

Resource Efficiency:

Economics and Outlook for Asia and the Pacific

UNEP

CSIRO

Resource Efficiency:
Economics and Outlook for Asia and the Pacific

in collaboration with
Division of Ecosystem Sciences, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

University of Western Sydney, Australia

Institute for Global Environmental Strategies (IGES), Japan

The Energy and Resource Institute (TERI), India

Institute of Policy and Management Science, Chinese Academy of Sciences, China

Funded by the Government of Norway and Partners

UNEP

CSIRO

© 2011 United Nations Environment Programme

ISBN: 978-92-807-3100-2

DEW/1299/BA

Disclaimers

The content and views expressed in this publication are those of the authors and do not necessarily reflect the views or policies, or carry the endorsement of the contributory organisations or the United Nations Environment Programme (UNEP).

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of UNEP concerning the legal status of any country, territory or city or its authorities, or concerning the delimitation of its frontiers and boundaries.

Reference to a commercial company or product in this publication does not imply the endorsement of UNEP.

The views expressed in this publication are those of the authors and do not necessarily represent those of, and should not be attributed to, the publisher or the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

© Maps, photos, and illustrations as specified.

Cover images (clockwise from top left): Vitaly Titov and Maria Sidelnikova; iStockphoto; United Nations; WDG Photo

Reproduction

This publication may be reproduced in whole or in part and in any form for educational or non-profit purposes without special permission from the copyright holder, provided acknowledgement of the source is made. UNEP would appreciate receiving a copy of any publication that uses this publication as a source.

No use of this publication may be made for resale or any other commercial purpose whatsoever without prior permission in writing from UNEP. Applications for such permission, with a statement of purpose and intent of the reproduction, should be addressed to the Director, Division of Communications and Public Information (DCPI), UNEP, P.O. Box 30552, Nairobi 00100, Kenya.

The use of information from this publication concerning proprietary products for publicity or advertising is not permitted.

This publication was printed in chlorine free ISO 9706 and ISO 14001 (environment) certified facilities, using vegetable inks and water-based varnish. The paper is from mixed sources and is certified by the Forest Stewardship Council.

Produced by
Regional Office for Asia and the Pacific
United Nations Environment Programme
UN Building
Rajdamnern Avenue
Bangkok, 10200, Thailand

Tel: (+66) 2 288 1870
Fax: (+66) 2 288 3829
Email: uneproap@un.org
Web: www.unep.org/roap

Resource Efficiency: Economics and Outlook for Asia and the Pacific, United Nations Environment Programme, Bangkok.
Published October 2011

Cover design by Audrey Ringler
Layout by Andrew Weatherill

Printed in China by 1010 Printing International Ltd

This publication is available from www.earthprint.com

UNEP promotes
environmentally sound practices
globally and in its own activities.
This publication is printed on chlorine free
paper from 100 per cent post-consumer waste.
Our distribution policy aims to reduce
UNEP's carbon footprint.

Foreword

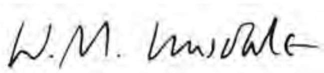
The period from 1970 to 2005 saw the most rapid growth in natural resource use in the history of the Asia-Pacific region, driven by unprecedented economic development and progress in most of its countries. This rapid economic growth, however, has come at a cost, with the increased use of resources resulting in greater environmental pressures, larger greenhouse gas emissions, lower resource and energy efficiency, and rising consumer waste, as this report clearly demonstrates.

Data and indicators are often an important prerequisite for policy planning and management. CSIRO, the national Australian research agency has, among other areas of investment, a strong focus on the environment including environmental information systems, data provision and modelling, economics, and environmental governance and planning. CSIRO also has an international role in contributing to the development of research capacity in Asia and the Pacific region, and to regional sustainability.

CSIRO Ecosystem Sciences' research covers many aspects of sustainability science including climate mitigation and adaptation, sustainable consumption and production, ecosystem services and biodiversity research. We pride ourselves on providing scientific information and advice to policy makers, businesses and the community at large.

In this context, I am pleased to commend the first *Resource Efficiency: Economics and Outlook for Asia and the Pacific* (REEO) to the reader.

This report focuses on the demand for and use of natural resources and their interaction with economic activity and social development. It provides a rich pool of data and analysis for natural resource use including materials, energy, water and land, and reviews policy initiatives in Asia and the Pacific which address resource efficiency. This report highlights ways to achieve sustainable resource use and greater resource efficiency through well-designed and visionary policy options, backed by better data.



Mark Lonsdale

Chief of the Division of Ecosystem Sciences
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Foreword

The world is again on the Road to Rio, almost 20 years after the 1992 Earth Summit that has shaped the contemporary response to sustainable development.

The remarkable changes that have occurred in the intervening years are perhaps nowhere more visibly illustrated than in Asia and the Pacific. Many countries in the region have seen breathtaking economic growth that has lifted more than half a billion out of poverty.

But this growth has come at a price, ranging from high levels of air pollution, sharply rising greenhouse gas emissions, loss of biodiversity, increasing pressure on freshwater resources and deteriorating ecosystems such as soils and land to forests and fisheries.

The two themes for the UN Conference on Sustainable Development 2012, or Rio 2012, are a Green Economy in the context of sustainable development and poverty eradication, and the institutional framework for sustainable development.

Both echo the urgency of forging a very different development path that makes a fundamental break from the past in favour of sharply rising resource efficiency that decouples GDP growth from environmental decline.

Good policymaking requires sound, solid and comprehensive scientific data and analysis on resource use: such an assessment for the Asia-Pacific region has been lacking until now.

The *Resource Efficiency: Economics and Outlook* (REEO) report for Asia and the Pacific bridges this knowledge gap by providing authoritative data on the use of materials, energy, water and land alongside the emissions and waste associated with using these resources. There is also detailed analysis of ten selected countries.

Innovative modelling and scenarios explore possible futures under a business as usual approach versus greater resource efficiency and systems innovation. The study reveals what progress Asia-Pacific has made in improving resource efficiency over more than three decades, where the region and the ten selected countries are today, the scope for dramatic improvements and how these might be achieved.

This is pioneering work and on behalf of UNEP I would like to thank the Commonwealth Scientific and Industrial Research Organisation (CSIRO) who led this research in collaboration with the University of Western Sydney, Australia, the Institute for Global Environmental Strategies (IGES), Japan, The Energy and Resources Institute (TERI), India and the Institute of Policy and Management of the Chinese Academy of Sciences (CAS), China.

The report underlines some sobering realities but also extraordinary opportunities for a transition to a low carbon, resource efficient Green Economy. Indeed Asia and the Pacific is the region where some economies, ranging from China to the Republic of Korea, are already demonstrating elements of the Green Economy path in areas from low emission vehicles to renewable energies and investments in 'ecological infrastructure' including forests and freshwaters.

Rio 2012 offers an opportunity to accelerate and scale-up these transitions across this region and indeed across the world in order to catalyze growth and employment opportunities for around nine billion people by 2050, but in a way that keeps humanity's footprint within planetary boundaries.

Achim Steiner

UN Under-Secretary General and UNEP Executive Director

We thank our collaborators:

Institute for Global Environmental Strategies

University of Western Sydney
Bringing knowledge to life

Contents

List of contributors

The Resource Efficiency: Economics and Outlook (REEO) for Asia and the Pacific report is part of UNEP's Resource Efficiency: Sustainable Consumption and Production sub-programme activities. Anna Stabrawa managed the overall coordination of the publication for UNEP. Heinz Schandl of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) managed the development of the report and supervised the author teams.

