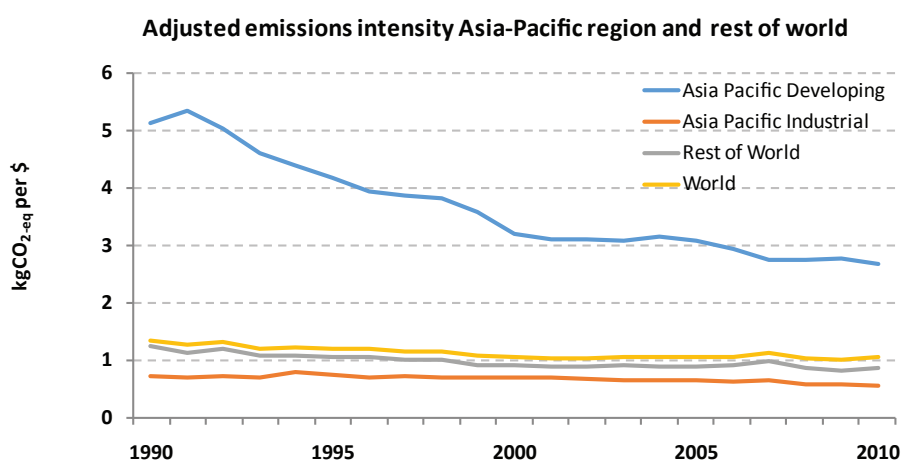


Figure 90 shows the general decline in emissions footprint intensity for all global regions but this is far more noticeable in the Asia-Pacific developing region where this metric has decreased more than 40%. The result for other global regions suggests a consistent consumption "lifestyle" in terms of direct and indirect energy requirements. That is,

although GDP increased in these regions, the characteristic energy intensity of the purchases made with that GDP is stable. By contrast, the aggregate GDP of the Asia-Pacific developing region increased markedly but so too did the emissions footprint of their energy consumption "lifestyle".

In all Asia-Pacific countries except the Maldives there was a decline in the GHG emissions footprint (GHGF) intensity between 1990 and 2010 (see Figure 91). This is particularly pronounced in the developing countries where many nations reduced their GHGF intensity by half. Indeed, this is the overall result for the Asia-Pacific developing region starting at 5.14 kg per \$ in 1990 and ending at 2.68 kg per \$ in 2010. Broadly, this reflects changes to the emissions intensity of residential energy use, for example, in the use of gas and electricity in the home instead of kerosene and biomass and it is also connected to changes in GDP and consumption patterns. As noted in Section 4.4 Emissions intensity of the economy, there has been a significant increase in the GDP of Asia-Pacific nations and, even where emissions levels have not been reduced, there may still be a decrease in intensity because of the change in the denominator of this indicator.

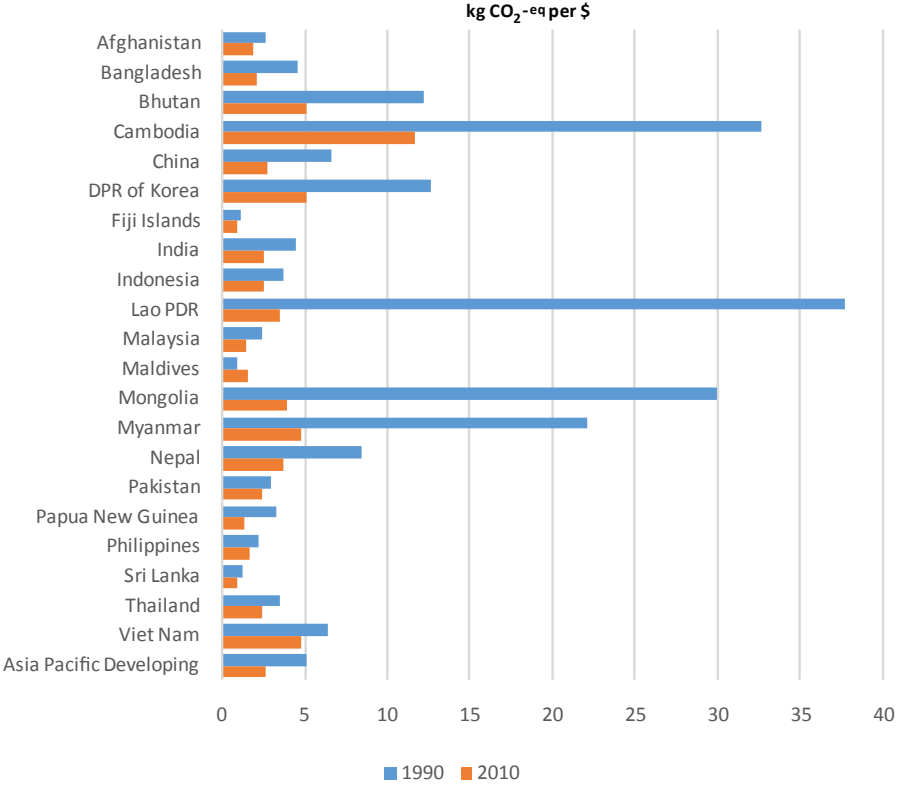
<sup>38</sup> <http://worldmrio.com/>

<sup>39</sup> <http://unstats.un.org/unsd/snaama/dnllist.asp>

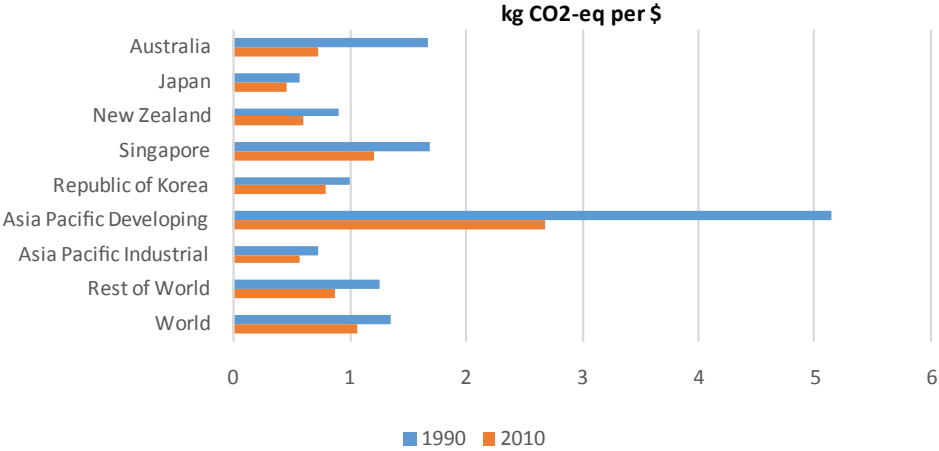
<sup>40</sup> One kilogram of CO<sub>2</sub>-eq is a universal way of measuring global warming potential for different GHG gases and \$US 2005 are also used to calculate emissions intensity in the International Energy Statistics database from the U.S. Energy Information Administration.

Figure 92 shows that the industrialized countries of the region have also experienced decreased GHGF intensity to a lesser extent and the comparison with the territorial emissions intensity in Figure 92 suggests that this may actually have something to do with the territorial emissions intensity related to production. As the territorial emissions intensity of the exporting, developing nations has decreased, so has the emissions intensity of their products. When these are purchased by other countries in the Asia-Pacific and the rest of the world, those regions' consumption-based GHGF intensity goes down.

**Figure 91 GHG Emissions footprint intensity, Asia-Pacific developing countries (1990, 2010)**

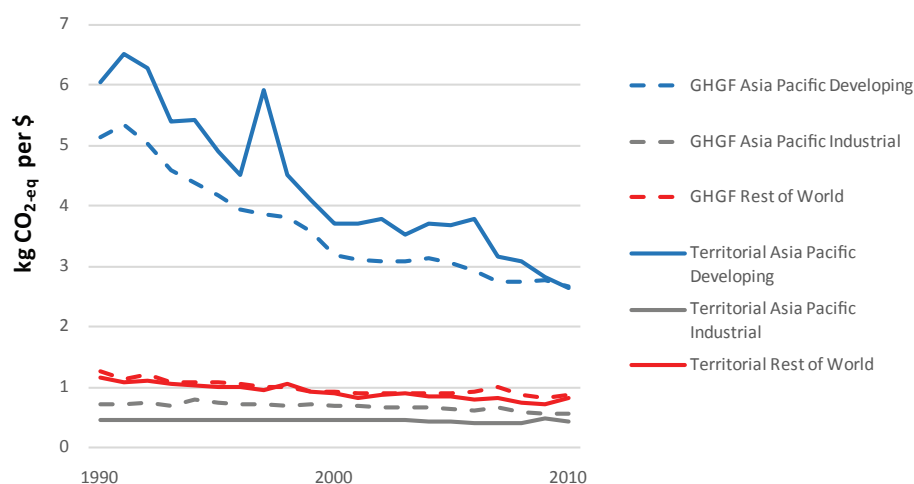


**Figure 92 GHG Emissions footprint intensity, Asia-Pacific industrialized countries (1990, 2010)**



The global regional trends for emissions intensity (GHGF and territorial) in Figure 92 show a steady decline both for the World and the part of the World outside the Asia-Pacific region. The consumption-based GHGF emissions in the Asia-Pacific developing group of countries is smoother and lower than their territorial emissions. This indicates that, per \$ of GDP, the developing nations consume goods and services that involve less emissions than the intensity of emissions embodied in their own products. For the Asia-Pacific industrialized countries it is the opposite: their consumption patterns have more embedded emissions per \$ of GDP than the intensity of production in their own economies. To some extent this represents a very basic geographical separation of production within the Asia-Pacific: industrialized countries like Japan and Australia have dominant service-based economies while developing Asia has more emissions-intensive manufacturing sectors. This is a coarse, high-level generalization as within countries their respective urban centres also host a great many service industries.

**Figure 93 GHG Emissions footprint intensity compared to direct GHG emissions intensity, Asia-Pacific and world groupings (1990-2010)**



Reducing the emission intensity of the economy has been an important policy goal for many countries in Asia and the Pacific to mitigate emissions that cause climate change. For developing countries, the objective is relative decoupling of economy and emissions because overall energy use and emissions are likely to grow in the decades to come. This indicator is of specific importance as it corrects for the embodied carbon emissions in trade for imports and exports and therefore shows a true picture of emissions for consumption within a country, which will play an important role in setting targets.







# Resources and human development

These indicators are suggested as complementary indicators to those that have been presented in this report. They are not presented here in entirety, but one example using HDI is selected to show how they can be used to provide new perspectives on resource use.

## Complementary Indicator 'Economic Growth and Human Development'

- **Human Development Index (HDI)**
- **Gini Index** (measure of income distribution in a nation)
- **Middle class consumers**
- **Poverty Index**
- **Economic Growth (GDP)**
- **Population, labour force and employment** (total employment and unemployment rate) by sector
- **Investment and consumption**
- **Debt, inflation**
- **Access to energy, water, sanitation**

**Feasibility:** Well established indicators based on the System of National Accounts and socio-demographic statistics with a long tradition, sound conceptual basis and well established methods for dataset and indicator development.

**Data availability:** Most data are available from national and international databases, including from the United Nations and World Bank.

**Policy Use:** Many of these indicators are frequently used in policymaking but their meaningfulness will be enhanced through the additional set of environmental and resource use indicators and will help broaden the compass of decision-making.

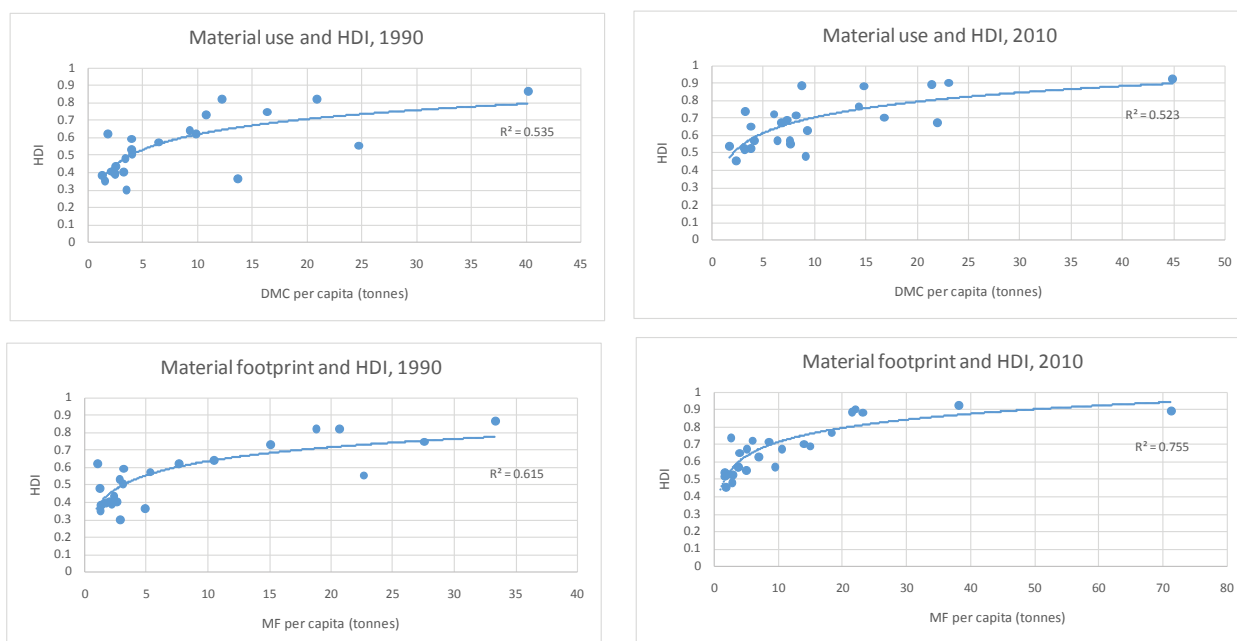
## The cost of high human development, in terms of natural resource use and emissions, has been reduced through innovation but resources need be shared more equitably.

Natural resources and emissions support economic activity and human development. They enable livelihoods either directly, outside the market, or via transactions in the formal economy. In this section of the report we ask to which extent the rapid growth in natural resource use and emissions in Asia and the Pacific has resulted in gains in human development as measured by the United Nations Development Programme Human Development Index (HDI). The HDI is a composite index of life expectancy, literacy and income and groups countries into very high, medium and low human development. Since the 1980s, almost all developing countries in Asia and the Pacific have markedly improved their HDI through improvements in all three domains leading to longer, healthier lives with more opportunities through higher incomes and consumption. The relationship between natural resource use, emissions and HDI is highly non-linear. At low levels of resource use, small changes in resource consumption may lead to significant improvements in HDI while at high levels of per capita resource use additional resource consumption and emissions have almost no effect on the HDI.

The different components of HDI have different costs in terms of resource use. Where life expectancy and literacy can be improved using minimal resources, rises in per capita income almost always rely on significant increases in resource use and emissions. The cost of HDI in terms of natural resources and emissions is, however, decreasing over time as is demonstrated by the upward shift of the curve representing the relationship between material use and HDI. Through innovation, new technologies and economies of scale achieving progress in human development has become less costly in terms of environmental pressure and impacts.

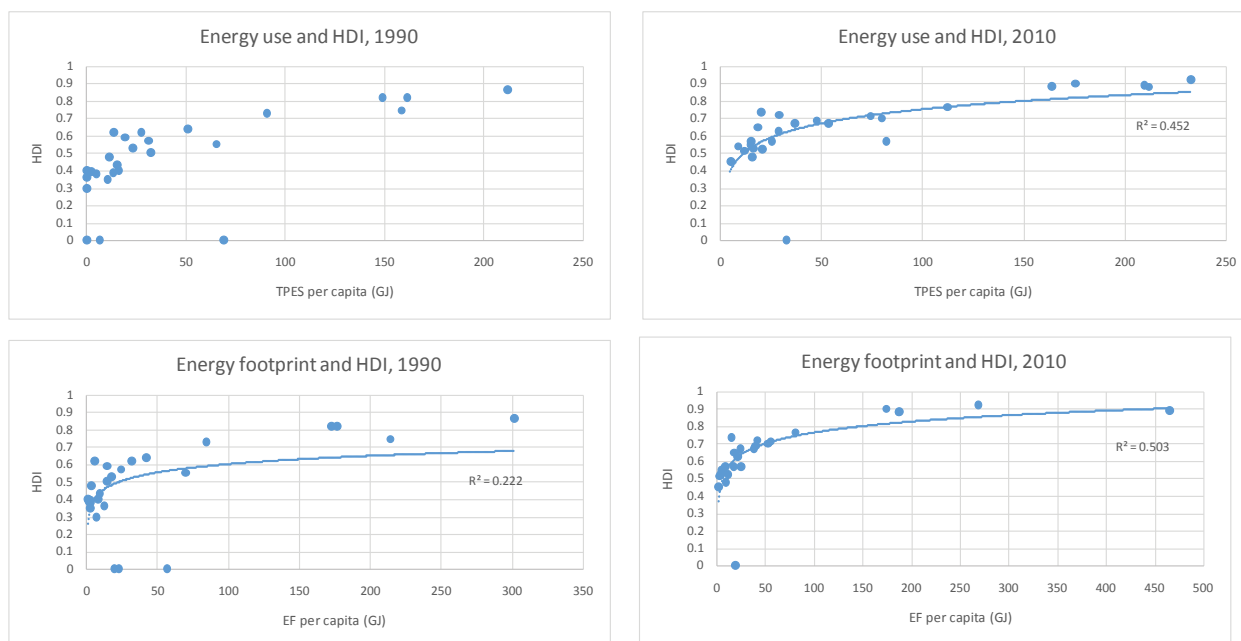
We first plot material use and material footprint versus the HDI for all 26 countries (see Figure 94). The relationship between material use (DMC) and HDI has not been very strong whereas the relationship between material footprint of consumption and HDI showed a much stronger, and over time, increasing correlation. This is not surprising, as the DMC indicator for material represents resource consumption of the production system where countries with large extractive or significant manufacturing activity display higher material use which may have little effect on the material standard of living of households.

**Figure 94 The relationship between material use and the human development index (1990, 2010)**



The link between energy use and HDI is much stronger, presumably because energy needs can be seen as a factor of production contributing to economic growth significantly beyond their share in total factor cost (Ayres and Warr, 2009). The relationship is even stronger for energy footprint and grew over the two decades from 1990. We again see the curve representing the relationship between energy use and HDI moving upward and to the left between 1990 and 2010, suggesting that the energy cost of HDI has decreased over time similar to the material cost of HDI.

**Figure 95 The relationship between energy use and the human development index (1990, 2010)**



Improvements in human development in Asia and the Pacific have been substantial over the past two decades and have been enabled by fast growth in natural resource use (materials and energy). The relationship between natural resource use and HDI has also become stronger over time. The incremental cost of HDI in terms of resource use has, however, decreased which signals the potential for achieving future human development gains at lower resource and emission intensity. Most of the improvement has occurred spontaneously, that is, in the absence of public policy directed to resource efficiency and decoupling. If well-designed policies were to encourage innovation and investment in green technologies the region could step up its endeavours to increase prosperity and well-being without risking environmental pressures and impacts that spiral out of control and avoiding bottlenecks in development caused by reduced supply security and higher costs for critical natural resources for production and consumption.



# The use of indicators in policy making

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Information systems, data and knowledge and indicators are a very important means of providing guidance for policymakers and business leaders as well as for the general public. This report presents a comprehensive set of data and indicators all in one place. This report presents a new indicators framework that is scientifically sound, timely, and relevant to policy formulation.

## 9.1 The conceptual framework for the Indicators

### Background

This sub chapter outlines the conceptual framework that was used to select the indicators quantified in this report. The framework was developed by Dr Heinz Schandl (CSIRO) and Professor Anthony Chiu (APRSCP and De La Salle University) and edited by Stefanos Fotiou and Janet Salem of UNEP.

The United Nations Environment Programme manages the EU-funded Regional Policy Support Component of the SWITCH-Asia programme (SWITCH-Asia RPSC). The SWITCH-Asia RPSC has two main objectives: To create an enabling environment to strengthen or initiate policies helping to mainstream Sustainable Consumption and Production and Resource Efficiency into regional, sub-regional and national development programmes.

To assist stakeholders in the project countries (government, private sector, civil society), in designing and implementing specific policy-oriented activities to shift towards Sustainable Consumption and Production.

The partners for implementation of the SWITCH-Asia RPSC include National governments of the SWITCH-Asia countries, partner UN agencies, the Asia-Pacific Roundtable on SCP, representatives of the private sector and SCP-related academia and experts. In 2013, these partners identified the need for the SWITCH-Asia RPSC to provide support for the development of indicators to measure progress on SCP. It was acknowledged that there are already a number of tools and indicators used today to monitor and evaluate national Green Growth or SCP programmes. On top of specific SCP indicators, there is a large amount of work on Green Economy/Green Growth indicators and other indicators related to resource use/resource efficiency. While all these indicators complement each other there is a profound need to identify common elements and practical approaches on how a core of these indicators can support the development, implementation and monitoring of resource efficiency related policies in Asia. UNEP was requested to focus on covering this gap. Building on the recommendations of the TAC, UNEP initiated a process that included the following steps:

- A consultation within UNEP and with other UN agencies and IGOs. The consultation revealed that the profound need to identify common elements between the various initiatives on indicators for SCP, Green Economy and Resource Efficiency, has been also highlighted in other global, regional and sub-regional fora. As a result the focus of the work under the SWITCH-Asia RPSC has been refined on identifying “Indicators for a Resource Efficient Green Asia”. Given the need to link to broader regional processes, this has since been expanded to the Asia Pacific.
- An open call to government bodies, intergovernmental organizations, bilateral and multilateral donors, academic and research institutions and other relevant organizations to submit cases describing their initiatives in the area of Indicators related to Green Economy, Sustainable Consumption and Production, Green Growth, Resource Efficiency, Circular Economy and relevant areas of work in Asia.
- The compilation of a background paper on the basis of the submitted cases as well as additional literature review. The background paper included, among others, a conceptual proposal for the development of a set of indicators on SCP, GE and RE.
- The organization of a regional workshop on “Indicators for a Resource Efficient Green Asia” that took place in Beijing on 25–26 September 2013. During the workshop the background paper was discussed and after consultation with the participants it was decided that an updated version should



be developed that would include a specific set of indicators. The updated paper included a total of 32 indicators within eight Indicator domains.

Of these 32 indicators, 24 indicators have been selected for the first dataset. These 24 indicators are further disaggregated or normalised according to population or GDP size to facilitate comparisons between small and large countries. The dataset that has been developed contains in total 118 indicators per country, with a time series span of 40 years (apart from footprint indicators which have a times series span of 20 years). The dataset is available at <http://uneplive.unep.org/>.

### **The importance of indicators**

Indicators are important to decision-making. They reduce the complexity of a phenomenon or a situation to a degree that decisions and actions can be based on information and evidence. Indicators seem to be addressed to experts, economists and statisticians, and yet they are part of our daily life. Some indicators dominate the public and policy debate – these include economic growth, unemployment figures, the inflation rate and the Dow Jones Index. Policymakers and the public are used to debate and decision-making being supported by this handful of economic indicators. This appears to be, however, increasingly problematic when we consider the public policy challenges faced in the context of globalization and global environmental change. New information, data sets and indicators are needed to underpin the complex policy and business decisions that are faced today. Decision makers need to know which natural resources are needed to fuel economic growth, at which prices they are available, and how secure the supply chains for these natural resources are. They also need information about the outputs from our economic system to better understand how waste and emissions are linked to economic activities. Most importantly, they need to know which economic sectors or activities are responsible for particular resource demands and emissions and the means by which they can be reduced.

New indicators are needed to supplement the current economic indicators and inform society about the challenges, options and pathways to success in the domains of sustainable consumption and production (SCP), resource efficiency (RE) and the green economy (GE).

### **The policy domains of SCP, Resource Efficiency and Green Economy**

Sustainable consumption and production, resource efficiency and green economy all refer to diverse but complementary approaches and ways for achieving sustainable development.

The core storyline of sustainable development recognizes the legitimate developmental aspirations of people across the globe and the fact that generalizing wealth for all under the current development paradigm would over-burden the world's natural resources and ecosystems. Economic growth is necessary to satisfy the legitimate needs of the world's poor. Economic growth should therefore be promoted, but gated in ways that are environmentally benign and socially just. Justice, in the context of sustainable development, refers not only to distribution within the present generation, but also across future generations. It is not just a strategy for developing countries but also for wealthy, industrialized countries, which must reduce the excessive pressure and impacts on the Earth.

Sustainable development, hence, views economic growth, environmental protection, distributive justice, and long-term perspective as mutually reinforcing. It builds on the idea of decoupling economic growth from environmental pressures and impacts, which, once achieved, will underpin high human development and good material standards of living in a healthy environment for all.

According to UNEP (UNEP, 2011b) a **green economy** is characterized as low carbon, resource efficient and socially inclusive. In a green economy, growth in employment and income are driven by public and private investment into such economic activities, infrastructure and assets that allow reduced carbon emissions and pollution, enhanced energy and resource efficiency, and prevention of the loss of biodiversity and ecosystem services. These green investments need to be enabled and supported by targeted public expenditure, policy reforms and changes in taxation and regulation. UNEP outlines a development path that understands natural capital as a critical economic asset and a source of public benefits, especially for poor people whose livelihoods depend on natural resources. The notion of green economy does not replace sustainable development, but creates a new focus on the economy, investments, capital and infrastructure, employment and skills and

positive social and environmental outcomes. Getting the economy right is viewed as a necessary condition for sustainable development. In high income and middle income countries achieving green economic outcomes will require the redirection of investments to economic activities that enable desired economic, social and environmental results. In low income countries, investment into the green economy will need to be supported through technical assistance and foreign aid.

**Sustainable consumption and production (SCP)** reflects the production and public and private spending for goods and services which satisfies basic needs and enables better quality of life while reducing the use of natural resources and the amount of waste and emissions over the life cycle of a service and product. Sustainable consumption refers to more responsible purchasing decisions by private households, business, and governments. It has a different focus in developing and industrialized country contexts. In developing countries sustainable consumption means expanding the resource base to meet human needs. In high income countries the emphasis is on altering consumption patterns to achieve well-being while reducing resource and energy use and emissions (UNEP, 2008).

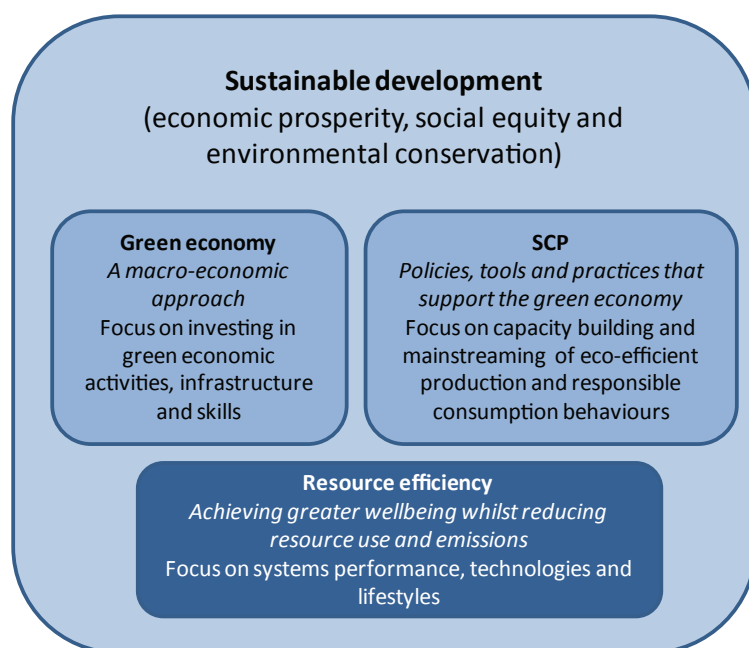
Sustainable production aims to improve production processes to reduce resource consumption, waste generation and emissions across the full life cycle of processes and products.

Resource efficiency refers to the ways in which resources are used to deliver value to society and aims to reduce the amount of resources needed, and emissions and waste generated, per unit of product or service. Resource efficiency can be achieved through reducing resource inputs, cyclical use of resources and recycling. Resource efficiency can be considered at a sectoral level or a whole of economy level (UNEP, 2011a).

From an operational point of view the concept of resource efficiency links core elements of economy, resource use and management within a national framework for sustainable development. The Green Economy provides a macro-economic approach to sustainable economic growth with a central focus on investments, employment and skills. Sustainable Consumption and Production provides tools and policies for the operational and micro level (in both the public and private sectors) that can support a green macro-economic approach with a focus on practices, capacity-building and mainstreaming.

The three notions of sustainable consumption and production, resource efficiency, and green economy all figure prominently under the umbrella of sustainable development (see Figure 96).

**Figure 96 The role of Green Economy, Sustainable Consumption and Production and Resource Efficiency for Sustainable Development**



They focus on different aspects of the interrelationship between social well-being, the economy, and the environment. Green economy focuses on public and private investment decisions and the resulting quality of productive capital, assets, and infrastructure. These investments will determine what kinds of technologies and processes are used to produce goods and services. The availability of green products and services will constrain the ability of public and private consumers in making environmentally and socially responsible purchasing decisions. Consumers provide signals to businesses and governments through their purchasing decisions and voting patterns that may trigger more or less investment in the green economy and supporting legislation and taxation. Resource efficiency is both a strategy and an outcome.

## A brief review of current approaches to SCP, RE and GE indicators

Over the past few years, there have been a large number of reports about SCP, RE and GE and also attempts to establish indicators sets for these policy domains. This activity was largely driven by international organizations including the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), the UN Economic and Social Commissions (UN ESCAP), the European Commission, the European Environmental Agency (EEA), the RE for Economic Co-operation and Development (OECD), the World Bank and the Asian Development Bank (ADB), and recently the Green Growth Knowledge Platform (GGKP, 2013).

The OECD has proposed a list of green growth indicators that cover socioeconomic drivers (including economic growth, productivity, trade, labour markets, skills and demographic patterns) and their relationship to environmental and resource productivity, the natural asset base and environmental health aspects (OECD, 2011). They also introduce policy responses in their indicator framework and hence provide a very comprehensive list of aspects they wish to monitor. The World Bank has presented a framework organized around environmental quality, economic indicators measuring total factor productivity, innovation and efficiency as well as social resilience, job creation and poverty reduction (World Bank, 2012). UNEP has an indicator set to inform green economy policies covering climate change, ecosystems management, pollution and resource efficiency and link those environmental indicators to policy interventions (such as green investment, ecological budget and tax reform, internalizing external costs, green procurement and green jobs and skills to explore the well-being and equity outcomes of such policies for society and the environment (UNEP, 2012a).

UNEP has also proposed an SCP indicator set for developing countries that distinguishes between the macro-level (policy and economy) and their relationship to producers and consumers (UNEP, 2008). The framework includes efficiency measures and indicators for compliance and connectivity as well as indicators for stocks and resilience that are critical to socioeconomic development.

Despite these many efforts there has not been significant achievement in bringing the knowledge base together or achieving agreement on indicators between these different organizations. There are a number of initiatives that will enable such a process of harmonization and will provide general guidance for developing strategies, data needs and indicator development. These include the System of Integrated Economic and Environmental Accounts (SEEA) framework that organizes data work and indicators with strong reference to the national accounts, and which is pivotal to the domains of SCP, RE and GE. The SEEA is a very flexible framework for data collection integrating economic and environmental accounts and not favouring a single headline indicator but offering a multipurpose system from which a variety of indicators may be derived (EU et al., 2012)<sup>41</sup>. The Driver, Pressure, State, Impact, Response (DPSIR) framework helps to distinguish between different aspects of measurement (OECD, 1994; UNDSO, 1997). It suggests focusing indicator development for SCP, RE and GE to economic drivers and environmental pressure indicators that are supplemented by a set of social and governance indicators to reflect the functional relationship between economic activities, investments, capital and assets, and resource demand, waste and emissions.

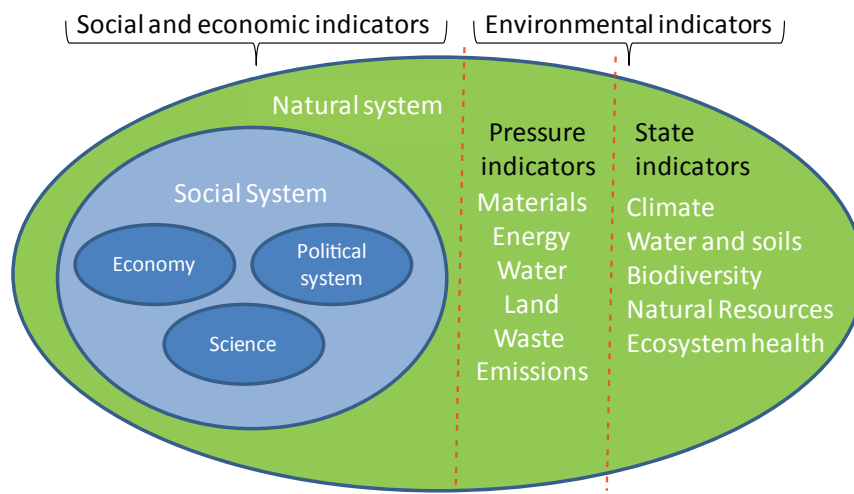
## A conceptual framework for developing indicators

As a starting point for any indicator set the criteria of **conceptual coherence, policy relevance, and feasibility** apply. For a **conceptually sound basis** for an indicator set for SCP/RE and GE we suggest using the concept of industrial metabolism (Ayres and Simonis, 1994). Industrial metabolism refers to the throughput of materials and energy that is maintained to fuel production and consumption for all social and economic activities. **Policy relevance** is achieved through linkages with the important issues of decoupling, SCP, and investing in a green economy but also through compatibility with system of national accounts (SNA) by applying the SEEA framework. This allows high-level indicators to be disaggregated to those economic activities that cause the resource flow or emission. Most importantly, indicators need to be based on **readily available data sources** to allow for timely delivery of information at a reasonable cost.

A conceptual framework for SCP/RE/GE indicators must, according to the definition of the concepts, address society and nature as well as the interaction between society and nature in the form of resource extraction and waste disposal and emissions (social metabolism). It should further differentiate the social system into the economy and the political system (governance) (see Figure 97)

<sup>41</sup> EU, FAO, IMF, OECD, UN and World Bank 2012. System of Environmental-Economic Accounting. Central Framework.

**Figure 97 Sustainability domains**



Each subsystem (natural system, economic system, politico-administrative system and social system) needs to be based on a sound theoretical understanding and a related empirical method for data generation and indicator derivation, as indicated in Table 8; that would allow the derivation of a set of standard indicators for every domain and the construction of information on efficiency such as labour-, energy-, and material productivity.

**Table 2 Indicators framework**

	Environment	Economy	Governance	Society
Function	Natural system – provision of natural resources and sinks for waste and emissions	Economic system – regulation of scarcity	Political-administrative system - establishment of collectively binding decisions	Social system
Conceptual background	Social (industrial) metabolism	Macro-economic theory	Policy and institutional theory	Sociology
Empirical approach	Quantitative analysis of metabolism (whole of life cycle perspective)	Quantitative analysis of economic activity (System of National Accounts)	Qualitative historical and institutional analysis	Qualitative and quantitative social analysis
Standard indicators	Material, energy flow, emissions (extraction, transformation, consumption and disposal)	GDP, employment, investment, debt, inflation	Effectiveness and efficiency of government	Social cohesion, equity

Herman Daly identified three issues when analysing sustainable development: allocation of natural resources to different economic activities, distribution of income and goods and services, and scale of the economy (society) relative to the ecosystem (Daly, 2005). A good allocation of natural resources is efficient; a good distribution of income or wealth is just (assuming a limited range of acceptable inequality); a good scale does not generate “bads” faster than “goods” and is also ecologically sustainable (i.e. it could last for a long time, although nothing is forever).

- **Allocation** – the division of the resource flow among alternative product uses and producing sectors – through competitive markets. There is, however, the common phenomenon of market failure and a need for policy development to ensure the most beneficial use of natural resources.

- **Distribution** – the division of the resource flow, embodied in products and services, among different people (households). Justice or fairness of distribution is a separate goal from efficiency and requires separate policy instruments.
- **Scale** – the total volume of resource flows, the matter-energy throughput taken from the environment as low-entropy resources and returned to the environment as high-entropy waste. Scale is relative to environmental carrying capacity and is often ignored by mainstream economics.

From this conceptual framing it follows that indicators that measure the progress of resource efficiency, SCP and the green economy should focus on the environmental and economy domains of the framework but should be linked to social and governance aspects when needed for specific questions. They should address scale and allocation (efficiency) but should not shy away from measuring distributional outcomes.

### Domains for headline indicators for a resource efficient and Green Asia-Pacific

The following provides a description of six headline indicator domains with suggested indicators under each domain. It also outlines the feasibility, data availability and potential policy use of each set of headline indicators. It is important to note that all indicators are derived from data sets that would allow more detailed policy questions to be addressed and can be utilized in models that analyse the impact of policy settings on the future in terms of environment, economic growth and employment.

**Table 3 List of indicators to monitor progress of a resource efficient green Asia**

Indicator Domain	Measurement	Indicator
Natural Resource Use	Total amount of natural resource use and natural resource use per capita	Domestic Material Consumption (tonnes) Total Primary Energy Supply (joules) Total Water Use (m <sup>3</sup> ) Greenhouse Gas Emissions (tonnes)
Primary Resource Trade Dependency	Dependence on natural resources from global markets	Physical Trade Balance (tonnes) Unit Price of Trade (\$/kg)
Resource Productivity	Economic output per unit of natural resource input	Material Productivity (\$/kg) Energy Productivity (\$/joules) Water Productivity (\$/m <sup>3</sup> ) GHG Intensity (\$/kg)
Eco-Efficiency of Production	Total sectoral resource use, resource use per employee and sectoral resource productivity	Water Use in Agriculture (m <sup>3</sup> ) Emissions of the Energy Sector (tonnes) Material Use for Manufacturing (tonnes) Material Use for Construction (tonnes) Emissions of Transport (tonnes) Material Footprint of Services (tonnes)
Consumption	Natural Resource Footprint. Attribution of natural resource use to final consumption in a country	Material Footprint (tonnes) Energy Footprint (joules) Water Footprint (m <sup>3</sup> ) Carbon (GHG) Footprint (tonnes)
Adjusted Resource Productivity	Economic output per unit of natural resource footprint	Adjusted Material Productivity (\$/kg) Adjusted Energy Productivity (\$/joules) Adjusted Water Productivity (\$/m <sup>3</sup> ) Adjusted GHG Intensity (\$/kg)
Investing in Green Economy	Total green investment and share of green investment in overall investment	Total Green Investment (\$) Share of Green Investment (%) Green Investment in Manufacturing (\$) Green Investment in Urban Infrastructure (\$)
Enabling a Green Economy	Total green taxes and share of green taxes in overall tax volume	Total Green taxes (\$) Share of Green Taxes (%) Subsidies for natural resources (\$) Share of subsidies (%)

## **9.2 How to use this indicator set to inform policy formulation**

This report has contributed new knowledge of the indicators for resource efficiency. It has provided new resource efficiency information within a specific geographic region: Asia and the Pacific region. The regional trends observed in this report support and build on the findings of previous research into resource efficiency (UNEP, 2011a).

The trends in resource efficiency are of concern at country, regional and global scales. The trends in resource efficiency indicate that to achieve the economic growth targets, substantial increases in material flows will be required. The trends, particularly in footprint analysis, indicate that the economies within the study region will experience resource constraints. These resource constraints are not going to resolve themselves. Concerted policy action is needed to promote resource efficiency.

Resource efficiency policy is most easily developed using existing governance frameworks. The governments of the nations represented are best placed to address resource efficiency individually through domestic policy mechanisms.

There is momentum behind existing policymaking mechanisms within the region. The SWITCH-Asia programme has provided support for domestic SCP policy development and UNEP has an ongoing role as technical adviser on SCP and resource efficiency policy. As a result, many of the nations represented in this study have resource efficiency policies under development or implemented. Indicators are important at all stages of the policy process. We present a four-stage model of the policy process and discuss the role of indicators at each stage.

### **Use of indicators at different stages of policy formulation and implementation**

Indicators are widely used across the functions of government and are integral to the performance good government. Good government responds to common perils and advances the common welfare (Wechsler, 1954). To understand common perils and welfare, government needs to be aware of and respond to current, emerging and potential issues that imperil or benefit society. Government awareness and responsiveness to societal issues comes about through the use of indicators. Thus indicators are necessary for more than policymaking, they are necessary for good government.

To understand the role of indicators in policymaking it is necessary to understand policymaking itself. Following from previous UNEP programmes (SWITCH-Asia and others), policymaking can be construed as a cycle. The policymaking cycle has four stages: problem identification and framing, policy framing and analysis, policy implementation, and monitoring and evaluation (UNEP, 2012b). The use of indicators in the policymaking cycle can be identified at each stage of the policy cycle.

The conception of policymaking as a cycle is one of several models of policymaking (Schlager, 1999). Kingdon's (1995) policy streams model recognizes the different areas that need to align to for a policy "window" to open. Sabatier's (1988) Actor Coalition Framework identifies the need to align actor incentives for policy formation. Peters' (2002) model recognizes that policy instrument choice is political, and thus dictates the policy framing as much as the problem. The choice of policy model should be contingent on evidence to support the model assumptions (Howlett and Ramesh, 2003).

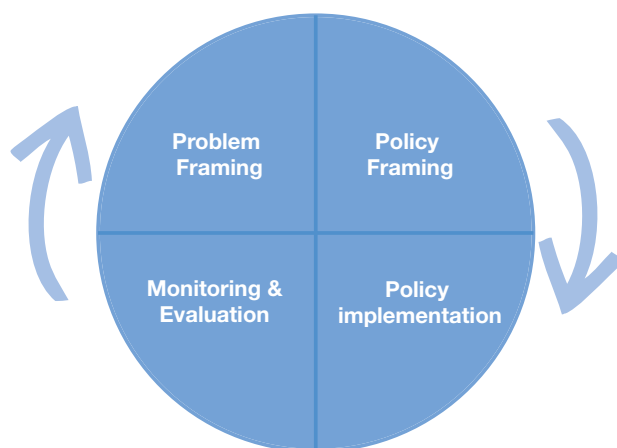
We use the policy cycle model as it is congruous with the five-year development planning process undertaken in many Asian nations and follows analysis previously undertaken in SCP policymaking (UNEP, 2012b).



## The policy cycle

Policymaking can be viewed as a cycle with four stages: problem identification and framing, policy framing and analysis, policy implementation, and monitoring and evaluation. Indicators are used in different ways in each stage.

**Figure 98 Policy cycle**



### Problem identification and framing

In this early stage in the policymaking cycle, the potential policy issues are identified and analysed. The intent of this stage is to learn about a potential policy issue so as to be able to transform the potential policy issue into a tractable policy problem (Dovers and Hussey, 2013). A tractable policy problem is where the issue has been clarified and understood, with identification of leverage points and measurement of the scale and scope of the problem.

Environmental policy is a complex and data intensive domain. Environmental issues are often complex, with interactions between society and the physical and natural world and differing interpretations of the world (Dryzek, 1997). Large amounts of data are needed to inform our understanding of the relationships, scale and scope of the problem.

New information, data sets and indicators are needed to underpin the complex policy and business decisions that are faced today. **Decision makers need to know about the use of natural resources in economic growth and how to manage these sustainably while developing their social and economic bases (UNEP, 2011b).** The complex policy and business decisions cannot be made confidently without data to inform our understanding of resource demands and emissions in society, in sectors and in regions.

Example uses of indicators in problem identification and framing include studies of phosphorous flows and early studies of atmospheric CO<sub>2</sub>. Studies of phosphorous flows identified the problem of finite resources and the need for better soil nutrient conservation and land-use practices. Early studies of atmospheric CO<sub>2</sub>, such as the Mauna Loa observations in the 1970s, identified the issues of global greenhouse gas emissions. The early CO<sub>2</sub> observations were not conclusive, but served to identify and frame an environmental problem, which, with further analyses, became a policy problem.

### Policy framing and analysis

Policy framing and analysis is the early structuring of government responses to an environmental problem. In this stage of the policymaking process, the environmental problem is transformed into a policy problem that can be addressed through government policy. A government policy contains both policy objectives (goals) and means of action (policy instruments). It is vital that there is logical consistency and congruence between the environmental problem, the policy problem and the policy response. This stage of the policy process includes analysis of potential policy responses and consultation with stakeholders.

In this stage, social, demographic and environmental indicators are used to gain a greater understanding of the context for policy action. Indicators play a vital role in designing policy as well as in assessing the circumstances for policy intervention and the potential confounding factors. Indicators may be used as the measures of achievement of policy objectives, or they may be used as evidence of the need for policy action. An example of indicators used in policy development and framing is the use of forest cover indicators to measure the success of forestry policy, as in the case of the Lao PDR. Pollution indicators may be used as evidence of policy necessity.

A variety of indicators may be used to gain a greater understanding of the context in which policy is to be implemented. For example, in tackling complex environmental problems caused by human behaviour, a multidisciplinary approach may be more effective than single disciplines (Gynther et al., 2012), and which in turn, requires a variety of indicators from multiple disciplines.

#### Policy implementation

The policy implementation stage is characterized as the coordinated enactment of government policy. Enacting policy includes using government resources or processes, enforcing rules, buying products or services, and informing groups and audiences.

At the implementation stage of the policy cycle, 'active' management is needed to fully realize policy objectives (ANAO, 2014). Active management requires monitoring, measurement and analysis, stakeholder engagement, adjustments and calibrations of policy. Active management requires timely information and indicators can serve this process.

Indicators may be necessary in implementation through the structure of government itself. Some policies are developed and implemented by different arms of government, or even outside of government. This can occur when policymaking is separated from policy implementation, the separation of 'steering' from 'rowing' (Osborne and Gaebler, 1992). Indicators are essential to monitor progress of implementation when government service delivery is separated from policymaking.

For example, the introduction of fishing licences requires active monitoring of implementation for their effective operation, and indicators are essential in active monitoring. Clean Development Mechanism projects with construction require reporting throughout the process, and common indicators include cost variance to budget.