Lead author

Heinz Schandl, CSIRO Ecosystem Sciences

Contributing authors

Kim Alexander, Kerry Collins, Sonja Heyenga, Karin Hosking, Franzi Poldy, Graham Turner, and James West, CSIRO Ecosystem Sciences

Steve Keen, The University of Western Sydney

Magnus Bengtsson, Yasuhiko Hotta, Shiko Hayashi, and Lewis Akenji, the Institute for Global Environmental Strategies, Japan

Arabinda Mishra, The Energy and Resources Institute, India

Shaofeng Chen, The Chinese Academy of Sciences, P.R.China

Editors

Peter Storer, Peter Storer Editorial Services

Julian Cribb, Julian Cribb and Associates

Karin Hosking, CSIRO Ecosystem Sciences

UNEP Production Team

Anna Stabrawa, Stefanos Fotiou, Arab Hoballah, Guido Sonneman, Tunnie Srisakulchairak, and Jinhua Zhang

Expert reviewers

Anthony Shun Fung Chiu, Center for Engineering & Sustainable Development Research, De La Salle University, the Philippines

Kanchan Chopra, Institute of Economic Growth, University of Delhi, India (Professor Emeritus)

Nicholas Conner, New South Wales Department of Environment, Climate Change and Water, Australia

David Duncan, Pacific Islands Applied Geoscience Commission (SOPAC), Fiji

Yu Hai, Policy Research Center for Environment and Economy, Ministry of Environmental Protection, P.R. China

Paula Holland, Pacific Islands Applied Geoscience Commission (SOPAC), Fiji

Alberto Isgut, Macroeconomic Policy and Development Division, UNESCAP

Inkar Kadyrzhanova, Environment and Energy Unit, UNDP Kazakhstan

Ian Lowe, School of Science, Griffith University, Australia

Frank Mueller, Asia Pacific Roundtable for Sustainable Consumption and Production (APRSCP), Thailand

Hongpeng Liu, Environment and Sustainable Development Division, UNESCAP

John Moon, Transport Division, UNESCAP

Hitomi Rankine, Environment and Development Division, UNESCAP

Budy P. Resosudarmo, ANU College of Asia and the Pacific, Australia

Anna Bella Siriban Manalang, Center for Lean Systems & Management, De La Salle University, the Philippines

Sergey Tulinov, Environment and Development Division, UNESCAP

De So Won, Korean Economic Institute (KEI), Republic of Korea

K Vijayalakshmi, Development Alternatives, India

Xia Yingxian, Ministry of Environmental Protection, P.R.China

Salmah Zakaria, Environment and Development Division, UNESCAP

Saltanat Zhumabekova, Network of Experts for Sustainable Development of Central Asia, Republic of Kazakhstan

CSIRO reviewers

Kerry Collins, Tira Foran, Alexander Herr, Thomas Measham, Sadanandan Nambiar, Franzi Poldy, Wendy Proctor, Ejaz Qureshi, Alexander Smajgl, Annaliese Spinks, John Ward and James West of CSIRO Ecosystem Sciences

UNEP reviewers

Joana Akrofi, Salif Diop, Stefanos Fotiou, Arab Hoballah, Phubalan Karunakaran, Patrick Mmayi, Kakuko Nagatani-Yoshida, Elina Rautalahti, Fulai Sheng, Tunnie Srisakulchairak, Anna Stabrawa and Jinhua Zhang of UNEP

We are also grateful to the following people for their assistance in the development of this publication:

Jaap van Woerden, Panvirush Vittayapraphakul, and Charuvan Kalyangkura, UNEP

Nilapha Ratanawong, Purna C Lall Rajbhandari, Adelaida Roman, and Seepus Sri-aksorn, AIT/UNEP Regional Resource Centre for Asia-Pacific

Introduction

The first 'Resource Efficiency: Economics and Outlook (REEO) for Asia and the Pacific' report focuses on the demand for, and use of, natural resources both as drivers and as consequences of economic activity and social development. The report highlights the recent history of natural resource use in the Asia-Pacific region, covering the period from 1970 to 2005, which has been a time of unprecedented economic development in many countries in the region.

The rapid growth in economic activity experienced by many Asia-Pacific countries since the 1970s has come at some cost, however, with an increased use of resources resulting in greater environmental degradation, greenhouse gas (GHG) emissions, and consumer waste. While growth in global resource use and emissions was until recently driven by wealthy industrial countries, today's main drivers are the rapidly developing economies such as China, India, and Brazil. This has ratcheted up the scale and speed of global resource use, with today's patterns of production and consumption approaching the limits of what the planet can offer and sustain. Pressure points – including climate change, water, and food availability, price surges for strategic raw materials, and peaking global oil supply – are converging rapidly in an unprecedented manner.

The current transition in developing Asian and Pacific economies from an agrarian, biomass-based resource use pattern to an industrial resource use pattern involves a major increase in material and energy flows, corresponding with a two- to fourfold increase in the demand for materials and energy. Despite rapid economic growth during the past decade, the Asia-Pacific region still shows relatively low material and energy consumption per capita, suggesting that major growth may follow. Infrastructure that is closely coupled with bulk material flows (transport, energy, and housing) will be critical to the future level of resource use.

At the same time, many Asian and Pacific developing economies are already approaching their limits in terms of domestically available resources, and have become net importers of raw materials, especially fossil fuels and metals. Future economic development will rely increasingly on their capacity to purchase these strategic resources on the world market, and prices for many strategic resources may increase.

Although, historically, economic development in many Organisation for Economic Co-operation and Development (OECD) countries was enabled by resources acquired from other countries, today's developing nations will not have the opportunity to use cheap resources from elsewhere. According to Herman Daly (2005), we are "moving from an empty to a full world", which changes the economics of all production and consumption activities. In order to remain competitive and to allow for increases in the standard of living of its people, the Asia-Pacific region will have to invest massively in infrastructure and technological innovation to foster resource efficiency. In a more general sense, energy generation, mobility, and transport, as well as housing, will require dramatic improvements and innovative solutions. The objective is to invent, design, and create new industrial infrastructure that uses less energy and is less dependent on a stable supply of energy, that uses fewer materials and allows for higher flexibility and lower risks in the face of global environmental change and resource scarcity.

Because Asia-Pacific developing economies are already planning to establish new infrastructure over the next decade, there is a window of opportunity to invest in resource efficiency that will have a lasting effect over the next 20–30 years.

This report provides an overview of resource use patterns in Asia and the Pacific, explains why sustainable resource use and resource efficiency will become an economic and social imperative for the region, and presents information on how to achieve resource efficiency and sustainable resource use through well-designed policies. The objective is to inform policy makers and practitioners working on integrated environment and development programmes and strategies in particular as well as sustainability policies more generally. The following are the highlights of each chapter.

Chapter 1: Resource efficiency and economics – discusses why resource efficiency is important for Asia and the Pacific and how to assess it in order to inform the challenge of decoupling economic growth from environmental degradation.

Chapter 2: Materials – highlights how the region has become the single most important resource user globally and is on an exponential growth path explained by a reduction in resource efficiency, caused by economic activity shifting from very efficient to less efficient producers from within and outside the region.

Chapter 3: Energy – assesses the ongoing energy transition that underpins increased productive capacity, changes in transport systems, and household energy demand due to rising incomes. It demonstrates how energy pathways based on coal are developing in parallel with green energy technologies.

Chapter 4: Water – presents current regional trends for water use in agriculture, manufacturing, and households and contrasts the patterns of use with water availability. It looks at water shortages that may arise from further economic development and population growth.

Chapter 5: Land use – highlights how the region has managed trade-offs between different land uses to service businesses, industries, and households. It shows ecological and social consequences of the fast changing land use systems in the region.