#### Monitoring and evaluation

As listed here, the final stage in the policy cycle is monitoring and evaluation. Monitoring and evaluation is the 'main game' of policymaking (Dovers and Hussey, 2013). It is an essential function of government regardless of style (Hood, 1991) and an essential part of any regulatory activities (Morgan and Yeung, 2007).

In a practical sense, monitoring and evaluation have important qualities with considerations for the use of indicators.

Monitoring of policy and programme performance is necessary to adaptive and responsive government. Indicators can communicate performance simply and quickly, especially if performance measures are clear. However using indicators for performance management should be undertaken with care (Jackson, 2005).

Evaluations are discrete assessments of the policy or program performance. They can be scheduled as part of the policy, or can be undertaken as required. They are more thorough than monitoring, in that they recognize that "value" in "evaluation" connotes some subjective elements. The usual criteria for evaluation are efficiency, effectiveness and equity, but there are other criteria such as government resources required, coerciveness and directness (Salamon, 2002).

Policy which addresses complex problems requires a widely scoped and thorough evaluation. As the SCP handbook notes, evaluations include 1) policy impact, effect or update, 2) environmental or social conditions which are the target of policy and 3) secondary influences which impact the performance of target.

Policy monitoring and evaluation are important for policy learning. Indicators provide important records of performance that are needed for future learning. Indicators can be used in a balanced scorecard (Kaplan and Norton, 1992) or in an integrated management system (Yetano, 2009). The integration of multiple indicators to form "dashboards" can be an effective means to communicate to a non-expert audience (Finkbeiner et al., 2010). They are good for learning right through the policy cycle.

A common experience in monitoring and evaluation are the five-year planning processes in many Asian nations. The success of any five-year plan cannot be communicated in a single number: many indicators are used to assess the performance of the plan. Thus a series of indicators are needed, reflecting a variety of goals and the observation that no policy is a complete success nor are there ever entire failures.

The level of development of resource efficiency policy can be located in the same policy cycle model. The policy development stage is evaluated based on 1) the presence of a specific resource efficiency or sustainable consumption and production policy and 2) the development stage of the policy from draft through implementation to monitoring and evaluation. There are some countries which have economic plans which include aspects of resource efficiency, but these are not considered as specific policies under the policy cycle.

### Application in the region

Using analysis of the policy development in the study countries we can plot the countries along the policy cycle (stages as shown in Table 10). Resource efficiency is a relatively new area of policy in many countries within the study area. Good policy can take years to formulate. Unsurprisingly, we find that resource efficiency policy is found in the early stages of policy cycle for many of the countries included in this analysis.

**Table 4 Resource efficiency policies in study nations**

Country	Resource efficiency or SCP policy?	Policy implemented?	Policy name
<b>AP developing countries</b>			
Afghanistan	<input type="checkbox"/>	<input type="checkbox"/>	
Bangladesh	<input type="checkbox"/>	<input type="checkbox"/>	
Bhutan	<input type="checkbox"/>	<input type="checkbox"/>	
Cambodia	<input checked="" type="checkbox"/>	<input type="checkbox"/>	National strategy on green growth (2013)
China	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Circular economy promotion law (2009) and Cleaner production promotion law (2003)
Fiji Islands	<input type="checkbox"/>	<input type="checkbox"/>	
India	<input type="checkbox"/>	<input type="checkbox"/>	
Indonesia	<input checked="" type="checkbox"/>	<input type="checkbox"/>	National action plan on SCP (draft)
Lao PDR	<input type="checkbox"/>	<input type="checkbox"/>	
Malaysia	<input checked="" type="checkbox"/>	<input type="checkbox"/>	SCP blueprint (draft)
Maldives	<input type="checkbox"/>	<input type="checkbox"/>	
Mongolia	<input type="checkbox"/>	<input type="checkbox"/>	
Myanmar	<input type="checkbox"/>	<input type="checkbox"/>	
Nepal	<input type="checkbox"/>	<input type="checkbox"/>	
DPR of Korea	<input type="checkbox"/>	<input type="checkbox"/>	
Pakistan	<input type="checkbox"/>	<input type="checkbox"/>	
Papua New Guinea	<input type="checkbox"/>	<input type="checkbox"/>	
Philippines	<input type="checkbox"/>	<input type="checkbox"/>	
Sri Lanka	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	National action plan for Haritha Lanka programme (2009) National cleaner production policy (2005)
Thailand	<input type="checkbox"/>	<input type="checkbox"/>	
Viet Nam	<input checked="" type="checkbox"/>	<input type="checkbox"/>	National action plan on SCP (draft) National strategy for green growth (2012)

Country	Resource efficiency or SCP policy?	Policy implemented?	Policy name
<b>AP industrialised countries</b>			
Australia	<input type="checkbox"/>	<input type="checkbox"/>	
Japan	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Sound material cycle society (2003)
New Zealand	<input type="checkbox"/>	<input type="checkbox"/>	
Republic of Korea	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	National strategy for green growth (2009)
Singapore	<input type="checkbox"/>	<input type="checkbox"/>	

The stage of policy development is likely to have a strong relationship to the use of indicators. The uses at particular stages are explained in further detail in Table 11 below.

**Table 5 Policy development stages and indicator uses**

Policy level: policy development stage	Use of indicators in this stage
Problem framing: government is undertaking the process of issue analysis and recognition of a problem which can be addressed	<ul style="list-style-type: none"> <li>• Inform problem analysis, including scale, duration, trend and impacts</li> <li>• Inform problem framing, including understanding how policy levers can be effective in addressing the problem</li> </ul>
Policy framing: developing policy objectives and designing measures to address the problem as analysed in the previous stage	<ul style="list-style-type: none"> <li>• Inform policy objectives and design</li> <li>• Inform measurement framework for policy as designed</li> </ul>
Implementation: activating government resources to enact policy	<ul style="list-style-type: none"> <li>• Guide implementation under uncertainty</li> <li>• Assess success of implementation</li> </ul>
Monitoring and evaluation: assessment of policy progress and occasional review, update of policy	<ul style="list-style-type: none"> <li>• Provide information for policy assessment</li> </ul>

### Why do governments need resource efficiency indicators?

Resource efficiency policymaking is complex, informed by a variety of disciplines and has previously lacked data. The data provided in this report provide a valuable contribution to our knowledge of resource efficiency in Asia. In particular, resource efficiency indicators are needed for the following critical aspects of policy:

- Resource efficiency indicators are **fundamental in understanding the dynamics** governing the allocation, production, distribution and consumption of goods and services.
- Resource efficiency indicators provide an **evidence base to stimulate policy development**: many Asia-Pacific nations do not have resource efficiency policies in place and the development of indicators enables an understanding of the problem that would lead to agreement on the need to develop policy.
- Resource efficiency indicators **enable monitoring and management** actions towards achievement of policy objectives: the development of indicators enables progress tracking following implementation and policy adaptation should performance deviate from expected.
- Resource efficiency indicators enable **benchmarking of scale and intensity of resource use across nations** with resource efficiency policies: a number of nations have resource efficiency policies and the development of indicators allows comparability over time and between countries.
- Resource efficiency indicators provide a **greater understanding of the relationships in complex social and natural systems**: the use of indicators enables changes in underlying relationships to

be detected, such as decoupling (Steinberger and Roberts, 2010), or to detect turning points in cycles, such as the leading indicators used in economics.

- Resource efficiency indicators enable **government to function more effectively, efficiently and transparently**: the use of resource efficiency indicators allows effective division of policymaking from policy implementation, which enables more effective and efficient government service delivery.
- Resource efficiency indicators **raise awareness**: indicators can be used for educational and awareness-raising purposes, serving to develop recognition of the policy problem and justify government policy responses.

To demonstrate the applicability of this guide we have developed several case studies of countries from the region. For the Lao PDR, Viet Nam and Japan we have analysed the current policy settings and the use of data within each.

### **Lao PDR: Problem analysis**

Lao PDR is one of the least developed study countries with a population of 6.7 million and GDP of USD 11 billion (World Bank, 2015). The Lao PDR has substantial policymaking challenges, as recognized in the policy handbook for SCP (UNEP, 2012b).

The Lao PDR has a five-year development plan, but no SCP, RE or green growth strategies. The current Lao PDR five-year development plan (the seventh National Social and Economic Development Plan (NSED) 2011–2015) is due to expire at the end of 2015. The new five-year plan, the eighth NSED, is currently in draft form and includes some resource efficiency and SCP actions. However, given the limited focus on resource efficiency and SCP, the five-year economic development plans are not in themselves resource efficiency policies. This finding is much the same for many other nations in the study region, where national economic development plans have recognition of resource efficiency but limited programmes and engagement compared the primary goals of economic development.

The indicators data in this report can inform existing policy in the Lao PDR. The NSED objectives, and future resource efficiency policy, will need formulation. The indicators data can inform the design of the economic master plan to ensure that the pathway to economic development does not prejudice future economic sustainability. As noted by the World Bank (2010), the Lao PDR is rich in natural resources but does not need to develop all of them to become a middle income country.

Most importantly, indicator data in this report can generate awareness of the problem of resource efficiency and recognition of the need for action. The use of information can motivate a range of other actors in the policy community to recognize the importance of policy for resource efficiency. Further, the problem framing that the Lao PDR government uses will inform the policy response. For example, resource efficiency in biomass use can be interpreted as a problem for rural economic sustainability, and related to maintenance of cultural integrity.

### **Viet Nam: Policy implementation**

Viet Nam officially achieved middle income country status in 2010 (United Nations, 2010). This follows from economic restructuring undertaken in the 1980s (Doi Moi) and significant economic growth in recent decades (World Bank, 2015). Rapid industrialization and a shift towards industry and services has been the economic development path, with large environmental consequences (Dore et al., 2008).

Viet Nam has a number of active policies that relate to resource efficiency. Viet Nam has a National Strategy for Green Growth, a National Strategy for Environmental Protection, and a National Strategy for Sustainable Development. Viet Nam also has a draft National Action Plan for SCP which includes resource efficiency, but this action plan is yet to be implemented. In this sense, the policy is at the stage of implementation, whereby the problem and policy framing have already been undertaken.

The implementation of a national action plan for SCP is yet to occur. The approval for implementation is held up in policy processes elsewhere, including the agreement on the measurement framework and the participation of multiple government departments.

The indicators provided in this report can be used for policymaking in Viet Nam in several possible ways. Firstly, indicators contained here can inform the progress of the existing policies with resource efficiency aspects.

Recent trends of increased resource efficiency predate many of the policies for Viet Nam but additional indicator data here may provide valuable progress monitoring for aspects of these policies. For example, energy efficiency policy under the National Strategy for Green Growth can be monitored and progress checked. Secondly, indicators from this report can be used to progress implementation of the draft SCP action plan. The recognition of resource efficiency at an international, regional and country level raises the profile of the policy problem. The increased awareness of the necessity of a policy response can create the necessary impetus for cooperation with other agencies to finalize and approve the policy. Agencies beyond the environment administration may use the indicator information here to demonstrate the environmental, economic and social logic of policy action.

Thirdly, the indicators in this report can lower the cost of policy implementation in Viet Nam. Viet Nam has developed a set of indicators as a measurement framework for the draft SCP action plan. There remains a discrete piece of analysis to cross check the indicators contained in this report with those developed in Viet Nam. The potential to lower costs comes from reducing the required indicator analysis and reporting to be undertaken by already stretched Vietnamese government resources.

### **Japan: Policy evaluation**

Japan is one of the most highly developed industrialized countries in the region. It has a GDP over USD 4 trillion and a population of 127 million. Japan has one of the most advanced policies for resource efficiency: the sound material cycle society policy (2003). This long-standing policy has mainstreamed many aspects of resource efficiency over its twelve years of operation within the Japanese economy (Moriguchi, 2007). This policy has been implemented in advance of indicators developed here and it has its own measurement framework.

The indicators in this report can assist the monitoring and evaluation of the sound material cycle policy. The long-term data contained within this analysis provide valuable information that has been developed externally to Japan's measurement framework. The rigorous analysis contained here provides an independent verification of the trends that existing measurement frameworks might not detect. The independent verification assists in the regular monitoring of progress, and can inform evaluations of the policy and any improvements to policy function that follow.

Additional policy insights may be gained from the indicators provided in this study. Unexpected and unintended policy outcomes may result from policy action. The existing measurement framework for the sound material cycle policy may not capture these outcomes. The scope of indicators contained in this report may enable unexpected outcomes to be detected.

### **Necessary but prudent use of indicators in policymaking**

Resource efficiency is a problem with regional and global repercussions. However, policy action advocated in this report is very much at a domestic level. The necessary policy levers, such as setting of production standards and economic policy, are located with governments of the countries included in this study.

This chapter has shown that indicators are valuable and necessary at all stages of the policy development process. It has demonstrated this with potential application to resource efficiency policymaking in the Lao PDR, Viet Nam and Japan. It has provided reference points for the other nations included in this study.

Resource efficiency is a regional and global problem, and regional and global coordination is desirable. The use of common indicators is a key enabling measure to ensure that policies and measures are coordinated. A common measurement method can ensure that performance measurement is consistent, that measurement at national level can be equated with regional and global measures, and that policy learning can occur between governments. The Marrakech Process and the UNEP Secretariat have worked to align measures for resource efficiency. This report follows this approach and presents a unified set of resource efficiency indicators for the region.



However, common indicators for every policy are not sufficient to ensure policy effectiveness. Every country has different dimensions to resource efficiency issues and different institutional, cultural and economic landscapes in which policies must be enacted. Indicators used to assess national policy should reflect the nations' characteristics and policy aspects. As has been noted in other contexts, the local determination of performance measures is important for their effectiveness (Jackson, 2005). The range of indicators used in each country and for each policy are likely to differ, and this is a good thing. The SCP handbook identifies criteria for good indicator selection (UNEP, 2012b) and the UNEP Secretariat can continue to assist many developing countries.

Some countries included in this study are developing or have developed their own indicator sets. For example, Viet Nam and Japan have developed or are developing indicator sets that tailored to their economies and preferences. Further research should assess the alignment of indicators in this report with those in development locally, with a view to complementary provision of indicators. This can lower the costs of policy implementation and independently verify performance of policy.

For the study of policy impacts, it is important to note that policy development may not follow a cycle model. For example, Kingdon's (1995) model of policymaking envisages policy streams: problem stream ("what is going on"), policy stream ("what can we do about it") and political stream ("what can we get support for"), in which alignment of all three is necessary to form a policy window for action. The political dimension to policymaking is important but is reduced in the policy cycle model (Colebatch, 2005). Indeed it is a common hallmark of environmental policy that political context is ignored in policy development, at much cost to the policy (Hollander and Curran, 2001). The political context of resource efficiency policymaking should not be ignored and further research should be conducted into models of policymaking in Asian nations. This may yield alternative models in which policymaking can be conceptualized and understood.

However, regardless of the policy model used, indicators are a necessary feature of policymaking. For example, in Kingdon's (1995) policy streams model, indicators are necessary in all of the streams identified and will promote the alignment of streams to create a future window of policymaking opportunity. Regardless of the policy model used, indicators are necessary to inform policymaking for resource efficiency.

Resource efficiency is important, more so, because it is a global problem that may too easily and consequentially be ignored. The incremental use of resources by society occurs in disaggregated fashion and the recognition of the problem may not occur at the individual actor, sector or government level. The consequences of not addressing resource efficiency are large for environmental, social and economic costs. Policy responses to resource efficiency are needed and the indicators provided here are an important mechanism for recognizing resource efficiency as a problem and setting an agenda for policymaking.

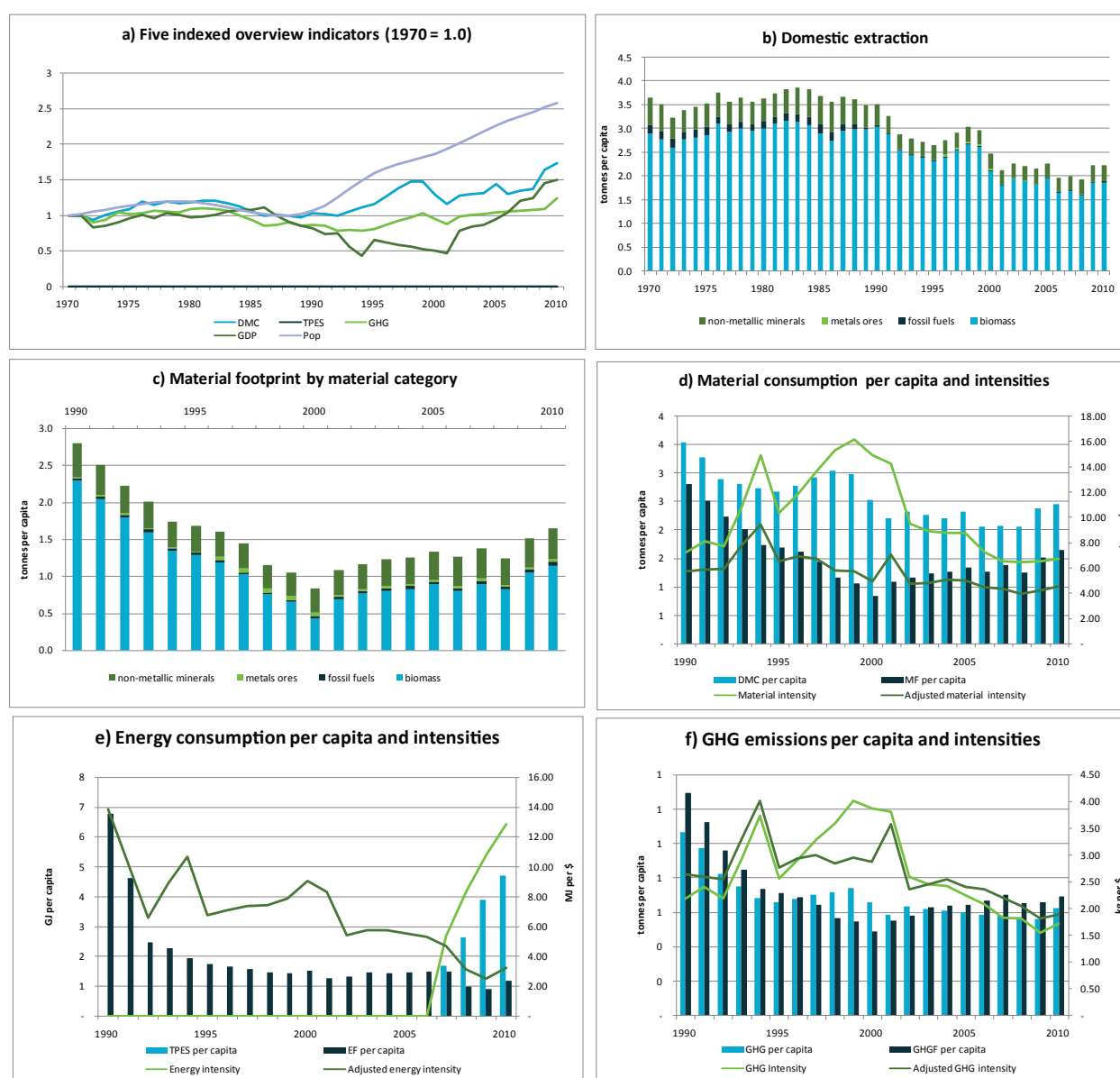
# Country profiles

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Progress in decoupling human well-being from natural resource use and emissions has varied in Asian developing countries. The new data set allows countries to monitor their progress in decoupling economic growth from resource use and environmental impact

## Afghanistan

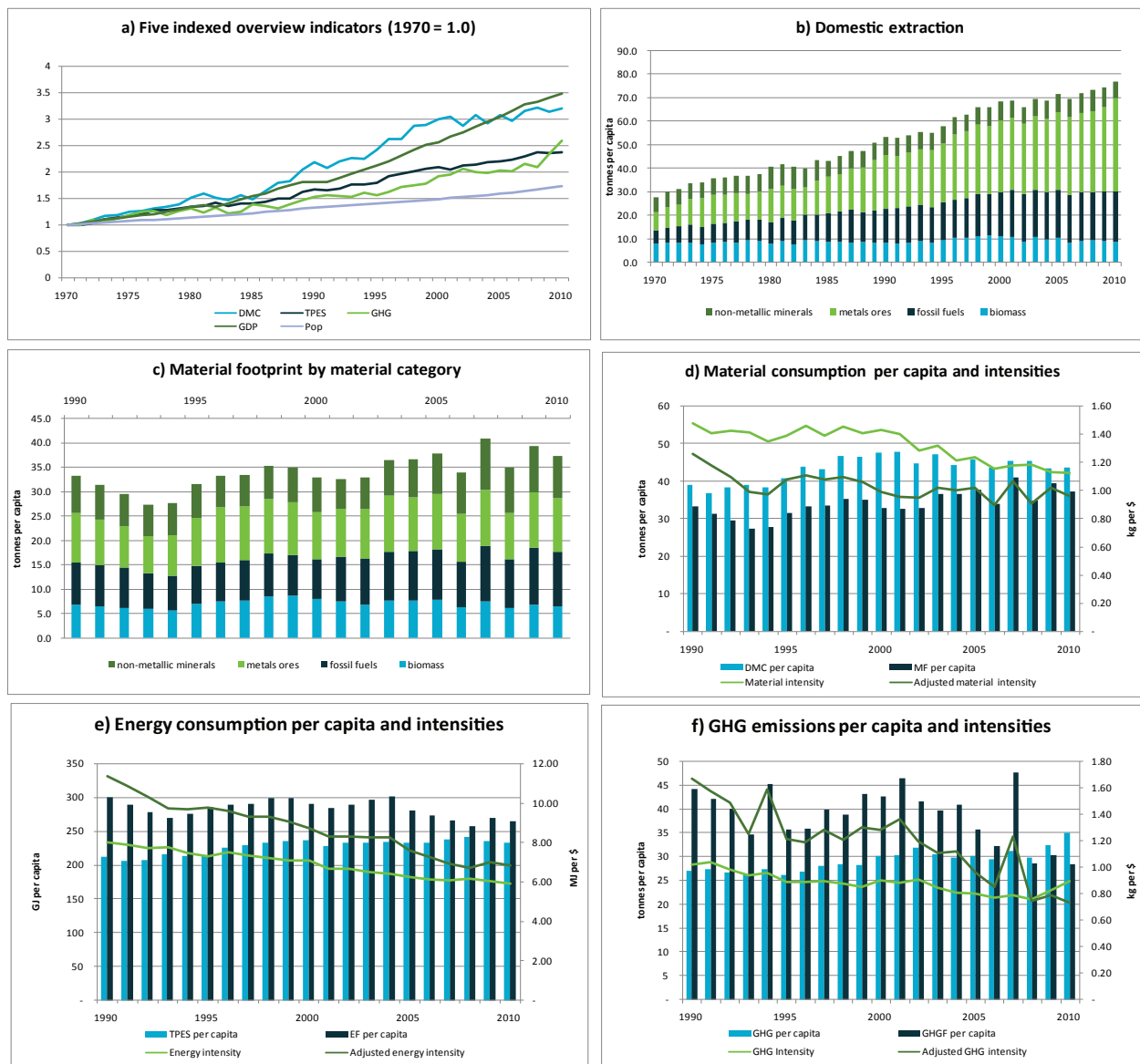
Figure 99 Summary panel: Afghanistan



In panel a) we can see that growth in Afghanistan's population growth has far outpaced growth in the other overview indicators (no TPES value was available for 1970 therefore no indexed value possible). GDP actually contracted until 2000, so we would expect increasing material intensities for most of the period 1970 to 2010, with no decoupling of growth from DMC. The trajectory of DE per capita in panel b) indicates that unless imports increased markedly, fewer resources were being used per capita off an already very low base. Panel c) confirms the pattern of decreasing total resources use per capita until the year 2000, with a rebound from that point but to levels far below those seen in 1990. The dominance of the biomass category in both panels b) and c) are what we expect of nations which are at a very early stage of industrialization. Panels d) and f) confirm the trends for materials and GHG intensities, and per capita, that we would expect from panel a) i.e. all intensities increased while consumption per capita decreased through to roughly the year 2000. The adjusted intensities, in contrast, do not increase significantly during the early period, and decline overall, while both MF and GHGF per capita decrease rapidly, suggesting an even more rapid decline in material standards of living for 1990 to 2000 than indicated DMC and GHG per capita. A similar but even stronger decline in EF per capita is clear in panel e).

## Australia

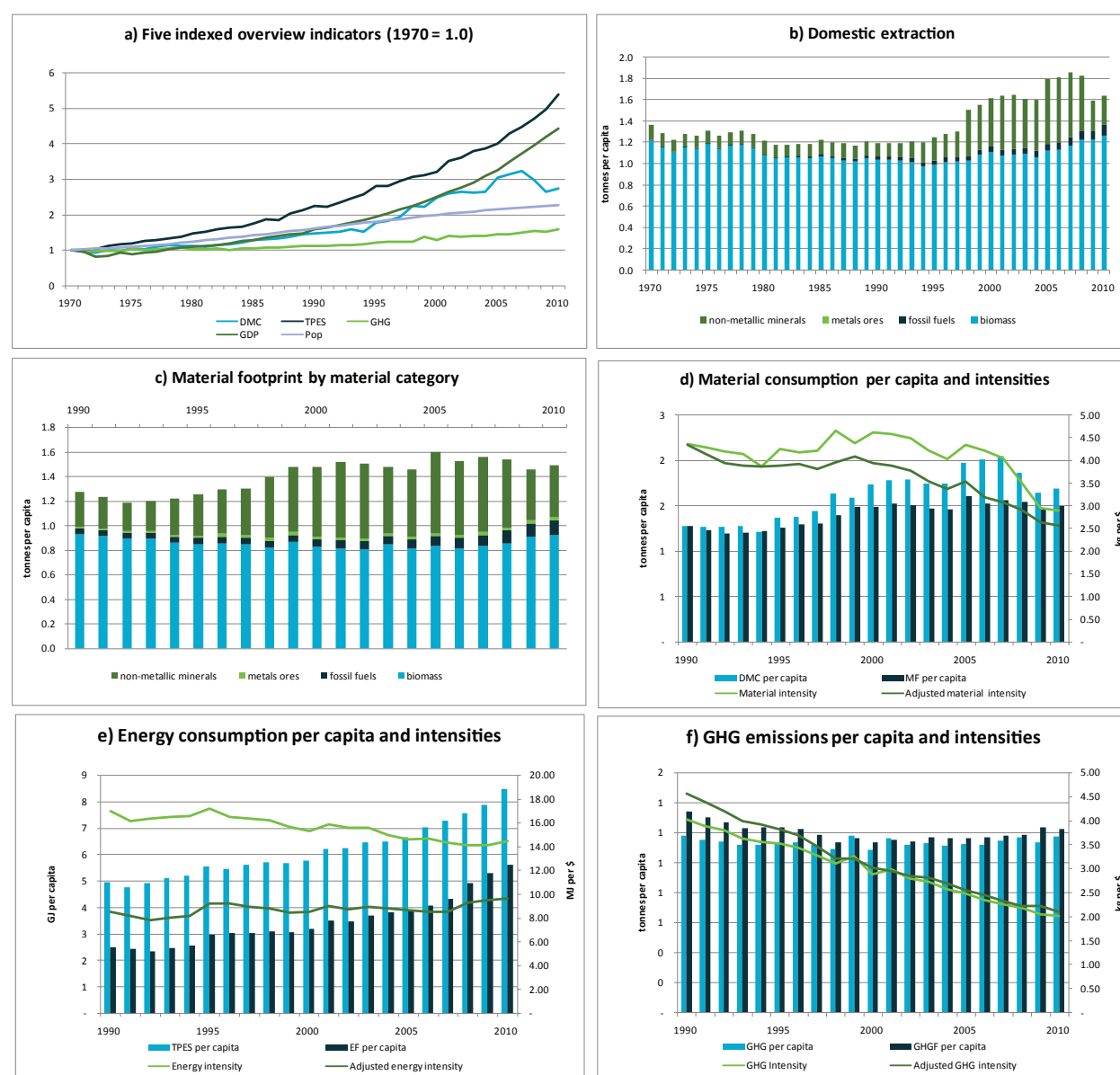
Figure 100 Summary panel: Australia



In panel a) we can see that Australia's GDP has grown roughly in line with DMC, and that both grew considerably faster than the other three overview indicators, so we would expect roughly static material intensities and improving decreasing energy intensity, with relative decoupling of growth from TPES (but not DMC), while the continued growth in total TPES make clear that there has been no absolute decoupling at all. The trajectory of DE in panel b) mirrors closely that for both DMC and GDP, suggesting that both are closely coupled to DE and so also to the local environmental impacts that extractive activities entail. Panel c) shows that Australia's MF is much less than suggested by its extremely high DE, and that much DE ends up embodied in exports for consumption elsewhere. Nonetheless, MF per capita is still very high compared to most countries. Panels d), e) and f) confirm the trends for material, energy, and GHG intensities, and per capita, that we would expect from panel a), however in panels e) and f) we see that the footprinting based measures yield higher intensities and per capita usage of energy and emissions of GHGs than indicated by conventional TPES and GHG measures, i.e. in these categories conventional measure underestimate Australia's requirements for domestic consumption. This contrasts to materials measures, where conventional DMC based measures overestimate Australia's consumption of materials.

## Bangladesh

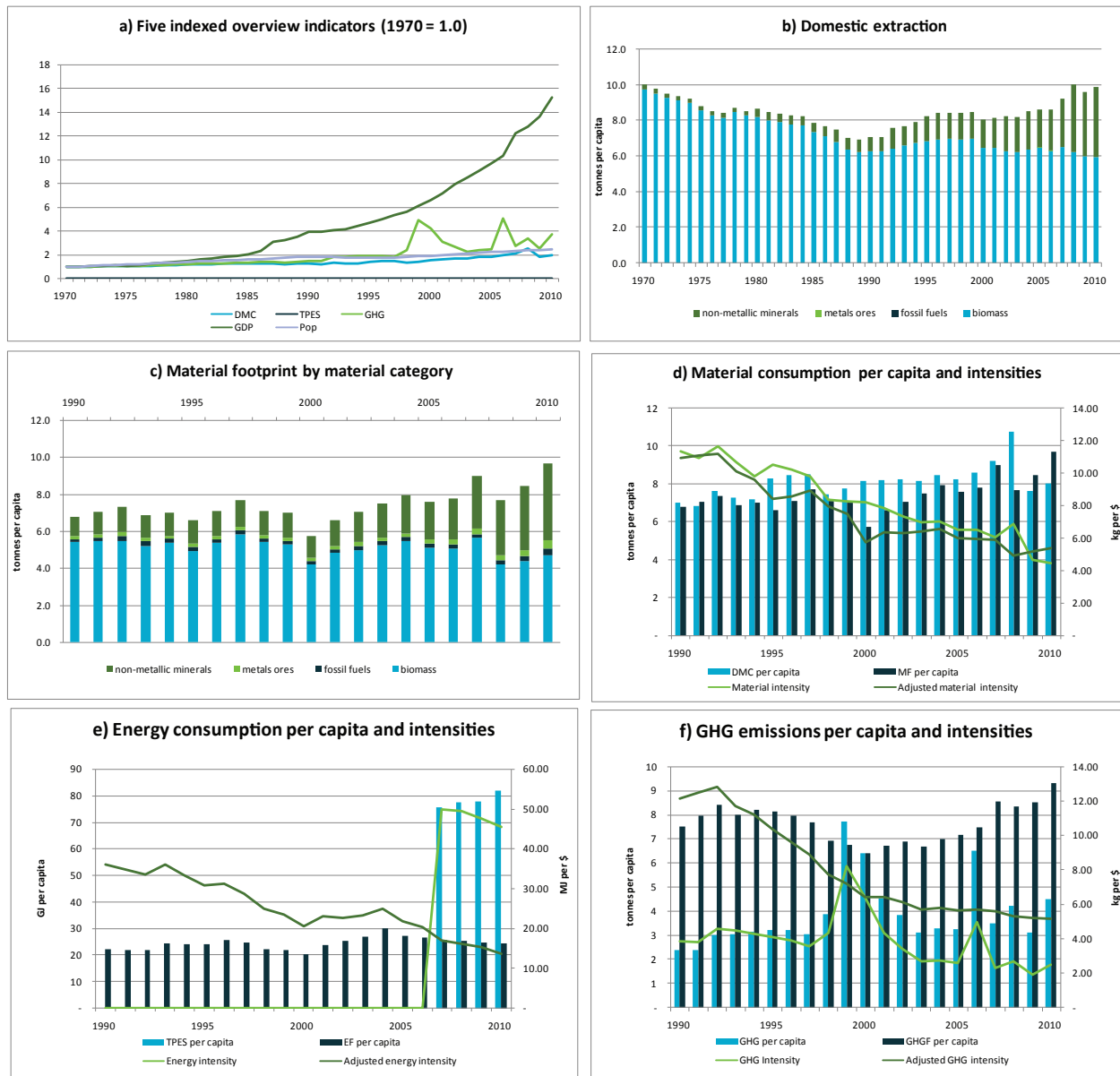
Figure 101 Summary panel: Bangladesh



In panel a) we can see that Bangladesh's TPES grew the fastest of the overview indicators, followed by GDP then DMC. This indicates that energy intensity increased, while material intensity decreased. Interestingly, even though TPES grew rapidly, the slowest growth was in GHGs. This indicates that either GHGs in Bangladesh are dominated by sources other than energy production, or that the change in energy sources has been towards lower GHG emissions intensities. Comparing trajectory of DE in panel b) with GDP in a), it appears that the doubling of GDP from 1970 to 1995 required little in the way of increased DE, however from 1995 on economic growth appears to have required increasing inputs from the domestic environment, notably of non-metallic minerals, presumably for construction. The MF data in panel c) further confirms a fairly rapid increase in Bangladesh's material requirements from around 1995, which plateaus within a decade, with a subsequent decrease in non-metallic minerals but continued growth in fossil fuels. Panels d), e) and f) show that all intensities decreased or remained relatively static over the period 1990 to 2010, so the deterioration in energy efficiency we would expect from panel a) was restricted to the earlier 1970 to 1990 period. Improvements in GHG intensities have been particularly strong and consistent for the 1990 to 2010 period. The large gap between energy consumption when measures on a TPES of EF basis noteworthy in panel e), with TPES estimates higher than EF by around 50% to 100%.

## Bhutan

Figure 102 Summary panel: Bhutan

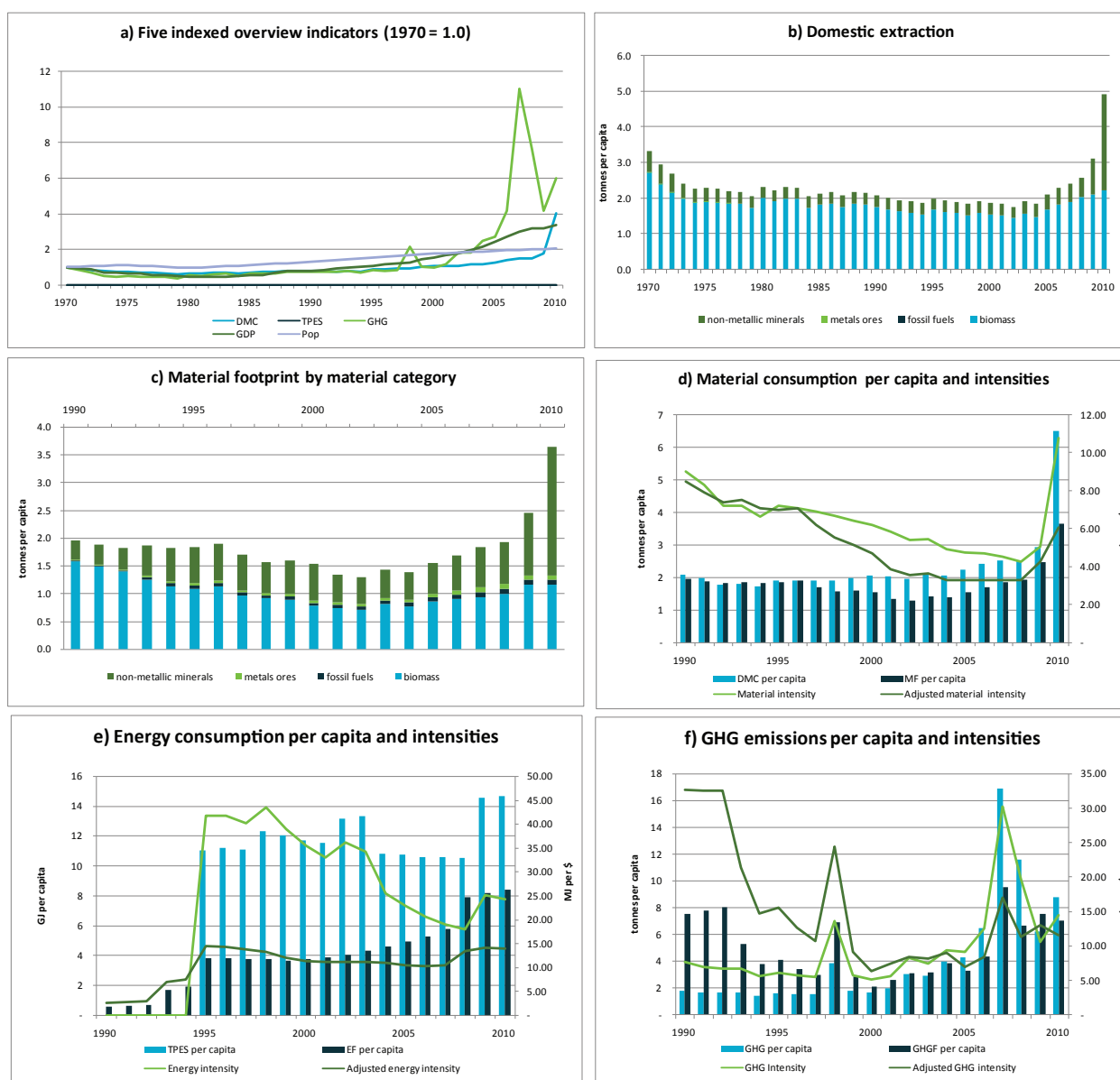


In panel a) we can see that Bhutan's GDP grew much faster than the three other overview indicators (no TPES value was available for 1970 therefore no indexed value possible). Growth in DMC appears to have been quite slow, taking 40 years to double, however this slow growth in DMC is not echoed by the trajectory of DE per capita in panel b). DE first decreased then recovered gradually over the same period, indicating that the rapid economic growth required no gross increase in DE. The recovery in DE was, however, totally dominated by extraction in non-metallic minerals. Panel c) also indicates that rapid economic growth has not been accompanied by anything like a proportional increase in MF per capita, although the shares of different materials has changed markedly, with an increase in non-metallic minerals again prominent. As increases in population over the corresponding period (1990 to 2010) were also modest, this restrained growth in MF per capita implies major decreases in MI and adjusted MI, which is confirmed in panel d). Panel e) shows a strong and consistent improvement in adjusted EI for 1990 to 2010, with panel f) showing an improvement in GHG intensity (GHGI) and a very strong improvement in adjusted GHGI.



## Cambodia

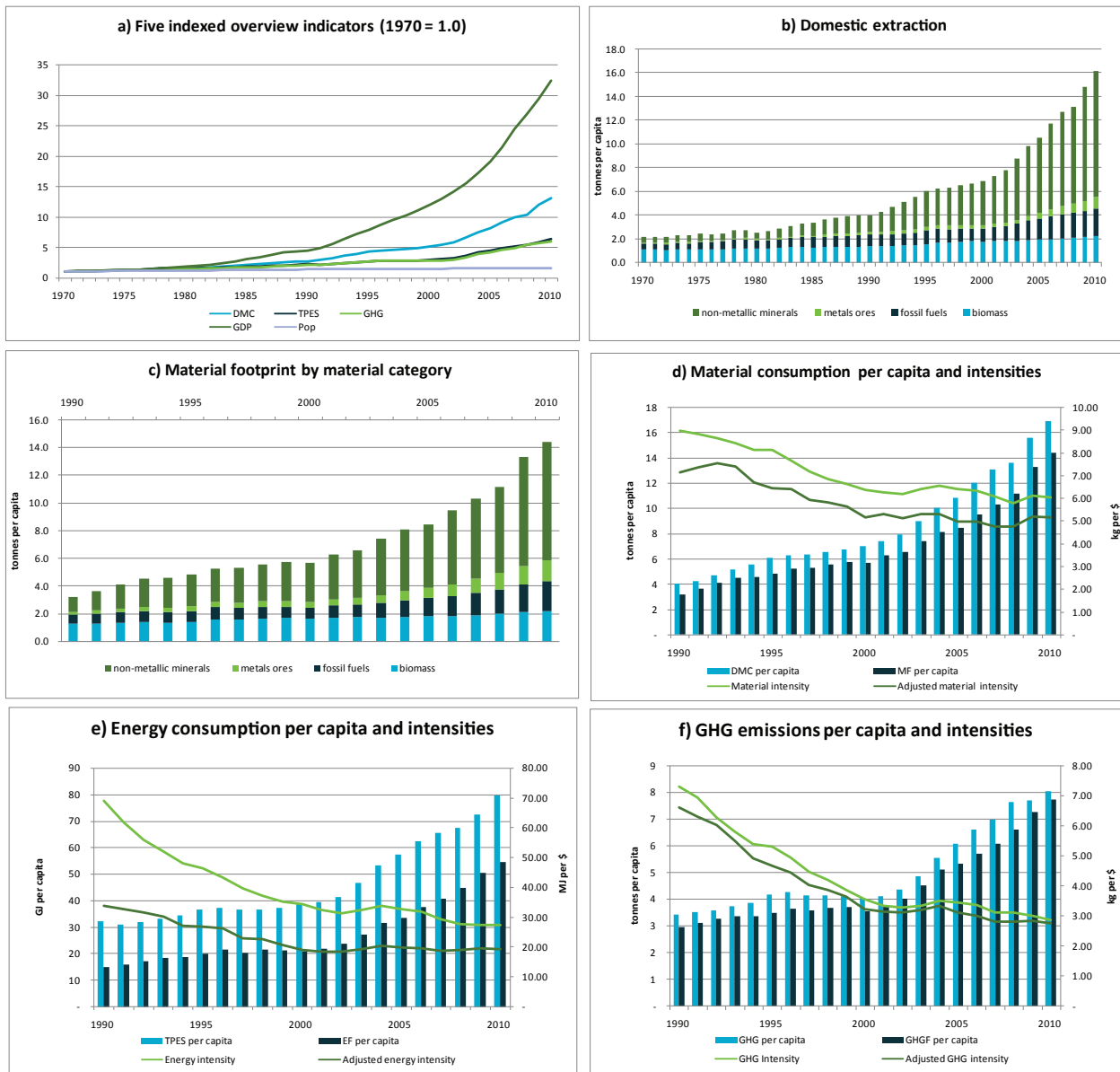
Figure 103 Summary panel: Cambodia



In panel a) we can see that growth in Cambodia's GHG emissions grew faster than the other overview indicators (no TPES value was available for 1970 therefore no indexed value possible), followed by GDP for most of the period, with a late spike in DMC. Cambodia's DE, in panel b), was long dominated by biomass, however non-metallic minerals grow very rapidly in the final years and become dominant by 2010, and account for the rapid increase in DMC described for panel a). A similar trajectory for the growth in the importance of non-metallic minerals is apparent in the MF shown in panel c), however on MF measures there was a major and sustained decrease in biomass used per capita between 1990 and 2002 which further emphasized the growth in non-metallic minerals. In panel d) we see Cambodia becoming less materials intense for the majority of the period 1990 to 2010, with this trend reversing rapidly from 2008 for both MF and DMC based measures. In panel e) we see that footprint based measures tend to estimate much lower energy intensities and per capita usage than TPES based indicators, while the reverse is true for GHGs in panel f), at least for the first decade (1990 to 2000), after which there is no consistent pattern.