Chapter 6: Emissions and waste – looks at trends in major emissions to air, water and solid waste, and their relationship to the rapid industrialization of many Asia-Pacific countries, and the related consequences for environment and health.

Chapter 7: Integrated assessment and scenarios – builds on previous chapters and presents three scenarios to the year 2050 including a baseline (business-as-usual) scenario, a resource efficiency scenario, and a scenario featuring sustainability transition through systems innovation. The scenarios help to explore alternative futures driven by different policies and societal choices.

Chapter 8: Policy instruments to support resource efficiency – presents the traditional approaches for motivating and guiding social change towards sustainable resource use, including market-based, regulatory, information-based measures and voluntary initiatives, which need to be combined and sequenced to achieve greater resource efficiency and reduced environmental impacts from the use of resources.

Chapter 9: Conclusions – Provides a summary of regional resource use trends and economics to highlight how well-designed policies could provide a triple dividend of continuing economic development and rising standards of living, competitiveness, and environmental benefit. There is a short window of opportunity for the Asia-Pacific region to enable environmentally sound and socially beneficial economic development.

The main findings of the report are summarized in a 'Summary for Decision Makers', which complements the comprehensive report.

REEO conceptual framework

The REEO assessment uses a pressure indicator framework for analysing interactions between socio-economic systems and their environment. The accounts on materials, energy, carbon, air pollutants, water, and land use established for the REEO are the first steps towards satellite accounts to Systems of National Accounts (SNA) on resource use. These accounts have a number of attributes including compatibility with the SNA, a sound conceptual background within the industrial metabolism concept, being based on readily available and credible datasets, and providing policy relevant information. The datasets have been established at the national economy scale on a country by country basis. More detail on relevant economic activities affecting resource use have been provided whenever possible.

The Driving Force–Pressure–State–Impact–Response (DPSIR) framework is based on the Pressure–State–Response (PSR) model originally developed by Statistics Canada in the 1970s (Rapport and Friend 1979). This was subsequently adapted and extended by a number of institutions, including the OECD (1994) and the United Nations Commission on Sustainable Development (UNDSD 1997). The DPSIR framework has underpinned UNEP's assessments since the first Global Environment Outlook report (UNEP 1997) and is used by the European Environment Agency (EEA).

Drivers are the underlying causes, including economic activity of production, distribution, and consumption, which lead to environmental pressures. Examples of drivers include population, profits, income, systems for the provision of energy, food, transport, and housing driven by technologies and lifestyles.

Pressures on the environment are operationalized as material and energy flows, water and land use, waste, and emissions. Pressures cause changes in the state of the environment such as changes in air quality, water quality, and soil quality and their ability to provide services to humans and other living beings.

Changes in state lead to impacts on human health and wellbeing, ecosystems, biodiversity, amenity value, and financial value, and include changes in the global environmental system.

Responses are the efforts taken by society (politicians, businesses, organizations, and households) to mitigate or to respond to the problems identified by the assessed drivers, pressures, states, and impacts and their linkages.

The individual REEO accounts are integrated within the Asia-Pacific Stocks and Flows Framework (APSFF), which is a technology-based, biophysical model of economic systems. It includes all the major elements of the physical economy including people, buildings and infrastructure, employment, trade, and natural resources. Using this comprehensive accounting and modeling framework allows the assessment of synergies and trade-offs between different resources and policies. The APSFF model is soft-coupled with a non-equilibrium, dynamic financial stocks and flows model to assess interactions between the monetary and the physical economy.

The preliminary satellite accounts on resource use and resource efficiency, the indicators and the modeling of future resource use scenarios are integrated within an assessment of possible policies, programmes, and measures that may provide incentives for transition to a green economy and low carbon development in Asia and the Pacific. As Figure 1 shows, the REEO report focuses on drivers and pressures and their linkages, as well as on policies that respond to observed pressures and drivers.

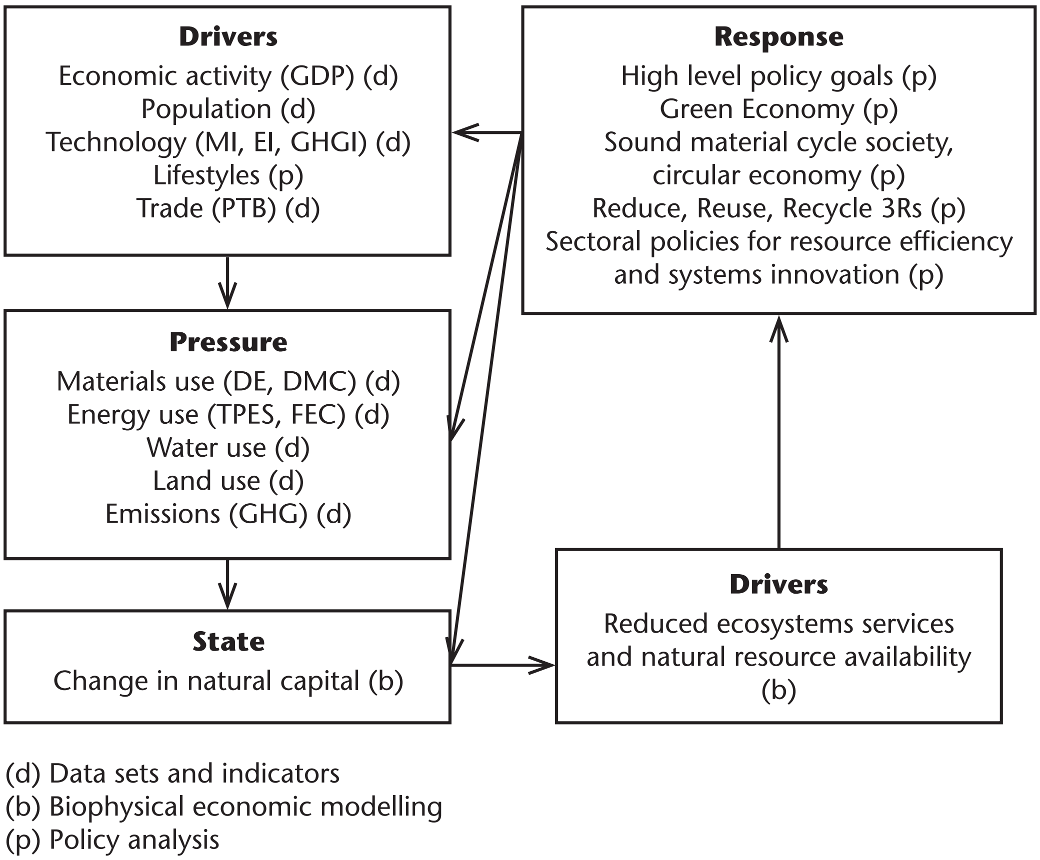


FIGURE 1
Focus of the REEO within the DPSIR framework

This approach has the advantage of tackling problems early in the DPSIR cycle, and enables the use of available socio-economic data for environmental and resource use accounts at reasonable cost and in a timely fashion. The approach enables environmental pressures to be linked to those actors that cause them, and thereby provides valuable information for targeted policies. The approach taken in the REEO is complementary to the approach used in UNEP's Global Environment Outlook, which assesses the state of the environment and related indicators using the DPSIR framework (UNEP 2007).

References

Daly HE (2005) Economics in a full world. *Scientific American* **293**(3): 100–107.

OECD (1994) *Environmental Indicators – OECD Core Set*. OECD: Paris.

Rapport DJ and Friend AM (1979) 'Towards a Comprehensive Framework for Environmental Statistics: A Stress-Response Approach'. pp. 11–510. Statistics Canada: Ottawa.

UNDSD (1997) *From Theory to Practice: Indicators for Sustainable Development*. United Nations: New York.