## China

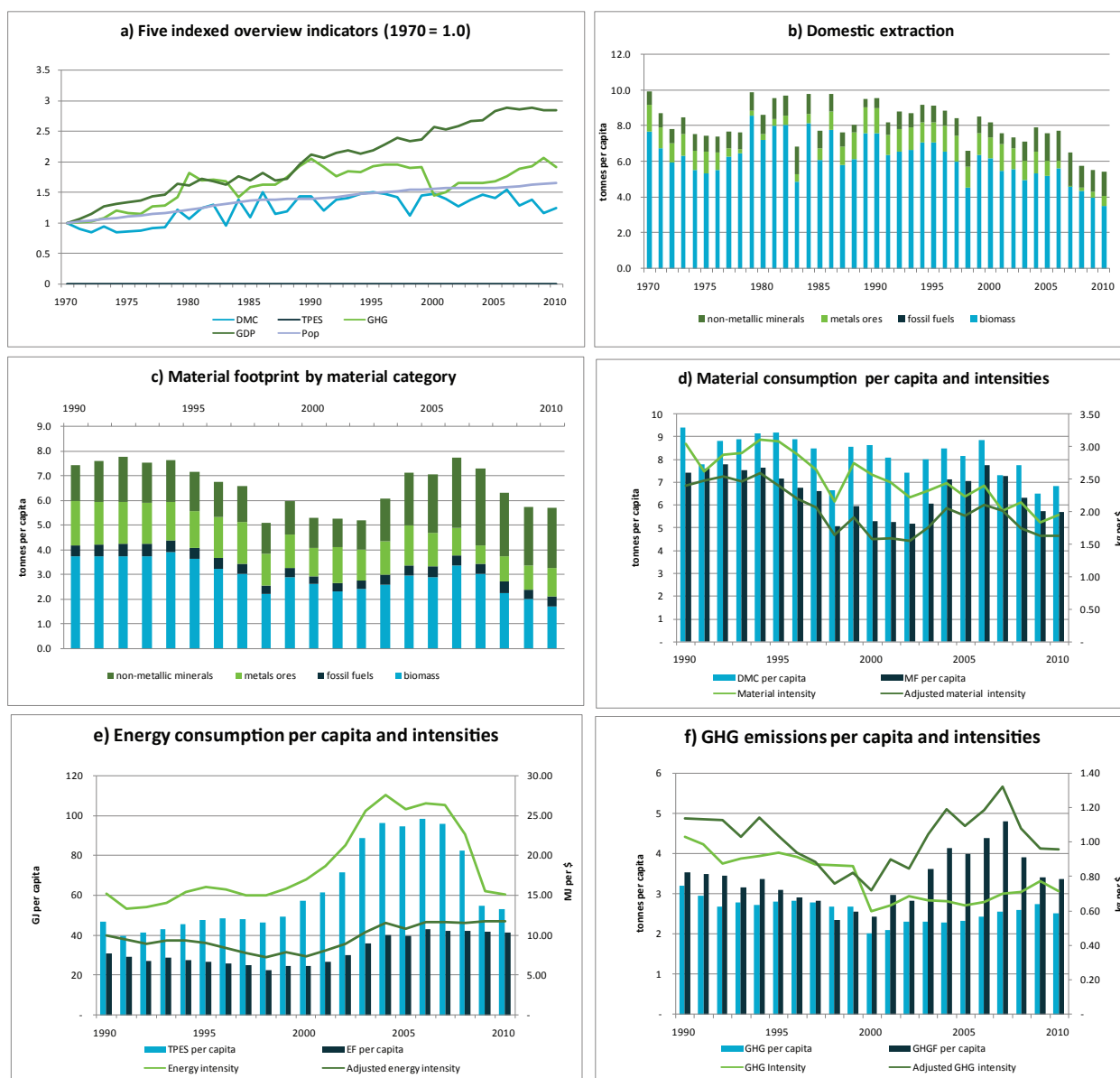
Figure 104 Summary panel: China



In panel a) we can see that growth in China's GDP has far outpaced growth in the other four overview indicators, so we would expect rapidly decreasing material and energy intensity, with relative decoupling of growth from DMC, although the rapid growth in both total DMC and TPES make clear that there is no sign of absolute decoupling at all. The trajectory of DE in panel b) makes clear the extent to which China's local extraction of materials has escalated to meet the requirements of its rapidly growing economy. While we know China to be a major importer of raw materials, panel c) shows that its total material footprint is less than DE by itself, although the relative shares of different material categories changes somewhat. Panels d), e) and f) confirm the trends for material, energy, and GHG intensities, and per capita, that we would expect from panel a) i.e. all intensities are decreased rapidly while consumption per capita nonetheless continued to increase for all. An aspect that was not clear from panel a) is the degree to which early, rapid improvements in intensities have plateaued since the year 2000, indicating that even relative decoupling is no longer occurring, while per capita consumption continues apace. The footprint based measures in panels d), e), and f) also agree well with the more conventional indicators, but are consistently lower, indicating that the traditional measures tend to overstate Chinese consumption of resources.

## Fiji

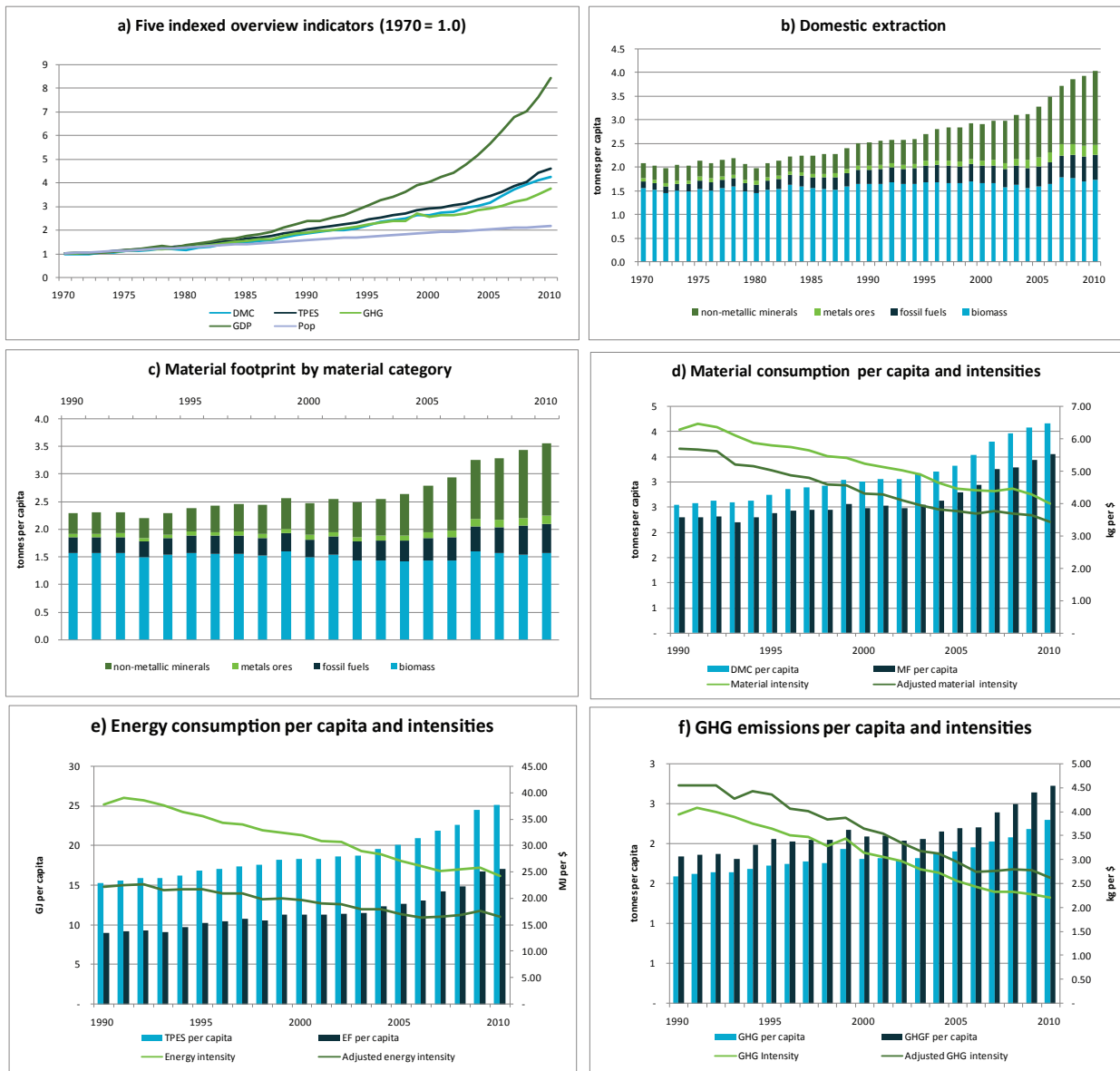
Figure 105 Summary panel: Fiji



Panel a) shows Fiji's GDP growing faster than overview indicators, followed by GHG emissions, population, then DMC. DMC appears to have grown very little over the entire period, and to have declined slightly since around the year 2000. This trend is reinforced by the pattern of DE per capita in panel b), with a major decline in metal ores and biomass in recent years compared to the 1990s. The MF trajectory in panel c) broadly echoes the trend seen in panel b), but it appears that Fiji's economy requires slightly higher inputs of primary resources than can be satisfied by DE alone, although per capita MF levels remain quite low. Panels d) and e) show that footprint based measures of materials and energy consumption are lower than traditional DMC and TPES based ones for Fiji, while in panel f) the reverse is generally the case.

## India

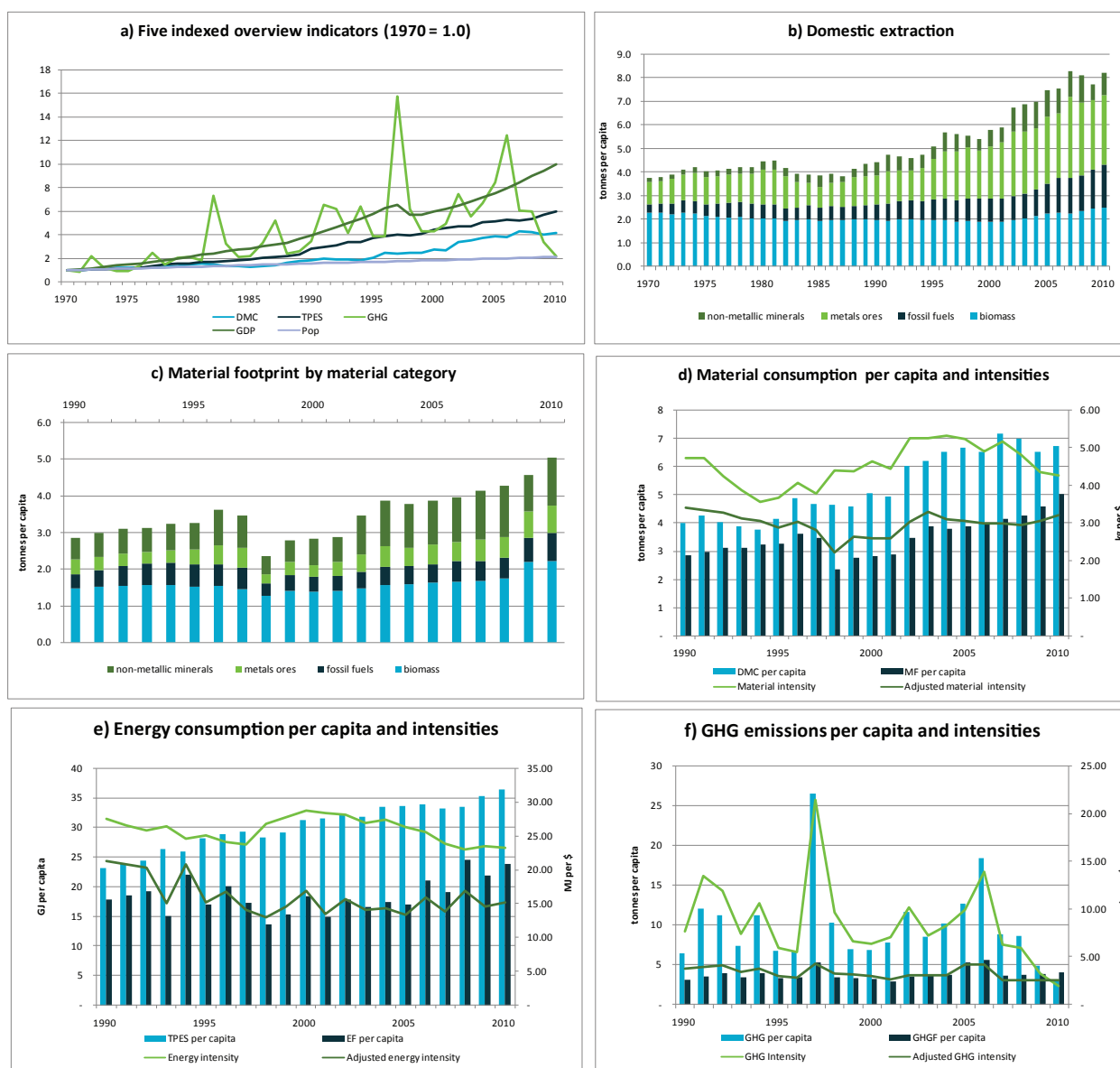
Figure 106 Summary panel: India



In panel a) India's GDP has grown much faster than the other four overview indicators, indicating decreasing material and energy intensity, with relative decoupling of growth from DMC. Continued and rapid growth in both total DMC and TPES show that no absolute decoupling has been achieved. Panel b) shows India's local extraction of non-biomass materials has escalated to meet the requirements of its rapidly growing economy. Panel c) shows India's total material footprint is lower than DE by itself, and so India's quite low level of per capita extraction is nonetheless in part used to satisfy external demand for primary resources, via embodiment in trade. Panels d), e) and f) confirm the trends for material, energy, and GHG intensities, and per capita, that we would expect from panel a) i.e. all intensities are decreasing quite strongly and consistently. Panels d) and e) show that footprint based measures of materials and energy consumption are lower than traditional DMC and TPES based ones for India, while in panel f) the reverse is generally the case.

## Indonesia

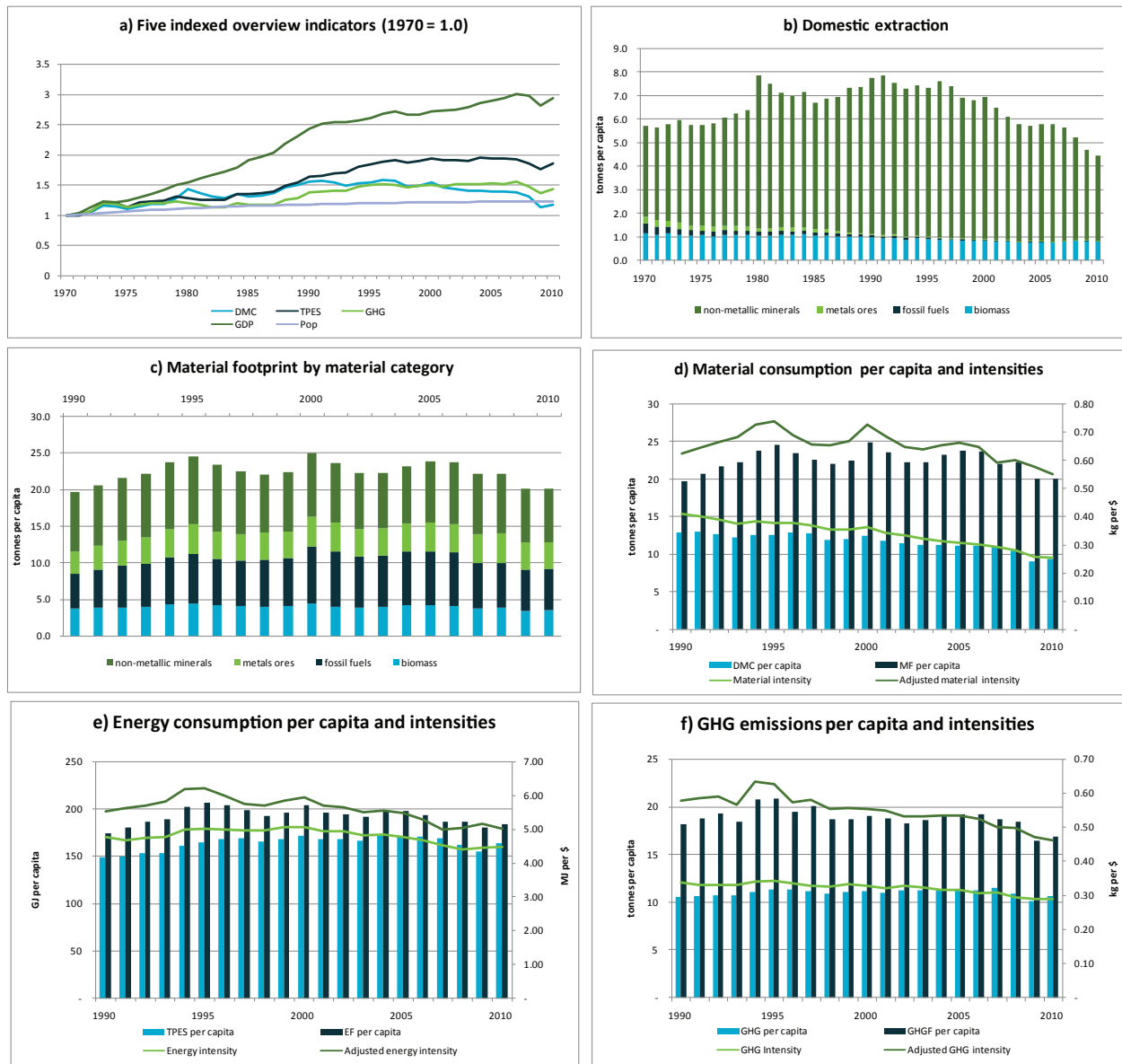
Figure 107 Summary panel: Indonesia



In panel a) Indonesia's GDP has grown considerably faster than the other four overview indicators, with the possible exception of GHGs. The highly erratic year-to-year values for GHGs (a result of large variable components from fires/clearing/land-use change) appear to roughly track GDP until the most recent years. Growth in DE in panel b) is slightly slower than the growth in DMC seen in panel a), indicating a growing dependence on imported primary resources, although DE of fossil fuels grew more rapidly in relative terms. Panel c) shows strong growth in MF derailed by the Asian economic crisis of 1997 and subsequent events in Indonesia, with a relatively strong rebound from 2001 on. Comparing MF to DE indicates that Indonesia's DE is more than that required, in gross terms, to support local primary material requirements. Panels d), e) and f) show roughly static to marginally decreasing intensities for materials, energy, and GHGs on both conventional and footprint based measures. It is also evident in panels d), e) and f) that footprint based measures attribute considerably lower consumption of materials and energy, and emissions of GHGs, to Indonesia than DMC/TPES based measures.

## Japan

Figure 108 Summary panel: Japan

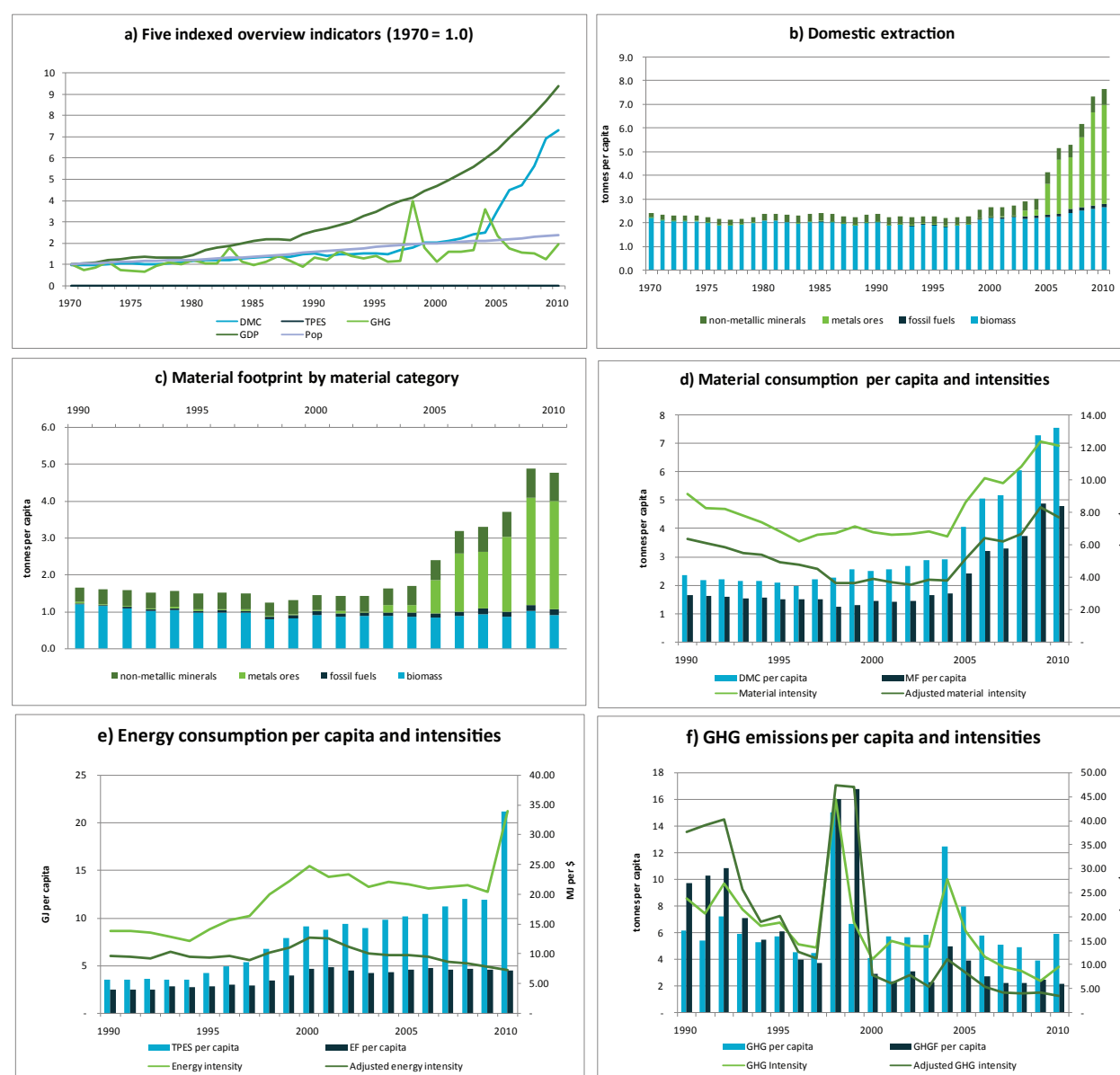


In panel a) Japan's GDP has grown considerably faster than the other four overview indicators, and continues to trend up, whereas all the others have plateaued or begun to decline since the mid-1990s. Panel b) shows that DE has generally been in decline since 1980, and has been almost entirely dominated by non-metallic minerals (for construction) over the whole period. Panel c) shows that MF has remained at 19 to 25 tonnes per capita for the whole period 1990 to 2010, with no clear trend. Comparing panels b) and c) shows that DE accounts for only a small fraction, usually less than 25%, of the resources required to support Japan's level of consumption. The DE to MF gap becomes even more pronounced when considering all categories other than non-metallic minerals, with Japan's DE of metals and fossil fuels accounting for almost none of its requirements. Panels d), and f) show that conventional measures grossly underestimate the material and GHG emissions required to support Japan's level of consumption, while panel e) indicates are smaller but still significant underestimation of energy requirements. Nonetheless, Japan has achieved improvements in all intensities on both conventional and footprint based measures, and so relative decoupling has been achieved in all. Furthermore, Japan's slow population growth and ultimate plateau have led to absolute decoupling since 1990 if we use the DMC metric, which is reflected in panel a).



## Lao PDR

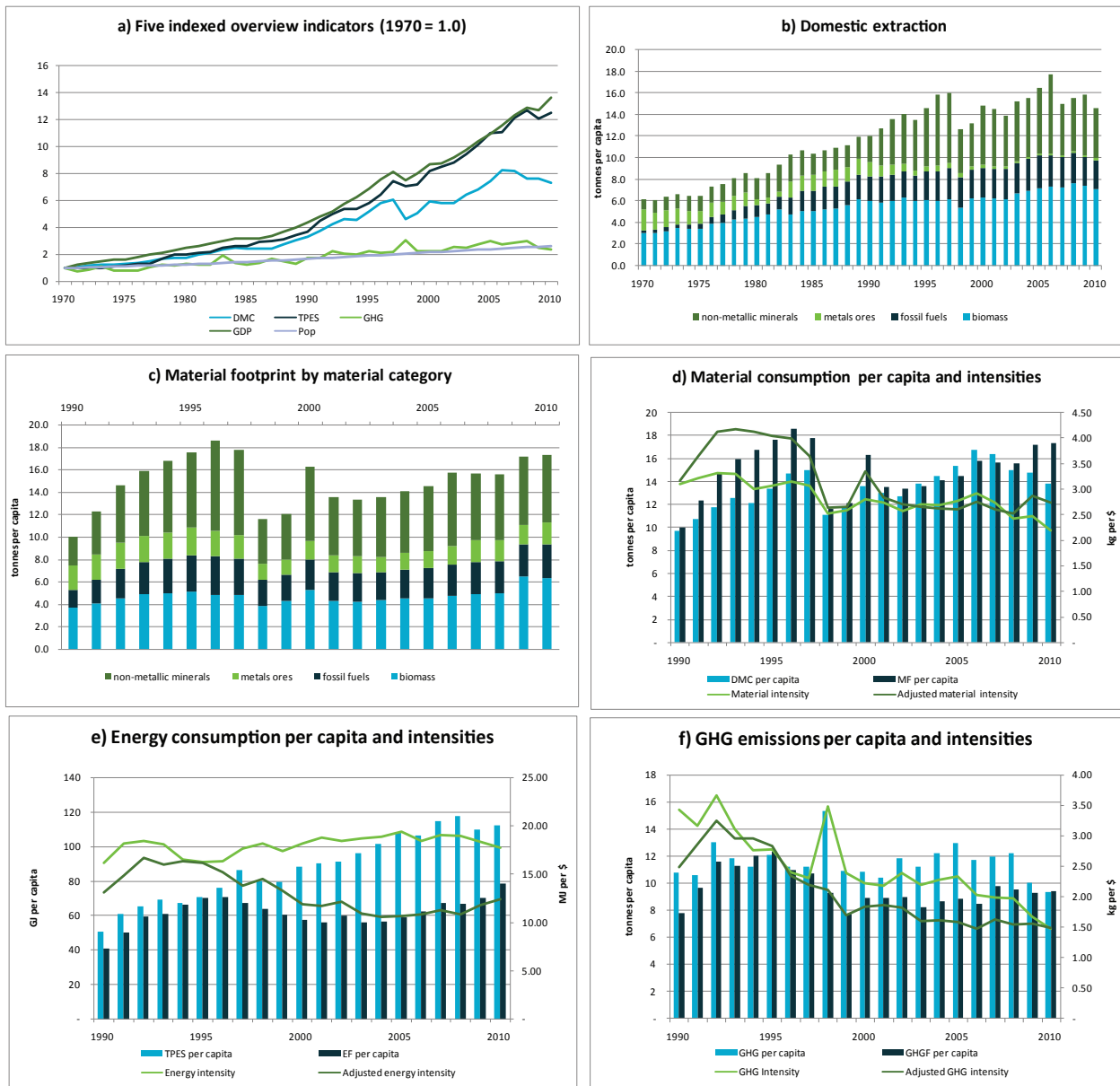
Figure 109 Summary panel: Lao PDR



In panel a) we can see that growth in the Lao PDR's GDP was much faster than the other overview indicators until 2004, when DMC began to grow much more rapidly, followed by population, then GHG emissions (which display intermittent spikes). No TPES value was available for 1970 therefore no indexed value was derived. Growth in DE in panel b) is quite slow until 2003, at which point there is a very large increase in DE of metal ores which quadruples total DE in less than a decade, displacing biomass as the main component of DE. Given Lao PDR's population of 6.4 million in 2010, the total increase in DE from metal ores is less than 30 million tonnes, which could be accounted for by a very few (or even one) major metallic mine commencing operation. Panel c) indicates that the MF of Lao society is much less than would be indicated by DE. Panels d) and e) show MF and EF giving much lower estimates of the material and energy use of Lao society relative to conventional measures. The difference is particularly pronounced when comparing the ongoing increase in TPES per capita since 2000 against the stagnation in EF per capita over the same period. The sharp increase in DMC from 2004 seen in panel a) is reflected in a rapid deterioration (increase) seen from this time for both MI and adjusted MI in panel d). No consistent trend can be identified for GHGs as against GHGF in panel f).

## Malaysia

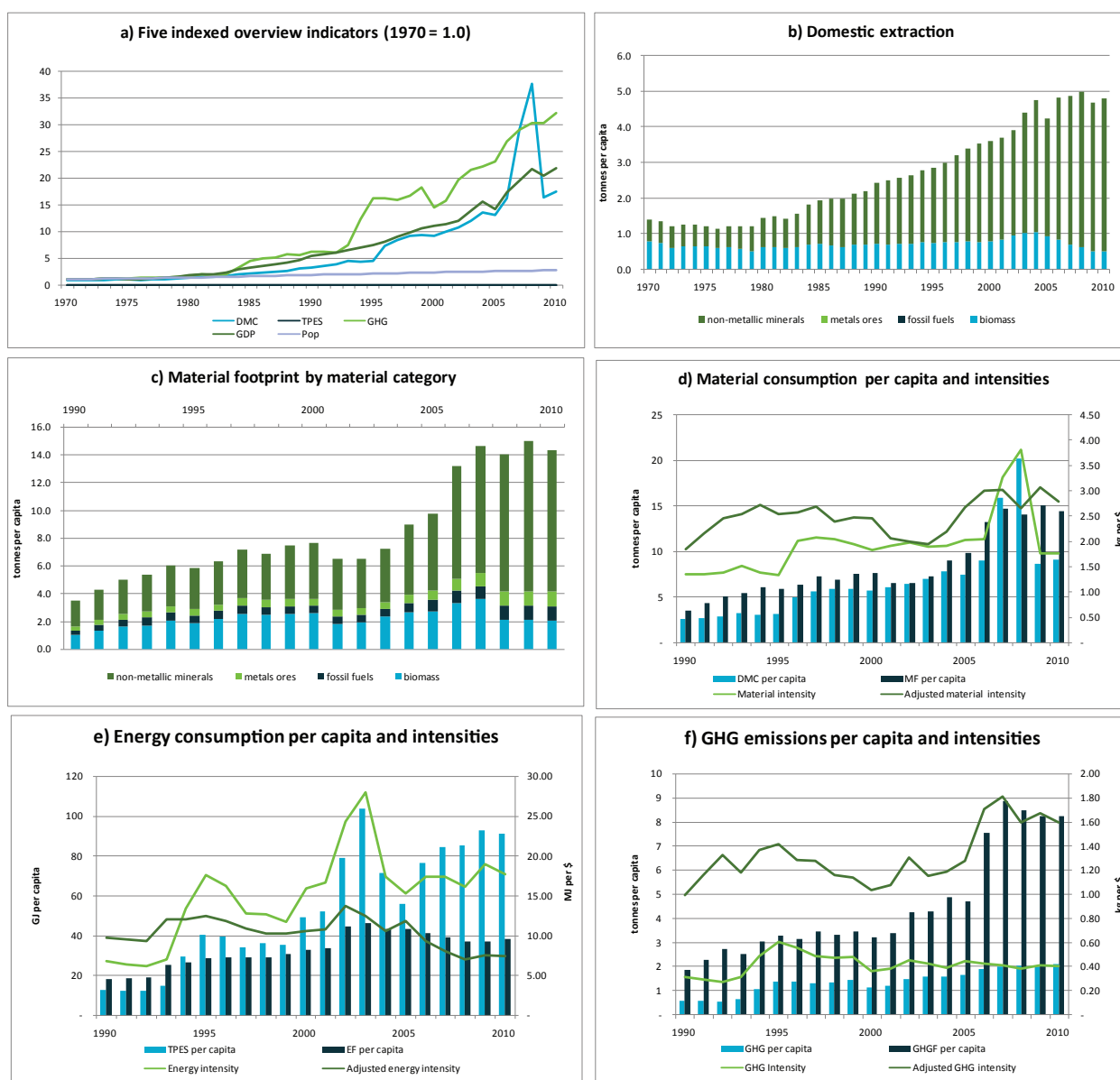
Figure 110 Summary panel: Malaysia



In panel a) very rapid growth in Malaysia's GDP closely parallels growth in TPES, with slower but still rapid growth in DMC, and much slower growth in GHG emissions and population, which parallel each other. Growth in DE in panel b) largely stops from the mid-1990s, with a marked but temporary decrease in the aftermath of the 1997 financial crisis. A decline in metal ores DE which begins around 1990 continues until the end of the period, to the point where DE of metals is negligible. Panel c) shows MF per capita conforming quite closely to the pattern seen for DE per capita, especially with regard to the impact of the 1997 financial crisis and recovery. Gross MF per capita indicates that Malaysia's consumption requires somewhat higher resource inputs than are supplied through DE, this being most pronounced for metal ores. Panels d), e) and f) shows no consistent relationship between footprinting and conventional metrics, with DMC underestimating MI relative to adjusted MI, EI overestimating relative to adjusted EI, and GHGI not having a consistent relationship to adjusted GHGI. Both measures of MI do show some relative decoupling over time, and an even stronger relative decoupling from GHG emissions is displayed for both GHGI measures.

## Maldives

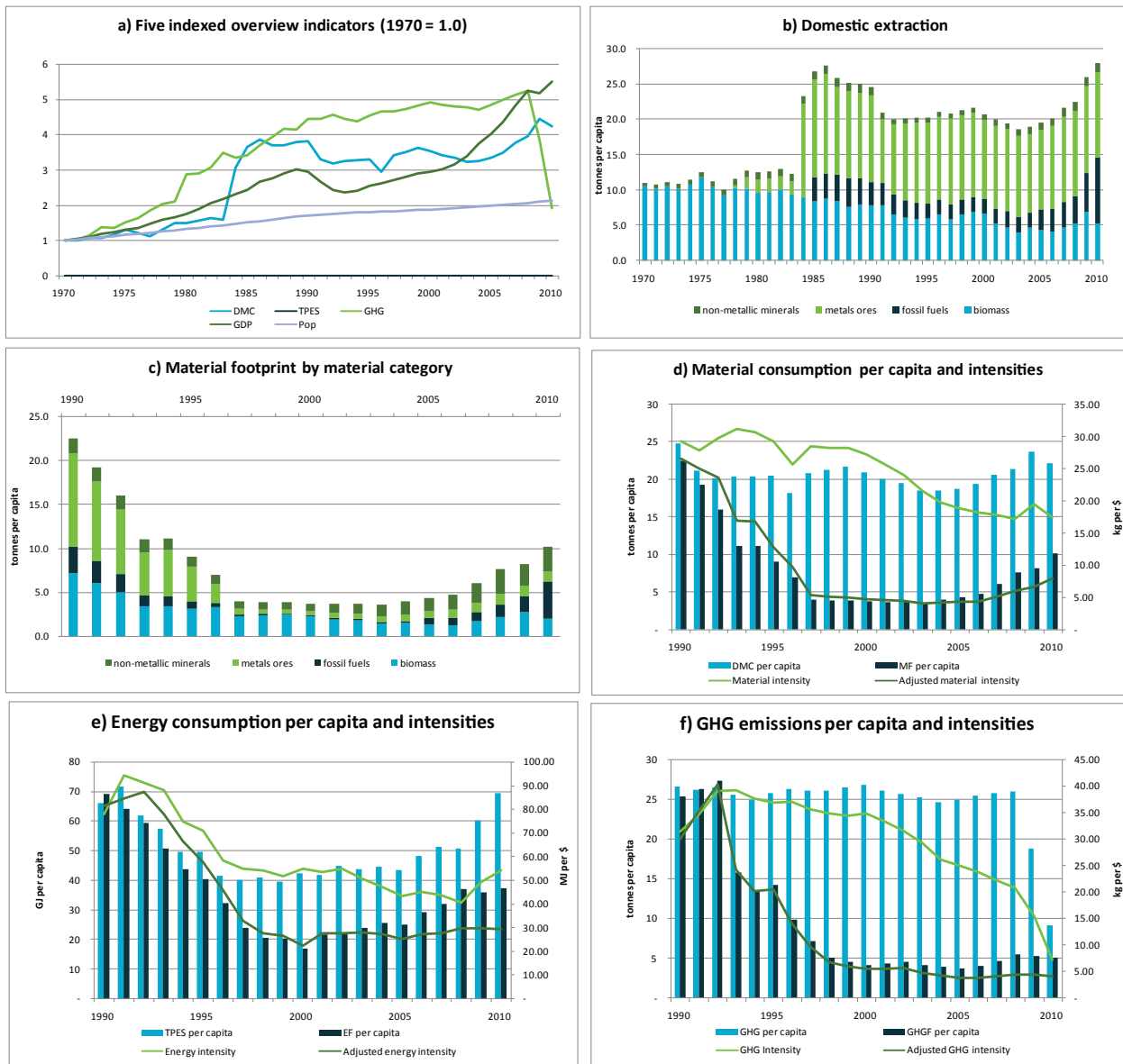
Figure 111 Summary panel: Maldives



In panel a) shows an extraordinarily rapid growth in the Maldives's GHG emissions, which increased over 30-fold. GDP and DMC also grew rapidly and at similar rates, while population increased much more slowly. DE shown in panel b) increases rapidly from 1980 to 2004, then plateaus. The growth in DE was dominated by increases in non-metallic minerals, with a strong decrease in biomass recorded in the later years. From panel c) we see MF per capita is two to three times higher than what is furnished from DE in gross terms, indicating a very strong reliance on primary resources embodied in imports. From panels d), e) and f), the only measure on which there has been even modest relative decoupling is the adjusted EI indicator. All other intensity measures have increased, with the largest relative decrease in efficiency occurring on the adjusted GHGI measure. Per capita consumption of materials more than doubled in the decade beginning in the year 2000.

## Mongolia

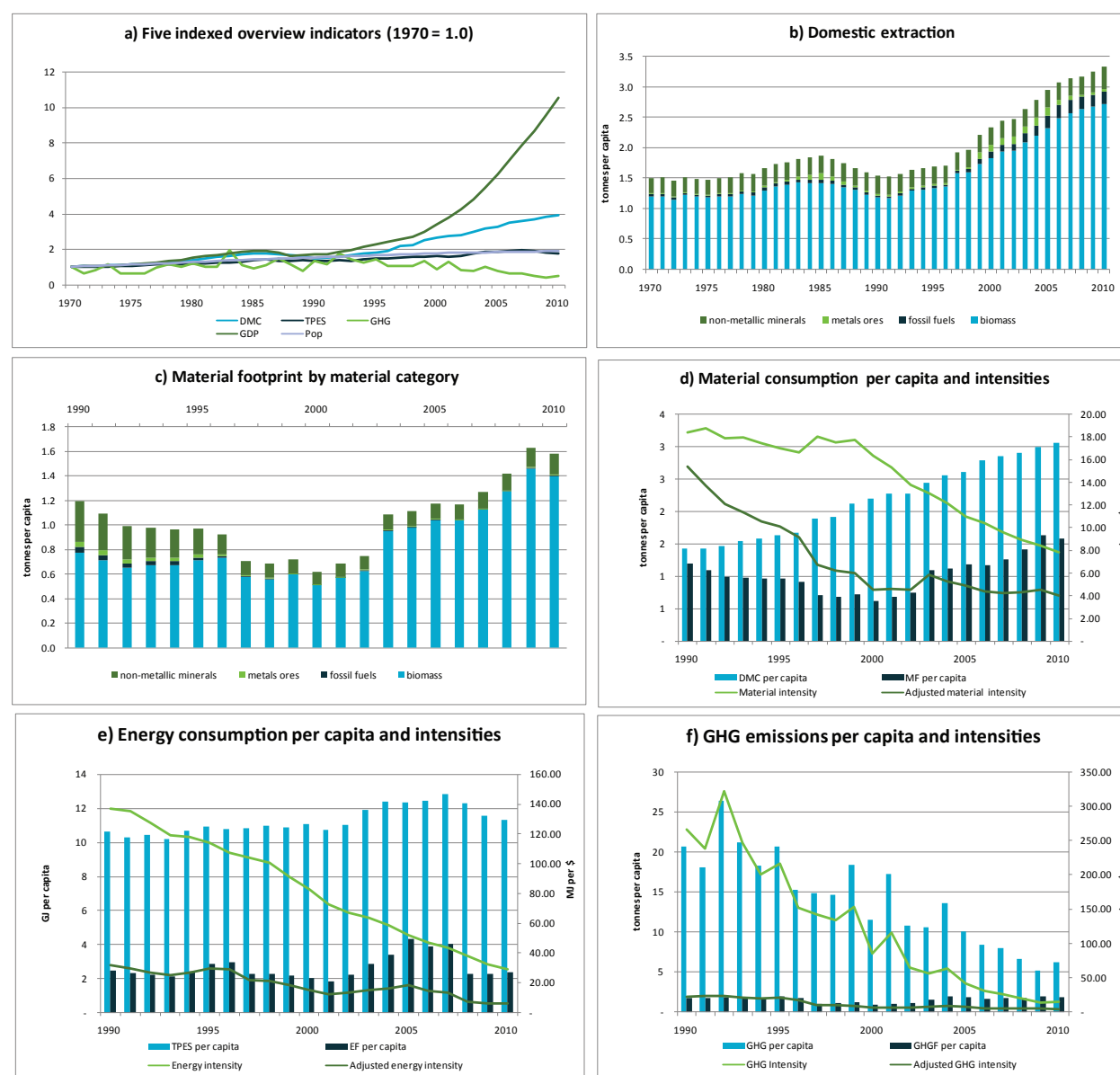
Figure 112 Summary panel: Mongolia



In panel a) the most rapid growth for Mongolia was in GHG emissions and GDP, with most of the increase of GHGs concentrated in the period from 1970 to 1990, while GDP growth was stronger in later years. DMC also grew strongly for a brief period in the 1980s, but then largely levelled off. The trajectory of DMC clearly reflects an abrupt increase in DE of metal ores in 1984 (panel b), followed by commencement of recorded fossil fuel extraction the subsequent year. Renewed growth in DE in the latest years is driven by expanded fossil fuel extraction, while DE per capita of biomass has been in steady decline since 1980. Mongolia's MF per capita, in panel c), began the period 1990 to 2010 much higher than DE in gross terms, but by the end of the period was less than one half DE. This indicates Mongolia has gone from a strong reliance on resources embodied in imports to being a net source of resources to other countries. Panels d), e) and f) indicate that there has been strong relative decoupling of economic growth from each of the six different metrics for material, energy, and GHG intensity. In most cases that decoupling was concentrated in the first decade of the period 1990 to 2010. Footprinting metrics are largely consistent in indicating lower consumption per capita and lower intensities than conventional DMC/TPES/GHG metrics.

## Myanmar

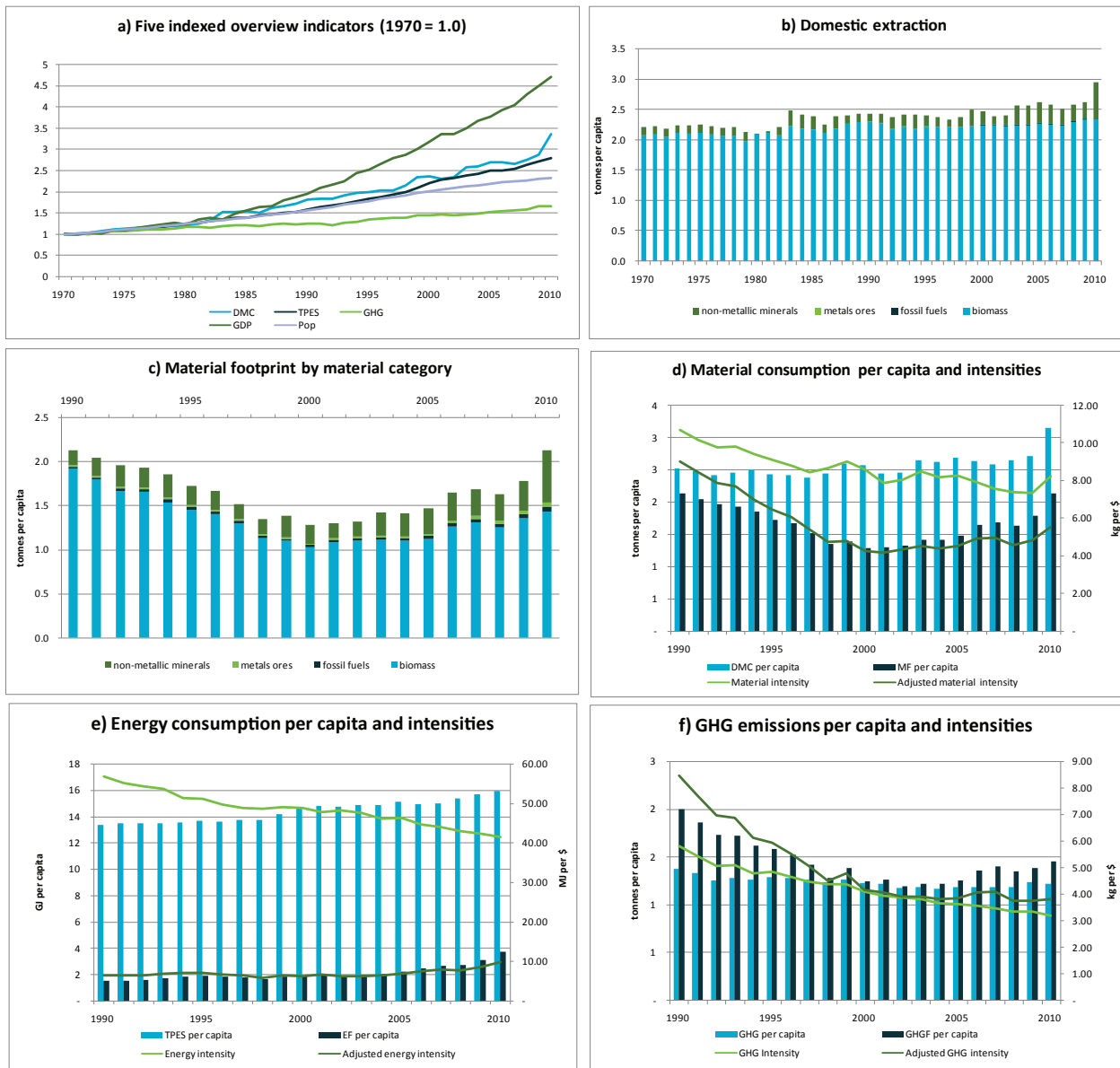
Figure 113 Summary panel: Myanmar



In panel a) Myanmar's GDP grew much faster than any of the other indicators, followed by DMC. A notable feature of panel a) is the decrease in GHG emissions, indication that absolute decoupling of economic growth from GHG emissions was achieved by Myanmar over the period 1970 to 2010. From panel b) it is clear that the very rapid growth in GDP was not accompanied by a proportional increase in DE, while panel c) further indicates that neither was it matched by an increase in per capita MF, with those material categories most usually associated with increasing wealth, fossil fuels, metal ores, and non-metallic minerals all decreasing. This is a very unusual result and raises two points which must be kept in mind when interpreting these summaries. The first is that the measure of GDP used is exchange rate based, and so to some extent can reflect decisions by governments to declare fix exchange rates at arbitrary levels. The second consideration is that the data on materials and energy usage is only as complete as the data furnished by national governments. Taking Myanmar's statistics at face value, panels d), e) and f) indicate moderate to very strong relative decoupling on all MI, EI, and GHGI measures.