UNEP (1997) *Global Environment Outlook*. United Nations Environment Programme: Nairobi.

UNEP (2007) *GEO4: Global Environment Outlook – Environment for Development*. United Nations Environment Programme: Nairobi.

Chapter 1:
Resource efficiency and economics

Heinz Schandl and Steve Keen

Main messages

- Economic development and social progress have been profound in Asia and the Pacific in recent decades. The region has continued to urbanize and industrialize and the aspirations of its people have changed as incomes have grown. The success story of economic development in the Asia-Pacific region has also resulted in environmental degradation and growing resource use. It will be important to use natural resources more effectively and efficiently to enable further social and economic progress in the region. New information on resource use and resource efficiency will be required to supplement economic indicators as the main compass to navigate social-economic decisions.

- The need for comprehensive information about the region, beyond the anecdotal, has grown. This chapter provides an overview of the resource efficiency concept and explains why it is a necessary, but insufficient, condition for decoupling economic growth and environmental degradation.

- Increasing resource efficiency will be vital for the future development potential of the Asia-Pacific region to ensure economic and social development in a world in which resources are becoming increasingly scarce and more expensive, and the absorptive capacity of ecosystems is decreasing rapidly. This will place constraints on economic opportunities and will require sound policies and management.

- Achieving sustainable resource use and increased resource efficiency in Asia and the Pacific will not be an easy task. The Asia-Pacific region is in the midst of an industrial transformation that will go hand in hand with a large increase in natural resource use, waste, and emissions, which will grow by a factor of three to five in coming decades. The speed and scale of this transformation is unprecedented in human history. Resources will need to be used more efficiently and current systems of provision will need to become more innovative where they fail to take into account sustainability needs. The challenge for public policy is to achieve a sustainable transition, enabled by resource efficiency and systems innovation despite the inherent growth dynamic of the industrial transformation. What is required is a new 'industrial revolution' that provides food, housing, mobility, energy, and water with only about 20% of the per-capita resource use and emissions found in current systems.

- Globalization of business, finance, trade, and information flows have contributed to exponential growth in the amount of traded goods. Resource use, therefore, has also become more global and is driven by international markets and global prices.

- Prices alone, however, do not provide appropriate signals for enabling resource efficiency and systems innovation because global resource markets are characterized by complex producer–consumer networks and complicated institutional and power relationships. It will require new forms of governance together with market incentives to improve current resource efficiency trends, alter consumption behaviours and trigger systems innovation.

- In recent decades, relative decoupling of resource use and economic growth has occurred in most countries around the globe. Very often, though, efficiency gains have led to higher levels of overall consumption, thus offsetting previous gains. In the light of already very high resource use globally, dematerialization – that is, an absolute reduction in resource use – needs to be achieved. This will require policies that actively deal with the rebound caused by efficiency gains. Most modern societies have not yet established institutions that observe the society–nature interface and resource use comprehensively. Measurement of resource use has become an important imperative for integrative policy planning and for the evaluation of policies and programmes that have been implemented. This report presents comprehensive accounts for materials, energy, and other resources for Asia and the Pacific for the first time to underpin policies on sustainable resource use.

- Today's decisions will influence our future. Modelling and scenarios help us to envisage possible or likely futures and to assess the impact of a set of policies. It is important to understand the growth dynamic inherent in the Asia-Pacific region not just from an economic point of view but also from a biophysical perspective, to enable integrated environmental and economic policies.

- Asia and the Pacific has become the most dynamic region in the world today and global sustainability will be decided in this region. At the same time, the competitiveness of the Asia-Pacific region will depend on the speed and scale at which new industrial infrastructure that uses less materials and energy can be introduced to offset the unprecedented economic growth and growing standard of living. The alleviation of poverty is closely linked to this overall economic success story. Fostering resource efficiency now will enable the region to continue on a path to prosperity for its people.

- Resource efficiency will be a necessary but insufficient strategy for Asia and the Pacific. It will need to be complemented by systems innovation in major areas including housing, transport, food and energy.

Economic growth: a continuous history

Over only around 200 years – 10 generations or less – the industrial revolution fundamentally changed the way society and the economy relate to, and depend upon, the natural environment. Since then, the agrarian, biomass-based metabolism has been replaced by an industrial metabolism (Ayres and Simonis 1994), unleashing a growth dynamic not experienced before by humankind. The new industrial metabolism used new resources (fossil fuels), enabled a new magnitude of the use of 'exotic' materials (metals and other highly transformed outputs such as plastics and agri-chemicals) and created new forms of waste and emissions. Energy became available in previously unimaginable quantities and at very low cost, and new technologies enabled the creation of new products and services. These had a dramatic impact on people's lives, and created high standards of living in many parts of the world that were unprecedented in human history. Figure 1.1 depicts world economic growth between 1970 and 2005. (Note that prior to the dissolution of the Soviet Union in 1991, the Soviet Union was counted in Rest of World figures; after the dissolution, the Central Asian Republics were included in figures for the Asia-Pacific region).

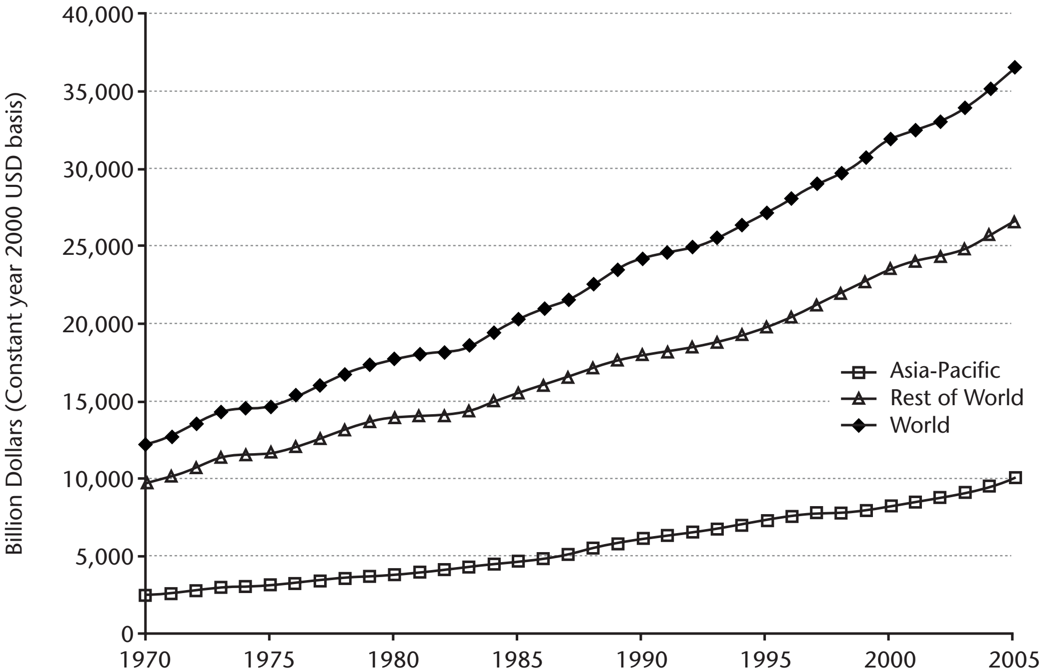


FIGURE 1.1.
GDP growth for the Asia-Pacific region, the Rest of the World, and the World, 1970–2005

Since the onset of the industrial revolution, human society and its economic activities have become a global geophysical force. Today, the amount of material and energy mobilized, and the waste and emissions created in production and consumption activities, have reached a magnitude similar to natural flows and thereby started to interfere with natural systems at all scales, from global to local. Paul Crutzen and others (Crutzen and Stoermer 2000) coined the term *Anthropocene* to describe the most recent period in the history of the Earth, when socio-economic activities have begun to have a significant global impact on the planet's climate and ecosystems.

As early as the 1970s, ecologists Ehrlich and Holdren (1971) investigated the issue of a growing population alongside growing per-capita incomes in their famous IPAT framework. IPAT stands for environmental impact (I) being a function of population (P) and affluence (A), mediated by available technologies (T). In a situation where both population and consumption grow quickly, there is a risk that technology is unlikely to be able to counteract the growth dynamic by allowing for greater efficiency of resource use (see Chapter 2).

The differences between agrarian and industrial metabolism are pronounced in regard to the amounts of materials and energy used. Making a transition from an agrarian to an industrial metabolism involves growth in per-capita material and energy use by a factor of three to five (see Box 1.1) (Krausmann *et al.* 2008).

Box 1.1: Social-ecological regimes and metabolic profiles

Social-ecological regimes involve the dynamic equilibrium of society–nature interactions and are characterized by typical patterns of material and energy flows (metabolic profiles) and land use patterns. From this perspective, industrialization is viewed as a transition from an agrarian to an industrial regime. This transition brings about fundamental changes in society and at the society–nature interface, which result in a three- to fivefold increase in resource use. Once the industrial transition in developing Asia has been completed, global energy and materials demand is likely to grow by a factor of two to three in coming decades.

	Unit	Agrarian	Industrial	Factor
Per-capita energy use	GJ per capita	40–70	150–400	3–5
Per-capita material use	Tonnes per capita	3–6	15–25	3–5
Population density	People per km^2	<40	<400	3–10
Share of agricultural population	%	>80%	<10%	0.1
Energy use per area	GJ per hectare	<30	<600	10–30
Material use per area	Tonnes per hectare	<2	<50	10–30
Share of biomass in energy use	%	>95%	10–30%	0.1–0.3

Source: Krausmann *et al.* (2008)

In their book *Socioecological Transitions and Global Change*, Fischer-Kowalski and Haberl (2007) explain how fundamentally different a sustainable society would be from the current industrial society, and show the difficulty of achieving a sustainability transition while large parts of the world are in the midst of the 'old' industrial transition.

The industrial transformation and the need to 'green' the economy

Many Asian countries, including the population giants of China and India have only recently embarked on their journey to become modern, industrial societies. Their huge agrarian populations have increasingly surged into urban agglomerations, creating vast settlements and challenges for urban mobility, housing, water availability, and waste and pollution control. Countries such as China have become the powerhouse of global economic development and the workshop of the world. Nonetheless, average per-capita income is still relatively low in comparison with more industrialized countries, as are the per-capita levels of material, energy, and water use. This is because the remaining large agrarian populations have not yet been subsumed into regional or global markets and do not share the material standards of living of the much wealthier population. Never before in human history has the industrial transformation occurred at the scale currently found in many Asian economies that are developing rapidly. This signals further new waves of growth to come.

The industrial transformation in Asian developing economies, the rise in material standards of living, and the reduction of poverty in many of these countries will require great amounts of natural resources and will generate large quantities of emissions. Because resources are finite and the absorptive capacity of the Earth's ecosystems is limited, the aspirations of nations and people will most likely be constrained by environmental factors. Recognizing these constraints, green growth was adopted at the fifth Ministerial Conference on Environment and Development for Asia and the Pacific (MCED) in 2005, as a key strategy for achieving sustainable development and the Millennium Development Goals (MDGs). Green growth can be defined as economic progress that fosters environmentally sustainable, low-carbon and socially inclusive development (ESCAP 2008). A green economy is characterized by substantially increased investments in economic sectors that build on, and enhance, the Earth's natural capital or reduce ecological scarcities and environmental risks. These sectors include renewable energy, low-carbon transport, energy-efficient buildings, clean technologies, improved waste management, improved freshwater provision, sustainable agriculture, forestry, and fisheries (UNEP 2010). This reshaping and refocusing of policies and investments can lead to better returns on natural, human, and economic capital while at the same time reducing environmental pressures and social disparities. This may well become a policy imperative to enable environmentally sustainable growth in the region that is home to almost two-thirds of the world's population. It also creates an unprecedented challenge for public policy. The Asia-Pacific region needs to achieve a sustainability transition, despite the forceful and persistent nature of the industrial regime.

Globalization and resource use

Global environmental change is closely linked to globalization. The notion of globalization, according to Bauman (1998), acknowledges the emerging global dimension of business, finance, and trade and information flows leading to ever more complex production–consumption chains. Despite increasing interconnectedness, part of the globalization process leads to progressive spatial segregation, separation and exclusion. As a result of globalization of economic activities, the physical quantities of goods imported and exported annually account for the fastest growing fraction of materials used. In many OECD countries, the domestic extraction of raw materials has grown slowly or stagnated, while trade flows have continued to grow quickly (Weisz *et al.* 2006). A similar situation occurs when the physical trade of many Asia-Pacific economies is examined.

In essence, this reflects that the increasing globalization of economic activities is enabled by a growing international division of labour and spatial separation of production and consumption activities. A national economy thus may externalize particular stages of the production of its domestically consumed final goods to other countries. This would involve the externalization of the environmental burden associated with the production of such goods. At the same time, a national economy may specialize in producing specific goods for the world market and would thereby internalize the associated environmental burden of production.

The overall tendency toward an increasing international division of labour and an increasing share of trade servicing consumption has important consequences for the definition of national resource use targets and indicators, if they are defined spatially. In this report, resource flows are presented within and between countries without assessing the embedded, upstream and downstream flows of energy, water, and carbon that accompany trade flows. Although the 'direct' accounts are an important first step towards establishing satellite accounts for resources in the Asia-Pacific region, subsequent work will need to focus on the resource consumption that occurs elsewhere but is caused by demand from the Asia-Pacific region and vice-versa.

Resource use and price signals

The ongoing process of globalization has created international markets for raw materials, goods, and services and has resulted in world market prices for many natural resources.

Economists have long argued that price is a measure of scarcity. If demand for natural resources is increasing in relation to supply this would result in an increase of the real price (i.e. after adjusting for inflation) of the natural resource. Conversely, if demand relative to supply is falling, then the price for natural resources would also fall. As early as 1963, economists Barnett and Morse started to collate prices for agricultural products, minerals, fish, and timber from the beginning of the 20th century and, in their account, the price of most resources had been falling over time (Barnett and Morse 1963). Updates of this analysis by Smith (1979) and Taylor (1993) tell a similar story. If economists are right that price reflects scarcity, this could only mean that natural resources were becoming more abundant with time. Why have prices of natural resources kept falling, suggesting increasing abundance?

Empirical research into price setting by corporations suggests that one reason for this apparent anomaly is that key assumptions in the neoclassical model of supply and demand are counter-factual: that is, the actual behaviour of supply curves in particular may be the opposite of what is assumed in theory. Blinder (1998, Chapter 4) found that 89% of firms surveyed had constant or falling marginal costs (where the sample represented 15% of the USA's manufacturing sector). This implies that production costs fall as volume rises, a phenomenon that could also apply to natural resources – at least up to the point at which diminishing remaining stocks reverse the fall in costs associated with higher volume extraction methods.

Markets show their greatest potential in providing a fast and cost effective coordination between supply and demand via the price mechanism. As Wit and Wilke (1998) have argued, the price mechanism works properly in situations of low complexity but fails in situations of high complexity. In cases where economic transactions are not characterized as free, short-term, direct, and transparent, and therefore easy to understand for everyone involved, markets are much less effective. These 'feedback' effects on prices, where, for example, an increase in demand can lead to a fall in price even if costs are consistent with the standard neoclassical model, were first highlighted by Sraffa (1960). The complexities of production in the multiple commodity real world are therefore likely to obstruct the apparently straightforward action of prices in signalling resource scarcity.