## Nepal

Figure 114 Summary panel: Nepal

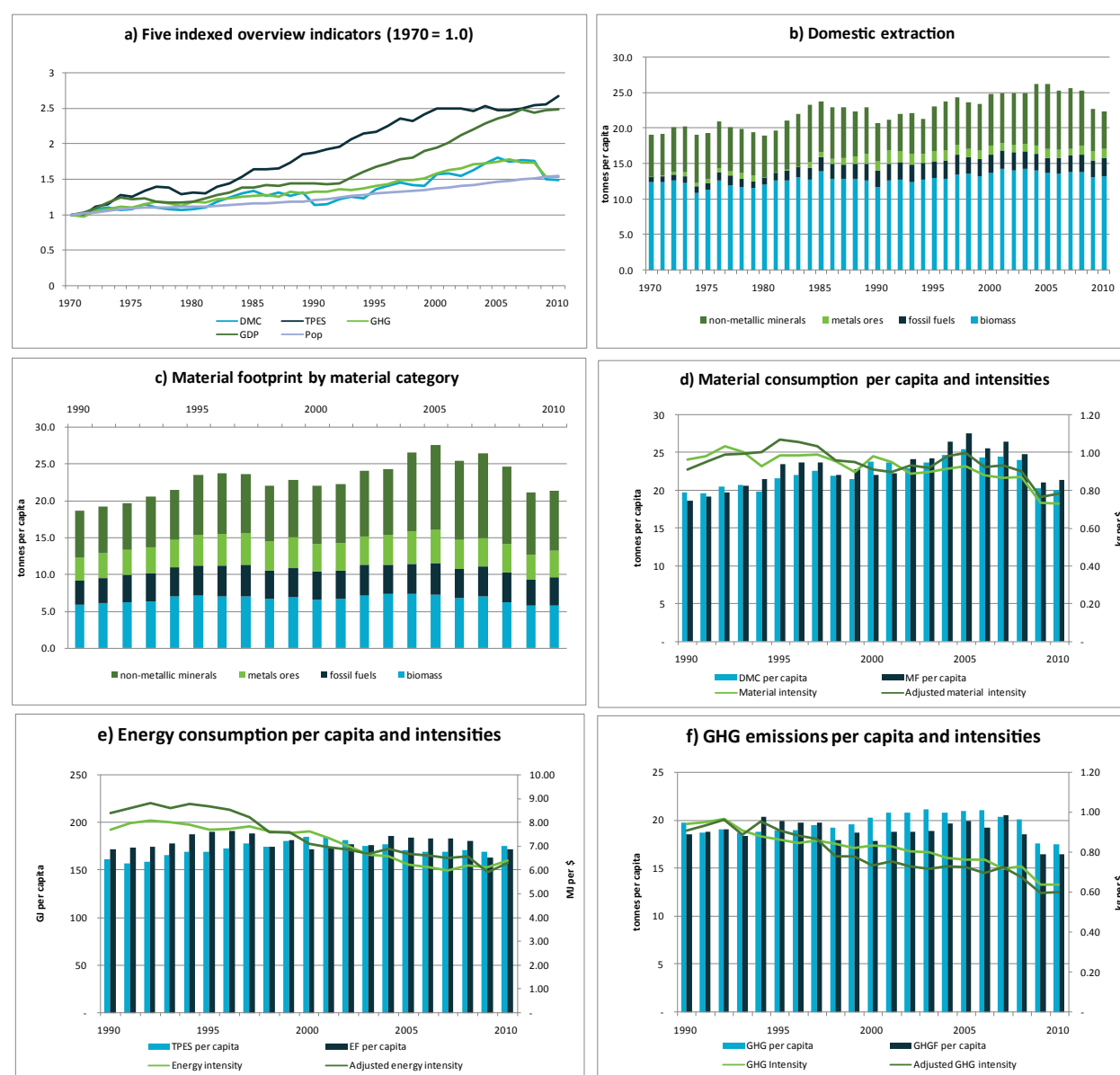


In panel a) Nepal's GDP grew considerably faster than any of the other indicators, followed by DMC and TPES, thence population, with GHG emissions growing at the slowest rate. Panels b) and c) indicate that the strong growth in GDP was not accompanied by much growth in either DE per capita, or MF per capita. The latter actually contracted markedly from 1990 to 2000, before recovering to 1990 levels by 2010. The mix of materials indicated in panel c) was much more strongly oriented towards mineral resources rather than biomass, indicating a significant structural shift towards a more industrialized status. Panels d), e) and f) show decreases in intensities on all material, energy, and GHG based indicators with the exception of adjusted EI. Material and energy consumption per capita increased on both conventional and footprint based measures, while both measures of GHG emissions per capita decreases. Footprint based measures of material consumption are significantly lower than DMC based ones, and footprint based measures of energy consumption are a small fraction (generally less than 25%) of TPES based measures.



## New Zealand

Figure 115 Summary panel: New Zealand



In panel a) New Zealand's GDP grew at roughly the same rate as TPES, with the former growing most in the latter half of the period 1970 to 2010, while TPES grew fastest in the earlier years. Taken over the full period, DMC, GHG emissions, and population grew at the same rate, although this result comes from a rapid drop in DMC and GHGs in the final two to three years of the series. The profile of DE per capita in panel b) is similar to that for DMC, as is that for MF per capita. Comparing panels b) and c) shows DE to be similar in gross magnitude to MF, however the mix of materials in MF has a much lower biomass component. This accords well with New Zealand supporting a high material standard of living by being a major producer and exporter of biomass based products. Panels d), e) and f) show little difference between material and energy consumption, or GHG emissions, regardless of whether footprint based or conventional measures are used. All six measures of intensity decreased, with the strongest relative decoupling seen for GHG emissions. Per capita measures of materials and energy consumption were largely static over time, while GHG emissions per capita declined on both measures.

## Pakistan

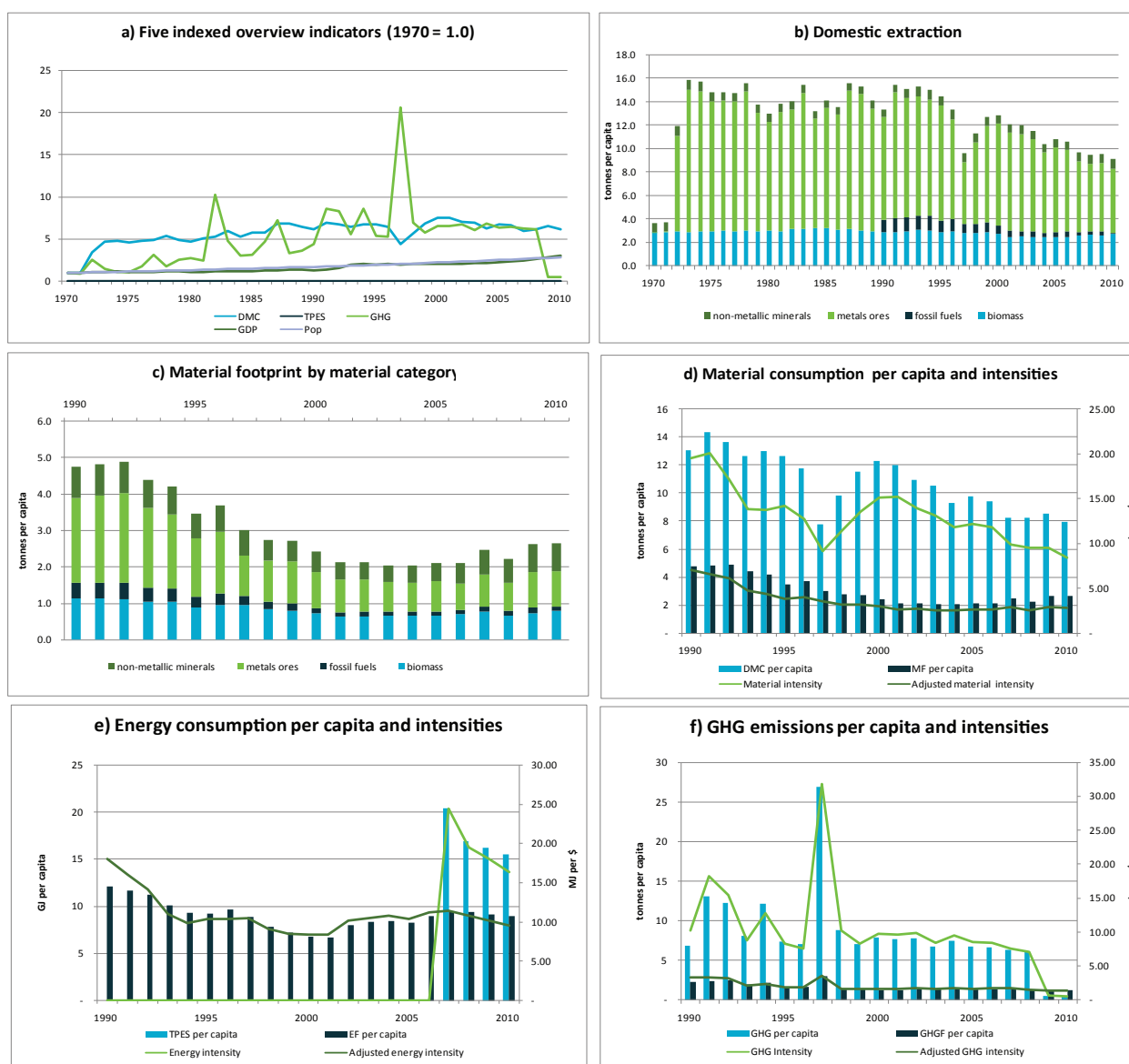
Figure 116 Summary panel: Pakistan



In panel a) Pakistan's GDP grew fastest, followed by TPES. DMC and GHG emission grew in parallel, while population growth was slowest, although population still tripled over the period 1970 to 2010. Panel b) shows modest growth in per capita DE, concentrated in the non-biomass materials categories. Panel c) also indicates little growth in MF per capita over the period. The lower gross level of MF compared to DE is accounted for by a much lower biomass component in MF, with the non-biomass components remaining comparable between DE and MF. Looking back at panel a), the relatively low rate of materials usage per capita has still translated to a fourfold increase in DMC, mainly a result of Pakistan's relatively rapid population growth. Panels d), e) and f) show stable to moderately increasing material and energy consumption, and GHG emissions, per capita regardless of whether footprints or conventional measures are used. All six intensity measures decreased (very slightly in the case of adjusted EI), giving across-the-board relative decoupling. Conventional measures of material and energy consumption overestimate relative to footprint based measures, almost doubling estimates in the case of energy.

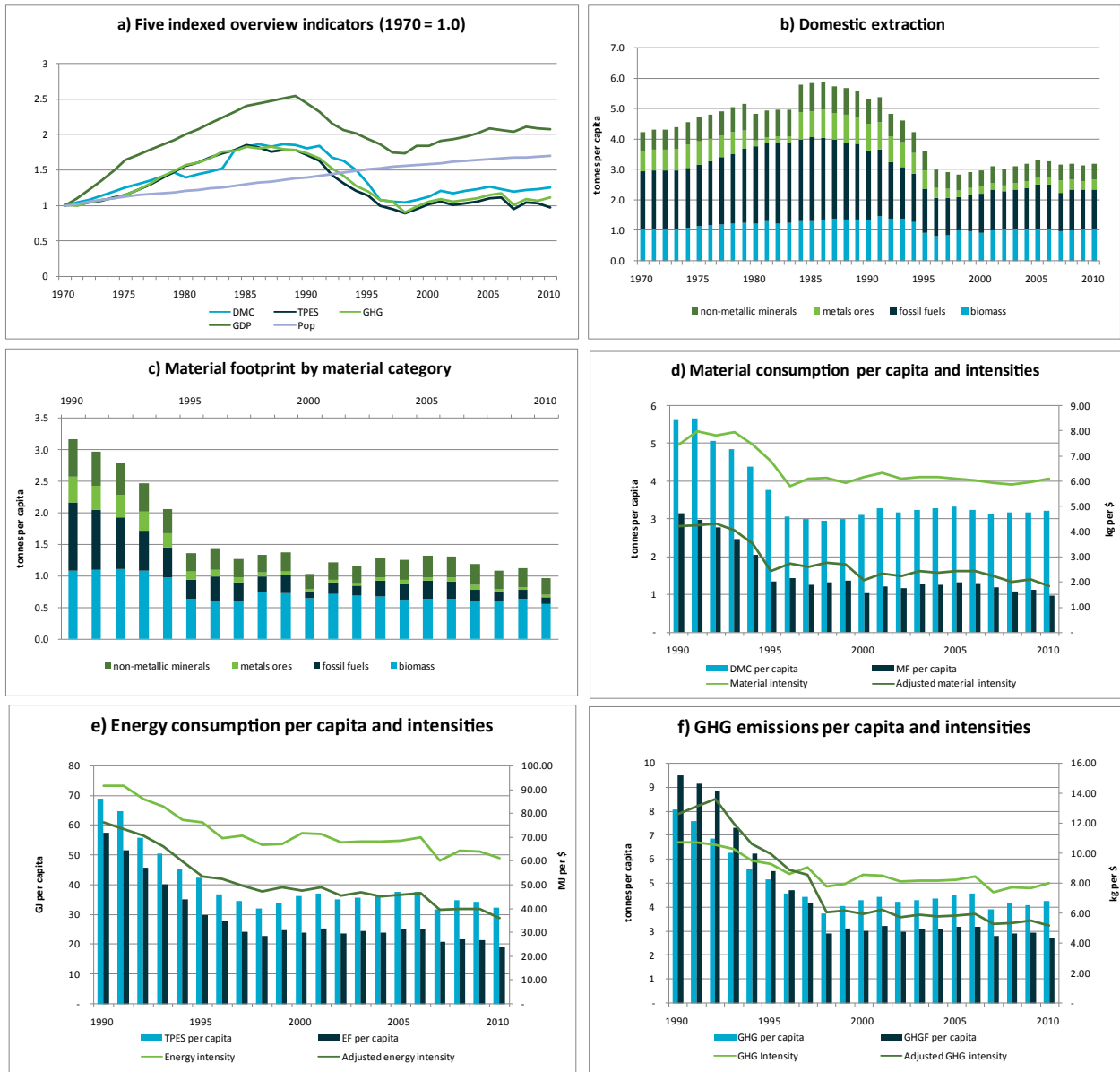
## Papua New Guinea

Figure 117 Summary panel: Papua New Guinea



In panel a) there is a clear step up in Papua New Guinea's DMC in 1973, accounting for the majority of growth in this indicator for the full time period, with further modest growth until 1987, from which point DMC remains effectively static since. The next strongest growth was in GHG emissions, while GDP and population appear to have grown in a closely coupled manner, tripling between 1970 and 2010. Panel b) makes clear that the step increase in DMC was a result of a massive expansion in DE of metal ores. Panel c) shows MF based estimates of raw material consumption are much lower than would be indicated from DE, at around one quarter the level. This reflects the fact that the great majority of metal ores extraction is embodied in Papua New Guinea's exports. Panels d) and f) show that MF and GHGF based measures attribute much less consumption/emissions to Papua New Guinea than conventional measures. Relative decoupling is indicated for all six intensity measures, as is decreasing per capita consumption of materials and energy, and emissions of GHGs.

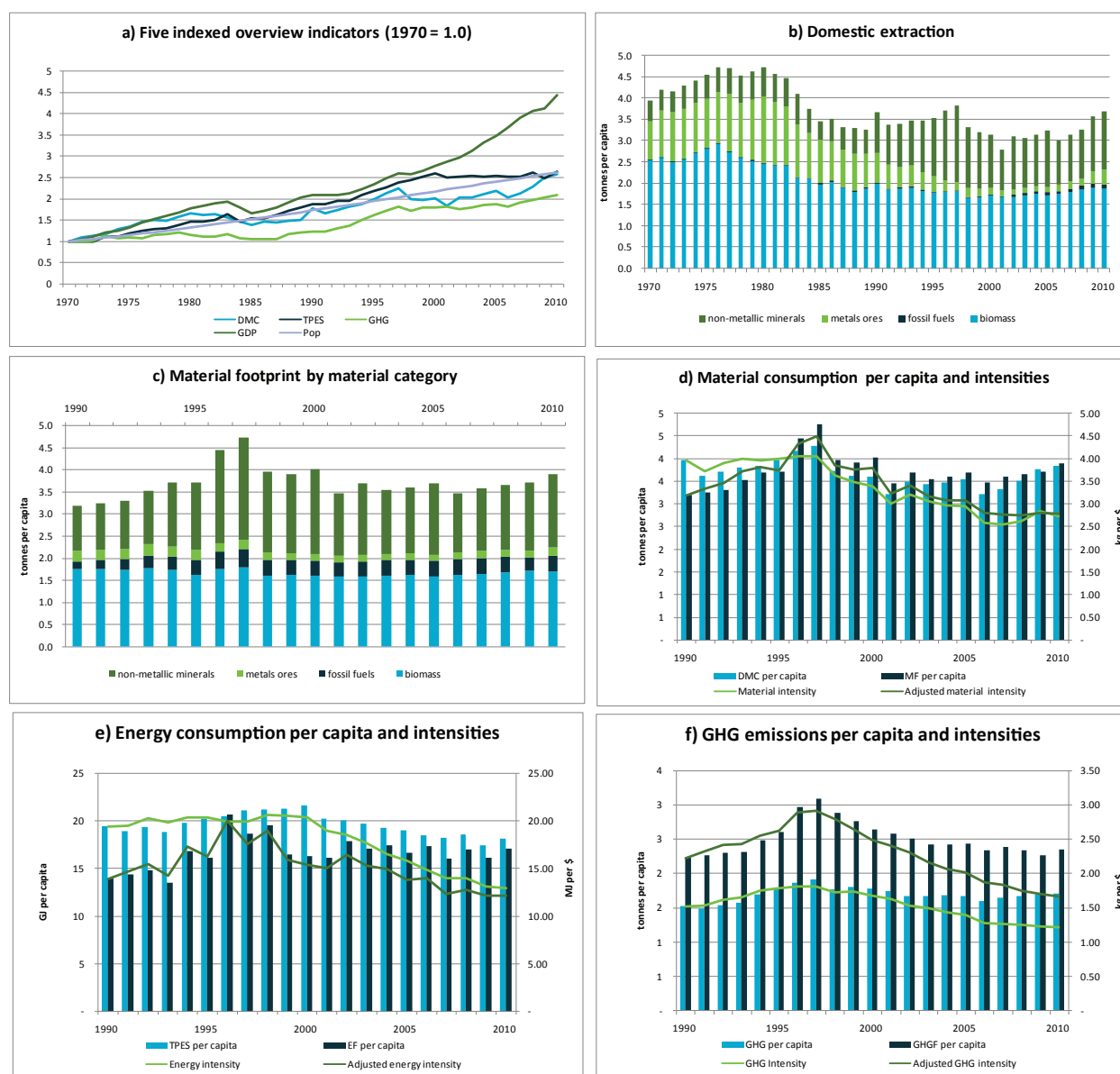
Figure 118 Summary panel: DPR Korea



In panel a) DPR Korea GDP grew over the first half of the period 1970 to 2010, and then declined to finish at roughly twice the level in 1970. The only other overview indicators to grow significantly was population, and that appeared to level off by 2010, and DMC, which increased by 25%. TPES and GHG emissions finished the period at the same levels as 1970. The profile of DE per capita in panel b) is similar in form to that for DMC, except that it shows a decrease of around 30% over the period. The detail of panel b) further shows that the decreases in DE were concentrated in the non-biomass materials categories. This trend is even stronger in the MF per capita displayed in panel c), where the consumption of non-biomass materials decreases from already low levels in 1990, to extremely low levels by 2010. Comparing panels b) and c) indicates that already low levels of DE would nonetheless grossly overstate the level of local consumption of resources compared to MF, especially in those categories of materials most closely linked to industrial development. Panels d), e) and f) show decreasing material and energy consumption, and GHG emissions, per capita regardless of whether footprints or conventional measures are used. Similarly all six intensity measures decreased, giving across-the-board relative decoupling. Conventional measures of material and energy consumption strongly overestimate relative to footprint based measures.

## Philippines

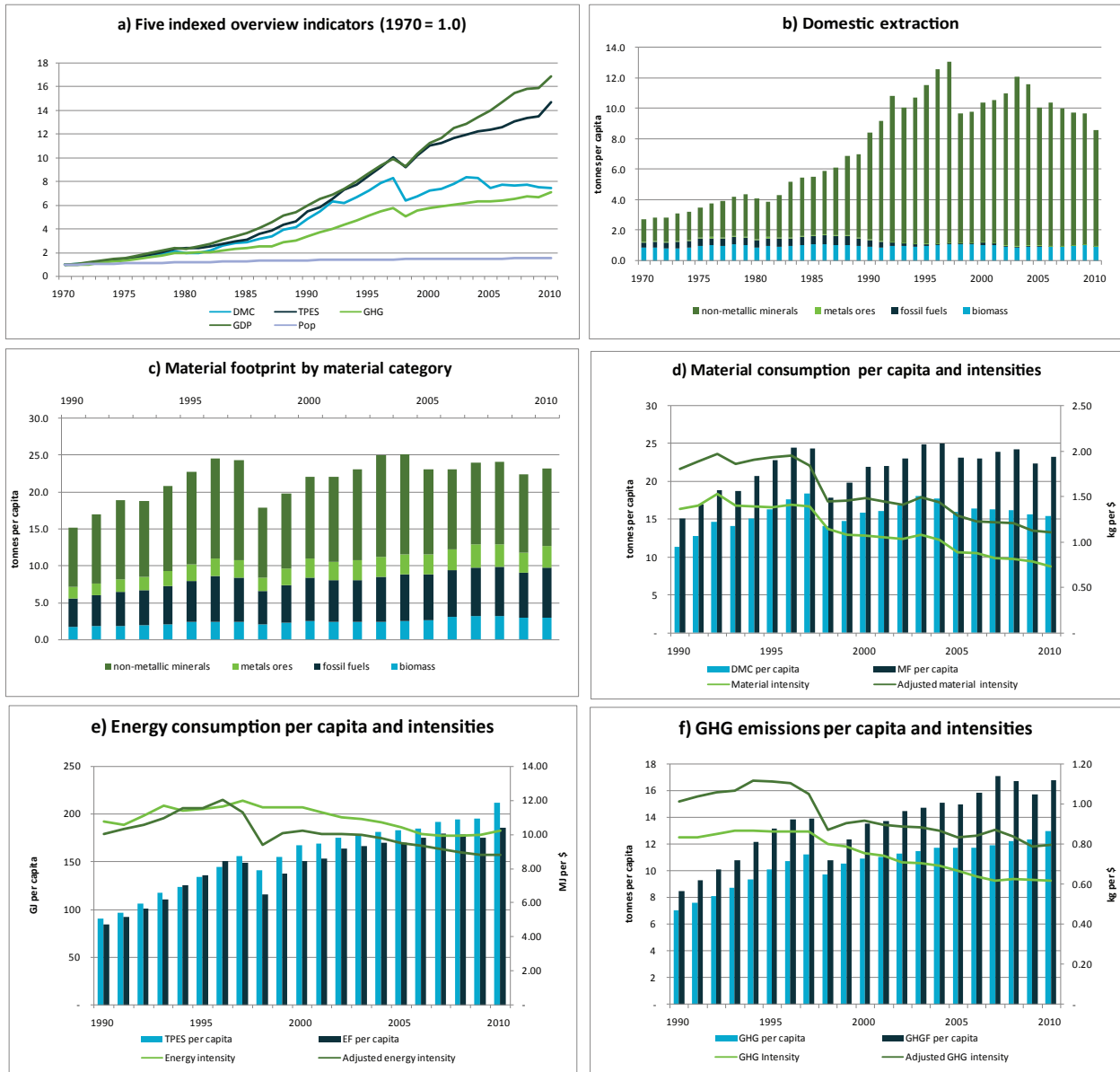
Figure 119 Summary panel: Philippines



Panel a) for the Philippines shows GDP growing fastest, followed by TPES, DMC and population (which all increased by a factor of 2.5), then GHG emissions which doubled. Panel b) shows a small reduction in DE per capita, with a major change in the mix of materials. Biomass has declined, but so too has metal ores, while non-metallic minerals grew strongly. Panel c) shows that MF per capita values which are broadly similar to DE values, although the material mix is somewhat different, with the share of biomass reduced somewhat. Panels d), e) and f) show little change in energy consumption, and GHG emissions, per capita between 1990 and 2010, regardless of whether footprints or conventional measures are used. All six intensity measures decreased (very slightly in the case of adjusted EI), indicating general relative decoupling. Conventional measures of consumption overestimate energy, and underestimate GHG emissions, relative to footprint based measures.