The institution of markets has reduced the complexity of economic exchange by introducing and allowing rational choice decisions. However, such evolutionary gains serve as a forcing house for new complexity to arise. The more complex are the products, forms of production, relations of exchange, time horizons, and cost–benefit calculations of suppliers and consumers, the more problematic is the assumption that markets could successfully regulate using the price mechanism.

Thus, models of ideal markets cannot be expected to operate in the real world because of the challenge of complexity and the very prominent issue of time. Lags in both price setting and the transference of resource shocks from one market to another mean that price changes may occur too late to prevent resource depletion; and they may overshoot and fluctuate wildly as productive constraints are approached. This is feasibly the case for global resource markets that involve large storage capacity, and extensive producer–consumer networks operating in complex and complicated institutional and power relationships.

In 2008, the world economy experienced price surges for a number of natural resources that occurred at the same time and were driven by increased production and consumption fuelled by rapid increases in economic activity in major developing economies, particularly China, India, and Brazil. This provides a reminder that natural resource prices behave much as any other commodity, with wide price swings in times of shortage or oversupply. The development of the oil price can be taken as an example. It has grown considerably since the end of 2003, and especially since the beginning of 2007. The price of West Texas Intermediate (WTI) – a leading benchmark crude oil – rose from a low of US$28 a barrel in September 2003 to US$74 in July 2006, before falling back to US$54 in January 2007. The price then rose to a peak of over US$145 in July 2008 (US Energy Information Administration 2010). Since the onset of the Global Financial Crisis in September 2008, prices have fallen back dramatically to levels as low as US$40, but have since recovered to US$80 per barrel by January 2010 as major economies are on a path toward economic recovery and consumption has picked up. Although further steep fluctuations in the price of crude oil due to economic cycles may well be expected, the International Energy Agency suggests an overall upward trend in crude oil prices resulting from a further tightening of market conditions, as demand increasingly outstrips installed crude production and refining capacity, and with growing expectations of continuing supply side constraints in the future. Hence, the IEA assumes a real price increase of 25% between 2010 and 2030 but puts caution behind this forecast. A continuing surge in demand, under-investment in production and refining capacity or a large sustained supply disruption caused by political crisis would result in much higher prices. On the other hand, a reduction in demand, faster than expected growth in investment or a shift to other energy carriers driven by higher prices or carbon reduction policies could well result in a lower average price (OECD/IEA 2010).

Metals are considered as a strategic input to many production processes and it has become more difficult and costly to extract metals from the less productive reserves that remain. An assessment by Halada *et al.* (2009) shows that the supply of metals will not keep up with rapidly increasing demand fuelled by growth in the Asia-Pacific region. Despite very high resource prices for major metals (such as iron and copper) prior to the Global Financial Crisis, research on long-term price trends (between 1947 and 2007) for metals by Mark C. Roberts (Roberts 2009a, 2009b) concludes that long-term real prices have been trendless.

During most of the 20th century hunger has become a problem of poverty rather than of absolute food scarcity. Koning *et al.* (2008) found that global food demand is on a steep increase (expected to more than double by 2050) while competing claims for biomass will also increase. Although the increase in demand may still be within the Earth's biophysical potential, the degradation of land and water reserves, potential stagnation in yields, a further rise in energy prices, and the underutilization of production possibilities in the developing world may well lead to a rise in food prices, similar to that experienced in late 2008, when prices for major food staples increased substantially.

Many of the natural resources upon which production and consumption activities depend, including fossil fuels, metals, major crops, and timber, are determined by global markets. The Asia-Pacific region has to be increasingly prepared to cope with a cost structure that is influenced by factors outside its sphere of influence. It will therefore be necessary to use resources effectively and efficiently to enable economic development and increased wellbeing within limited means.

The notion of decoupling

The dynamic and self-regulation of industrial development can be illustrated with a simple systems model describing the interrelationship between quality of life, wealth, and natural resource use (Fischer-Kowalski 1997). In modern, industrial societies, these three components are positively linked (Figure 1.2). In other words, industrial societies – within certain limits – experience positive feedbacks between economic development, the amount of natural resources used, waste and emissions generated, and quality of life. Additionally, each of these components may have an internal growth dynamic.

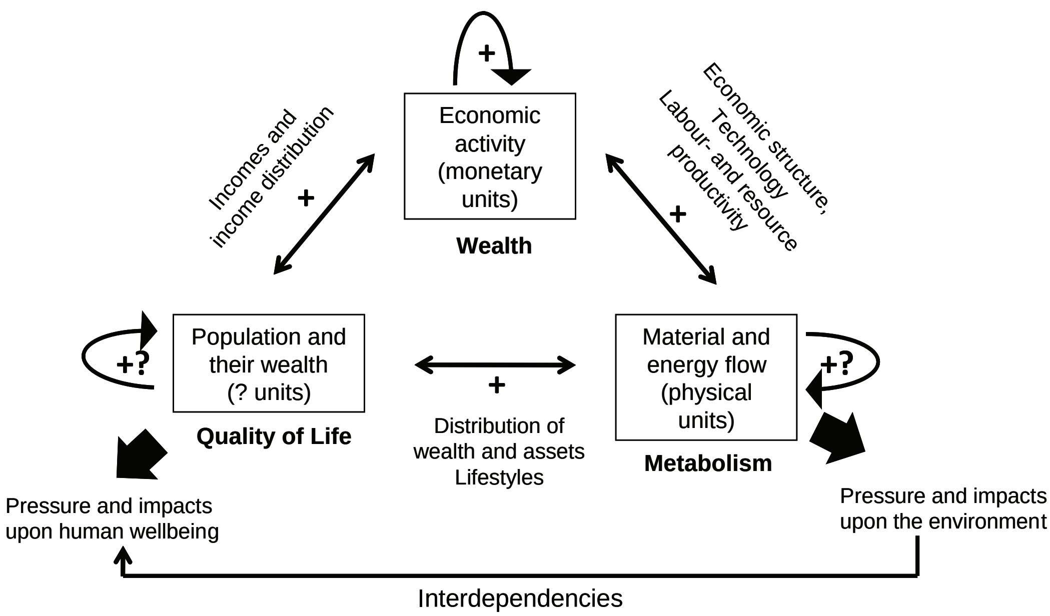


FIGURE 1.2. Modelling the interrelationship between quality of life, wealth, and metabolism. (Source: Fischer-Kowalski 1997)

Whether such self-reinforcing growth can occur indefinitely or only until certain constraints or limits hinder further growth is a key question facing environmental and economic policy makers. Thermodynamic considerations suggest that eventual scarcity of important resources (such as fossil fuels and rare metals) will occur. At the same time, the capacity of natural systems to absorb waste and emissions will decrease, thus further curbing economic activities. In reaction to the constraints to economic development that may come from the source or sink function of nature, three types of de-linking have been discussed within the environmental policy discourse of the last four decades.

In the 1970s, a Club of Rome report (Meadows *et al.* 1972) argued that improvements in the quality of life could be de-linked from economic growth and that economic growth, above a certain income level, does not further enhance quality of life. The authors argued that in a resource-constrained world, sustained exponential economic growth (above a threshold level that is exceeded by a large margin today) would lead to catastrophic outcomes and would result in the antithesis of a good life for many people. The notion of steady state and zero growth attracted harsh political antagonism, but, ultimately, even the advocates of economic growth have had to acknowledge that GDP has been used as a measure of welfare, without actually measuring welfare. As a consequence, attempts have been made to correct GDP in order to show the 'real' welfare effect in industrial economies. Most prominent among the attempts to calculate a green GDP was the Index of Sustainable Economic Welfare (Cobb and Cobb 1994).