## Republic of Korea

Figure 120 Summary panel: Republic of Korea

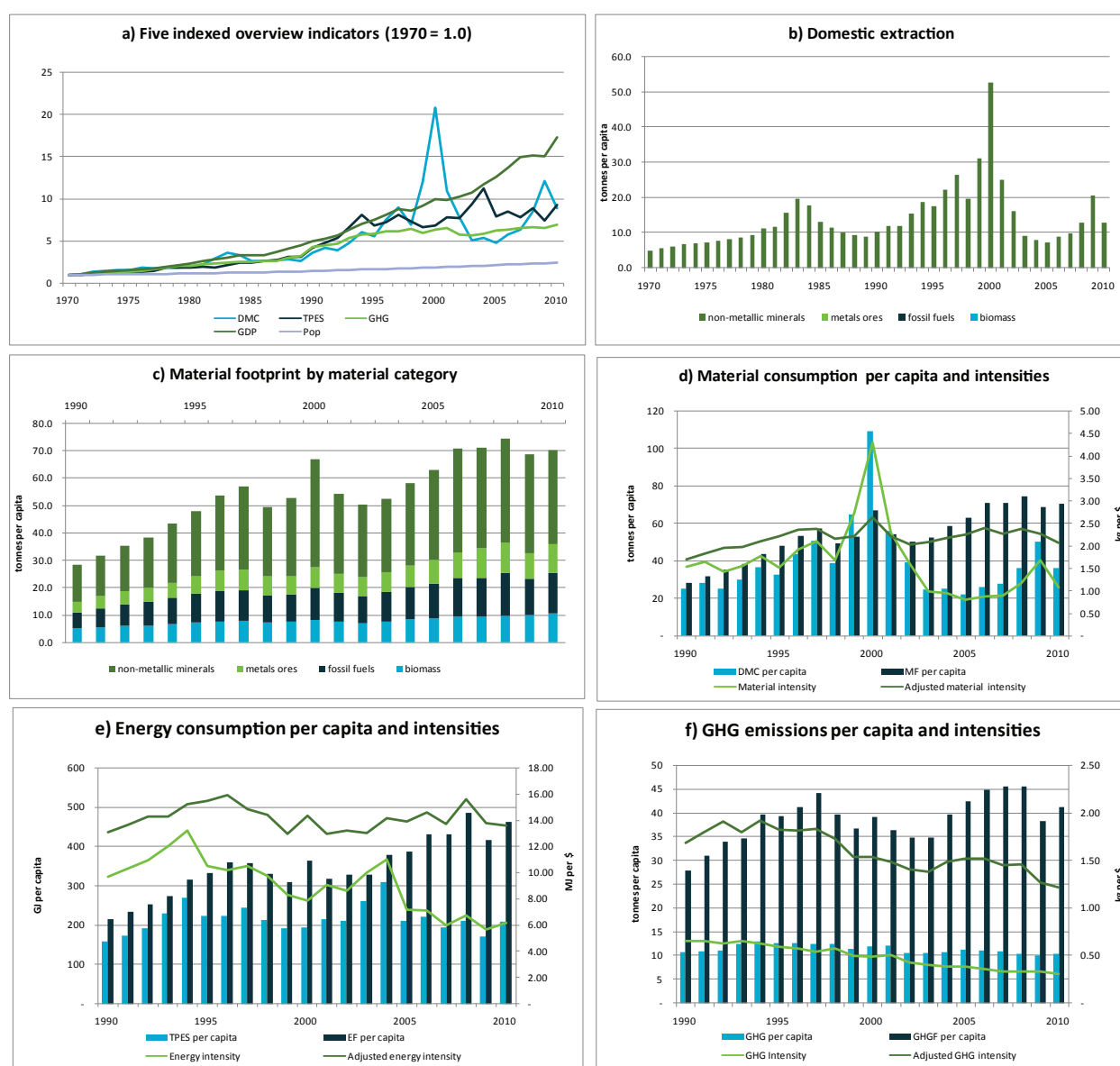


Panel a) shows the Republic of Korea's GDP growing fastest, increasing by a factor of seventeen, followed closely by TPES (factor fifteen). DMC and GHG emissions both increased at around half the rate of TPES. Panel b) shows DE per capita growing strongly, dominated by non-metallic minerals, with the effects of the 1997 financial crisis and its aftermath clearly visible. Comparing DE to the MF per capita in panel c) indicates how heavily reliant the Republic of Korea is on imports (direct or embodied) for key categories of primary materials, most notably fossil fuels and metal ores which underlie its economy, including virtually all of its requirements for fossil fuels, metal ores, and biomass. Panels d), e) and f) show per capita consumption has increased on all measures, and that all six intensity measures have decreased, indicating relative decoupling. Conventional DMC and GHG based measures underestimate the Republic of Korea's requirements for materials and its GHG emissions relative to footprinting, while its energy use is broadly comparable on both conventional and footprint based measures.



## Singapore

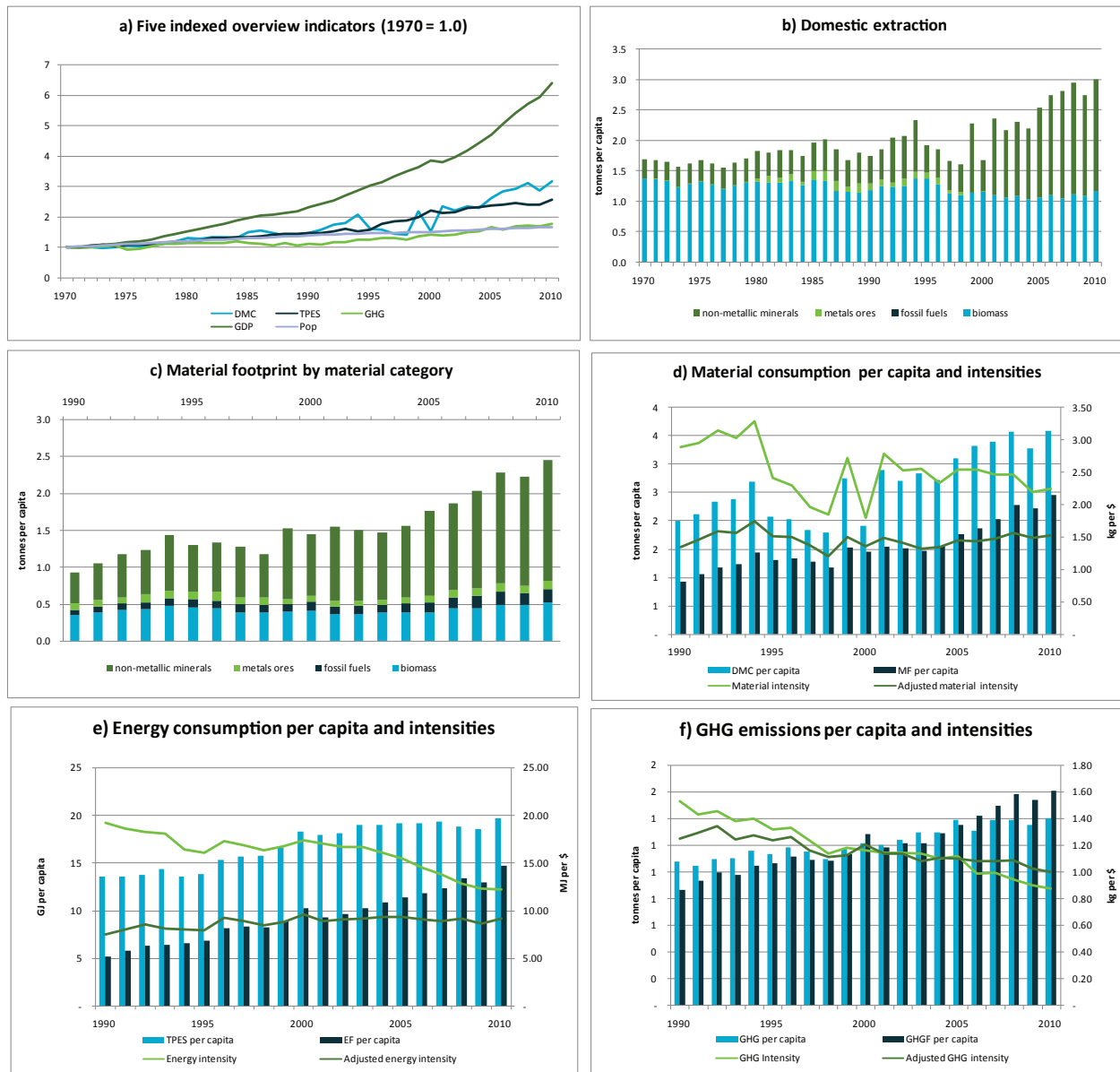
Figure 121 Summary panel: Singapore



Panel a) shows Singapore's GDP growing fastest, followed by TPES and DMC (which both increased ninefold), then GHG emissions which increased sevenfold. Panel b) shows highly variable DE per capita, totally dominated by non-metallic minerals. The large DE spikes can be attributed to major construction and/or land reclamation projects. Comparing panel b) with the MF per capita in panel c) shows how little of Singapore's demand for raw materials is met from DE, and how heavily reliant it is on imports (direct or embodied) for the primary materials which underlie its economy, including virtually all of its requirements for fossil fuels, metal ores, and biomass. Panels d), e) and f) show per capita consumption has increased on all measures except on conventional GHG measures. There are large differences in material and energy intensity depending on whether footprint based or conventional measures are used, with relative decoupling indicated by conventional measures, while footprinting gives increasing intensities. GHGI and adjusted GHGI in panel f) both indicate relative decoupling, although the GHG footprint is typically two to four times higher than that indicated by conventional measures.

## Sri Lanka

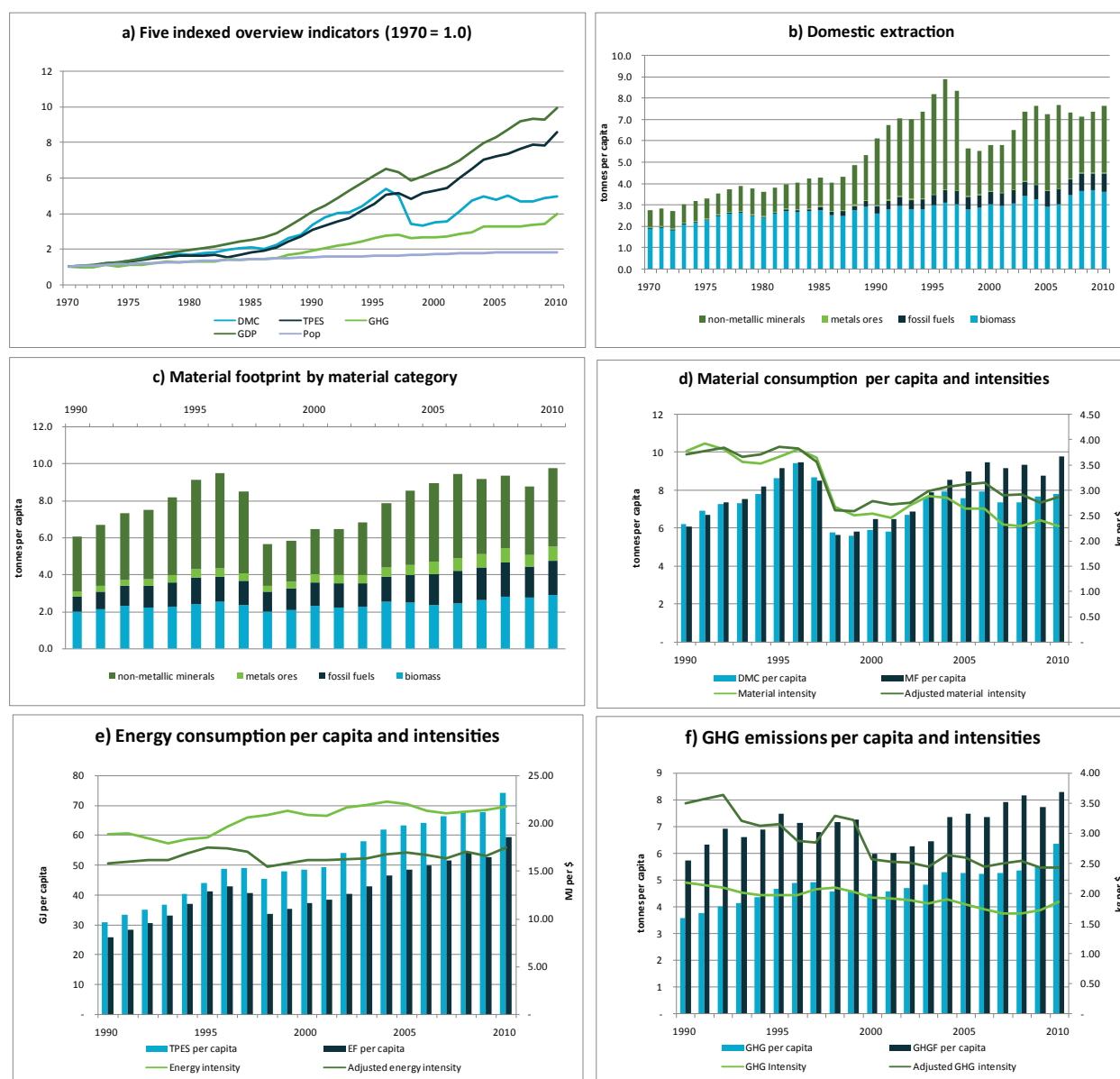
Figure 122 Summary panel: Sri Lanka



Panel a) shows Sri Lanka's GDP growing fastest, increasing by a factor of six. DMC and TPES increased at less than half this rate, with population and GHGs less than doubling. In panel b), DE per capita has not grown in proportion to DMC, implying an increasing reliance on imports (or at least diminished capacity to export). While DE per capita did not keep pace with DMC, much less GDP, in gross terms, the non-metallic minerals component of it did, growing sixfold. Comparing DE to the MF per capita in panel c) indicates that Sri Lanka more than meets its material requirements from DE, in gross terms, but is heavily reliant on imports (direct or embodied) for fossil fuels and metal ores. Panels d), e) and f) show per capita consumption has increased on all measures, and that all conventional intensity measures have decreased, indicating relative decoupling, while materials and energy footprint based measures indicate that no relative decoupling has taken place. Conventional measures overestimate Sri Lanka's requirements for materials and energy relative to footprinting.

## Thailand

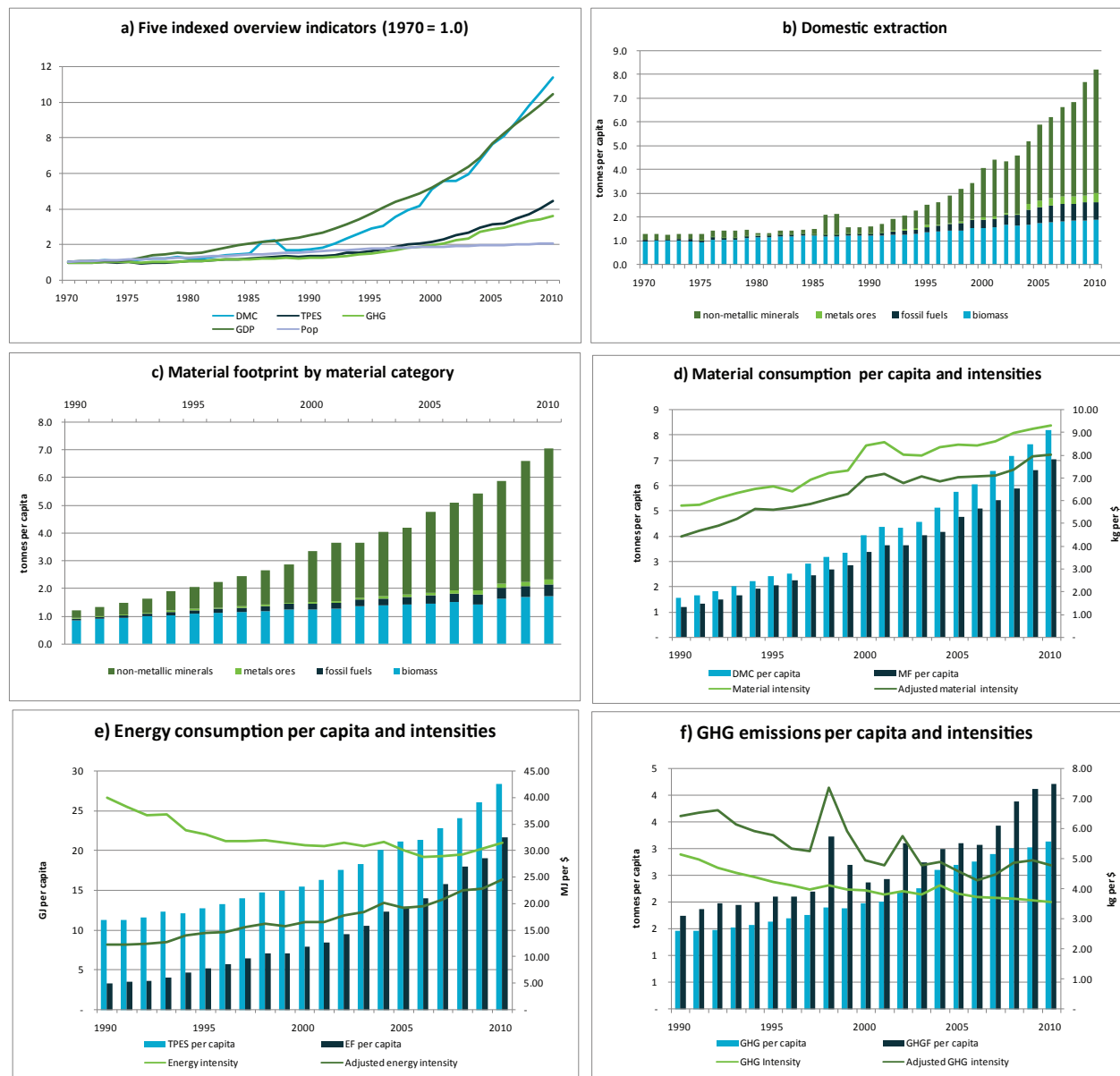
Figure 123 Summary panel: Thailand



Panel a) shows Thailand's GDP increasing by a factor of ten, followed by TPES (factor eight), DMC, GHG emissions, and population, which doubled. Panel b) shows that DE per capita had not grown even in proportion to DMC in gross terms, but that non-metallic minerals had, while almost one tonne per capita of fossil fuels were being extracted in 2010, were none in 1970. Comparing DE to the MF per capita in panel c) indicates that Thailand's DE was slightly less than its material requirements in gross terms, but is somewhat reliant on imports (direct or embodied) for fossil fuels and metal ores, while producing more biomass than locally required. Thailand is another country where the impact of the 1997 financial crisis is clearly discernible in its material flows. Panels d), e) and f) show per capita consumption increased on all measures. Panel d) shows a major step decrease in both MI and adjusted MI in the wake of the 1997 financial crisis. Panel e) indicates that both EI and adjusted EI have increased, indicating increased coupling of economic growth to energy use, however this has not translated to GHG emissions intensity, which decreased on both footprint based and conventional measures. Conventional indicators appear to overstate energy consumption and understate GHG emissions relative footprint based measures.

## Viet Nam

Figure 124 Summary panel: Viet Nam



Panel a) shows Viet Nam's DMC increasing by a factor of eleven, closely followed by GDP. Increases in TPES and GHGs were less than half this, while population which doubled. Panel b) shows a strong and consistent increase in DE per capita beginning in the late 1980s, contemporaneous with the start of the period of economic reforms under Doi Moi. In Viet Nam's case, growth in DE is roughly in proportion to economic growth since the 1990s, and growth in the non-biomass categories has outstripped growth in GDP. Comparing DE to the MF per capita in panel c) shows an unusually close match between both measures, such that Viet Nam appears notionally largely self-sufficient both in gross terms, but also within the four specific materials subcategories. Panels d), e) and f) show per capita consumption and GHG emissions have increased strongly on all measures. Panel d) shows a strong increase in both MI and adjusted MI from 1990 to 2010, indicating economic growth is becoming less eco-efficient with regard to raw materials. Panel e) presents conflicting data on energy intensities, with substantial improvement on conventional measures, but a major deterioration (increase) on the adjusted EI measure. Another interesting feature of panel e) is the degree to which footprint based and conventional measures are converging over time. Panel f) indicates that GHG emissions intensity have decreased on both footprint based and conventional measures. Conventional indicators appear to overstate materials and energy consumption, and understate GHG emissions, relative to footprint based measures.

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## About the UNEP Division of Technology, Industry and Economics

Set up in 1975, three years after UNEP was created, the Division of Technology, Industry and Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: **climate change, harmful substances and hazardous waste, resource efficiency.**

DTIE is also actively contributing to the **Green Economy Initiative** launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for **fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund** and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

**The Office of the Director, located in Paris, coordinates activities through:**

- > **The International Environmental Technology Centre** - IETC (Osaka), promotes the collection and dissemination of knowledge on Environmentally Sound Technologies with a focus on waste management. The broad objective is to enhance the understanding of converting waste into a resource and thus reduce impacts on human health and the environment (land, water and air).
- > **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- > **Chemicals** (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- > **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- > **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- > **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

*DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.*

For more information,  
[www.unep.org/dtie](http://www.unep.org/dtie)

This report reveals the patterns and the evolution of natural resource use in Asia and the Pacific region over the last 40 years. The analysis shows that resource use in the region is both inefficient and unsustainable. The Asia-Pacific region will not be able to base its future economic growth on declining costs of natural resources as was possible during most of the twentieth century. An increasing reliance on resources from abroad and volatility in the global resource markets will pose challenges to the economic resilience of countries in the region. In this new economic context resource efficiency and decoupling of economic growth and resource use will be fundamental to the economic success of the region. Nevertheless there is a window of opportunity for Asia-Pacific countries to invest in policies and the infrastructure that will support resource efficiency in the decades to come. Acting now will reduce economic vulnerability, especially of low income groups, and will help secure the competitiveness of tomorrow in a low carbon resource efficient global economy.

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