A second critique that emerged was about the link between quality of life and resource use. The main proponents argued that ultimately more material goods and possessions do not automatically lead to greater happiness and that aspirations buoyed by the advertising industry lead to a cycle of work and spending, which stresses people and households. As an example of this line of argument, Juliet Schor (1998) showed how US society has been increasingly involved in a vicious cycle of overworking and overspending, which is reinforced by the socialization process from childhood (Schor 2004). For similar research in an Australian context, see Hamilton and Denniss (2005).

As a third perspective, the new public and policy discourse around sustainable development has allowed a rethinking of the de-linking debate by avoiding questioning economic growth as such. The main focus of the emerging efficiency and dematerialization debate has been to avoid wasteful management of precious natural resources through inefficient use. A significant increase in the efficiency of material and energy use to produce certain goods and services would, so the argument goes, enable economic growth and an increase in quality of life alongside reductions in material and energy throughput.

The potential for increased resource efficiency has been characterized by striking slogans such as Factor 4 – doubling wealth while halving resource use – (Von Weizsäcker *et al.* 1997) and Factor 10 (Hinterberger and Schmidt-Bleek 1999) and more recently Factor 5 (Von Weizsäcker *et al.* 2009). As many analytical studies have shown, there is great potential for efficiency gains, which have been well documented in the area of energy use (Jaenicke and Weidner 1995). The dematerialization debate has often used the argument that increased wealth eventually leads to better environmental policies and therefore reduced environmental impact, and has used the so-called 'Environmental Kuznets Curve' to demonstrate this argument (Selden and Song 1994; De Bruyn *et al.* 1998). Although empirical examples for dematerialization can be demonstrated for emissions that may be targeted by end-of-pipe technologies, there is little evidence on dematerialization in regard to overall material and energy use. For most countries, gains in efficiency of materials and energy use have been relative, and have not led to a decrease in total throughput (Weisz *et al.* 2006).

Rebound effect

A significant volume of literature exists around the issue of whether or not increased efficiency leads to environmental (or social) improvements. There is substantial empirical evidence and theoretical argument that efficiency gains, by themselves, have not generally resulted in an overall decrease in pressure, but instead are likely to have contributed to increased pressure due to the 'rebound' effect – also known as 'take-back' or Jevons' paradox as shown by Polimeni and Polimeni (2006) and in a special issue of Energy Policy (Schipper 2000).

Historical research has shown that, for many industrial economies, carbon intensity has been continuously decreasing for well over a century (Warr *et al.* 2010). At the same time, overall carbon emissions have grown exponentially (Grübler 1998). There is debate over whether efficiency gains have enabled overall growth or whether emissions would have been even higher without the efficiency gains because of growing population and economic growth (e.g. Laitner 2000). An alternative view takes a broader systems perspective and considers potential social or economic feedbacks between production and consumption – suggesting that technological improvements have led directly or indirectly to economic growth (Homer-Dixon 2006) and the conditions for population growth (Brookes 2000).

Such views are given more general theoretical grounding by the work of Saunders (2000) who showed that the theoretical existence or lack of rebound depends on the production function assumed for the economy, and that the magnitude of rebound is driven by the degree of substitution between factors (e.g. labour, capital, and energy). Of particular importance is the existence of interactions between factors of production (e.g. technological improvements increasing energy efficiency and simultaneously or subsequently increasing labour productivity), which may produce strong rebound and even 'backfire' – that is, where environmental impact is greater than if no efficiency improvement had been made. All this means that policies enabling greater resource efficiency will need to include additional measures to avoid rebound, which decreases overall achievements in the dematerialization of production and consumption.

Basic concepts around decoupling economic growth, resource use and environmental impact

Resource efficiency is defined as the efficiency with which materials and energy are used throughout an economy – that is, the added value per unit of resource input or emissions output.

Decoupling refers to de-linking economic growth from environmental pressure. Two forms of decoupling are important to consider: namely decoupling economic activity from resource use, and decoupling economic activity from environmental impacts. Decoupling of economic activity and resource use, also referred to as dematerialization, implies using less materials, energy, water, and land per unit of economic activity. Decoupling of economic activity from environmental impacts is more difficult to measure because impacts can be diverse, their trends may be quite different, and system boundaries and weighting strategies are often contested.

Decoupling may be relative or absolute. Relative decoupling refers to when economic activity grows faster than resource use (environmental impacts) grows. Absolute decoupling occurs when economic activity grows while overall resource use stabilizes or declines.

In many countries, relative decoupling is occurring, which means that economic activity (GDP) grows faster than resource productivity (GDP/resource use) leading to growing resource use but at a lower rate than that of GDP growth. To allow for absolute decoupling (i.e. reduction in resource use and environmental impact), resource efficiency and emission intensity must improve at a faster rate than GDP growth. Only if resource productivity increases faster than the volume of output (GDP) is an absolute reduction of resource use possible (Figure 1.3).

This criterion:

$$\delta GDP < \delta(GDP/\text{resource use})$$

is a necessary (but not sufficient) condition for environmental sustainability. This may be interpreted as a minimum condition for sustainability (see Spangenberg *et al.* 2002).

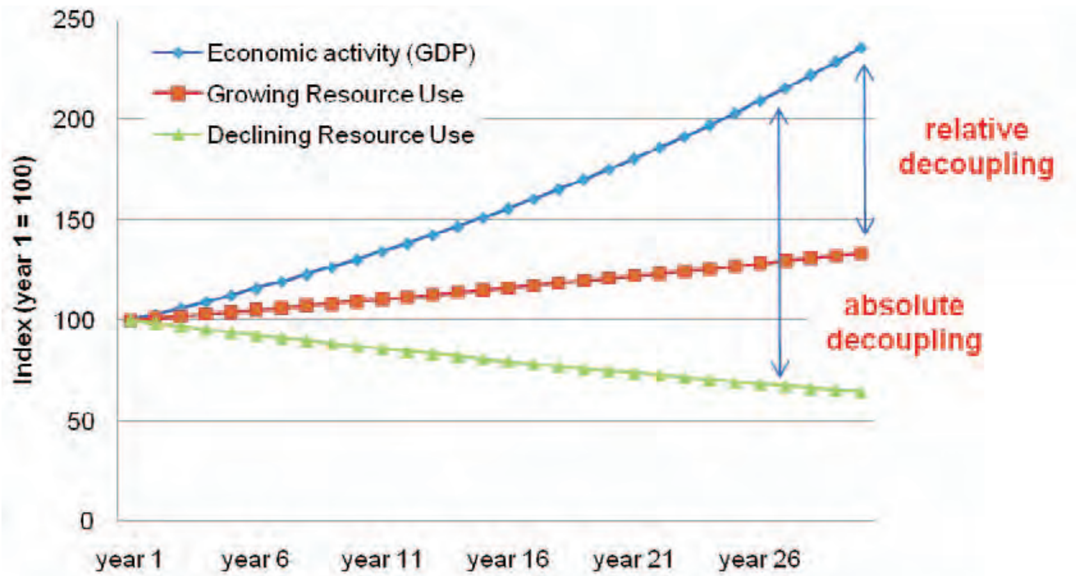


FIGURE 1.3.
Relative versus absolute decoupling of economic growth and resource use

The other focus of any sustainability strategy will be on employment and raising standards of living in order to lift people out of poverty and meet their aspirations. Overall employment will only grow if economic activity (GDP) grows at a faster rate than labour productivity (GDP/employment).

This criterion:

$$\delta GDP > \delta(GDP/\text{employment})$$

describes a precondition for more employment in absolute terms (necessary, although not sufficient for social sustainability), namely that overall labour productivity grows more slowly than the rate of economic growth. Labour productivity depends on hourly productivity as well as on the number of working hours per person. Employment policies may focus on either of those components.

In most of economic history, national economic development has been characterized by rapid improvements in labour productivity, which often occurred at the cost of material and energy productivity. This seemed an appropriate strategy in a situation when labour was a scarce resource and natural resources were abundant.

The overall context of economic activities has changed, to there being an abundant supply of labour and scarcer resources, especially in many Asia-Pacific economies. There is an increasingly urgent need to harmonize these two minimum conditions for sustainability by providing well-designed policies that allow for high employment and low resource use, thus setting overall resource and labour productivity on new trajectories.

This criterion:

$$\delta(\text{GDP/employment}) < \delta\text{GDP} < \delta L(\text{GDP/resource use})$$

provides a necessary condition for socio-environmental sustainability. As a minimum condition, it enables us to distinguish growth patterns that are certainly not sustainable from those that might be.

While it is increasingly debated whether economic growth should be the main policy objective in industrial countries (Victor 2008), there is a shared understanding that developing countries will need further economic and material growth to raise material standards of living and overcome poverty. It is argued that this additional growth in developing economies should be based on modern technologies and infrastructure in order to keep resource use and emissions as low as possible. However, the relationship between economic growth and household income needs to be examined to explore the extent to which economic growth will help to alleviate poverty.

There have been three contrary positions on the relationship between economic growth – both its rate and volatility – and the distribution of income from Kuznets's original speculation that there is a non-linear relationship between the two over time, to arguments that inequality promotes growth, and that it retards growth.

Galbraith, in a recent paper (2009), comes to several very important conclusions that overturn conventional beliefs about the relationship between inequality and growth. They are also consistent with the behavior of the disequilibrium, finance-oriented economic model developed for the REEO. Galbraith concludes that Kuznets was broadly correct about a non-linear relationship between growth and inequality, but that the relationship is broadly downward sloping in most countries: strong growth reduces inequality most of the time (Galbraith 2009). However, there are exceptions at both ends of the distribution. In countries such as China, which have a comparably low per-capita GDP and are in-midst the canonical transition of agriculture to industry, inequality rises with more rapid growth. By contrast, the United States and a few other advanced countries are on upward-sloping Kuznets curves for a different reason: they supply capital goods to world markets and so the highest incomes vary positively with the business cycle. The 'augmented Kuznets curve' that takes all of this into account has the form of a sideways inverted S.

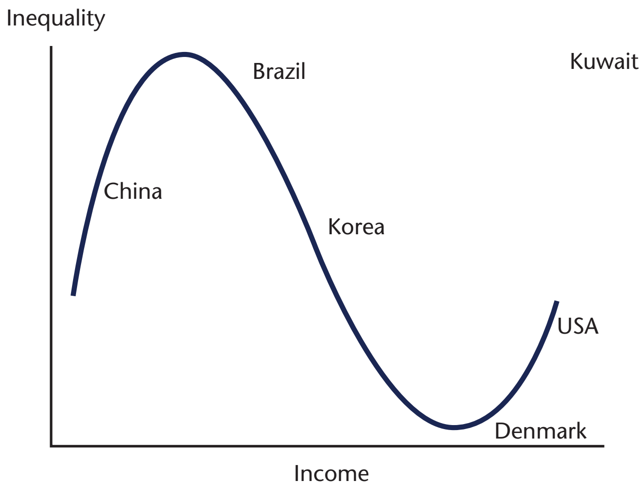


FIGURE 1.4.
A Kuznets curve for income and income distribution. (Source: after Galbraith 2009)

Measuring resource use and resource efficiency

There are many reasons why information on resource use will become more politically relevant at times when resource demands are growing quickly and supply systems show difficulties in coping with the rising demand. One main objective of this report is to provide such information to support high-level decision making. To do so, standard and harmonized concepts and methodologies are employed for establishing accounts on the major domains of natural resource use, including materials, waste and emissions to air, energy and carbon dioxide emissions, water use, and land use. These accounts represent the first attempts towards satellite accounts to systems of national accounts (SNA) and report on major pressures upon the environment.[1] The accounts and indicators share a number of attributes including compatibility with the SNA and policy relevance. Hence resource flow accounts can be linked to socio-economic activities and actors. This will help inform policy planning and policy evaluation in regard to sustainable resource use, resource management, and resource efficiency. The accounting is based on the credible scientific concept of industrial metabolism (Ayres and Simonis 1994) and utilizes existing statistical data and information from well-known and trusted sources.

Material use and material efficiency

Since 2006, important intergovernmental organizations such as the OECD and the European Statistical Office (Eurostat) have invested in establishing methodological guidelines for material flow indicators in a participatory process involving statistical offices and major scientific institutes. It is therefore possible to establish material flow accounts and indicators for national economies based on the standardized set of rules and methods provided in the 'MFA Compilation Guide' (Eurostat 2007). There is substantial background information available in a series of reports by the OECD (2008) on measuring material flows and resource productivity, including information on policy interpretation and use.

Material flow accounts take stock of all relevant natural resource inputs from domestic or imported sources, covering biomass, fossil fuels, metals and industrial and construction materials, and exports,

1 Establishing satellite accounts will require many years of effort from statistical offices in Asian and Pacific countries, and also at a regional level. This study should be seen as a major first step to encourage such investment by exploring feasibility and the impact on policy.

as well as waste and emission outputs. The most basic accounts treat the national economy as a 'black box' and focus on inputs and outputs, as well as changes in physical stocks of infrastructure. A set of high level national material flow indicators is based on those basic accounts and includes indicators for domestic extraction (DE), imports (IM), direct material input (DMI), exports (EX), the physical trade balance (PTB), and domestic material consumption (DMC) (Figure 1.5).

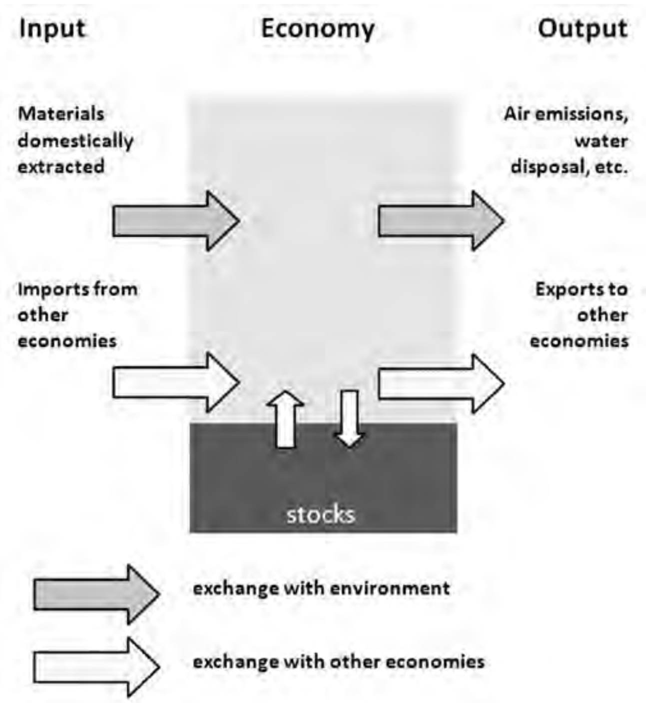


FIGURE 1.5.
Scope of material flow accounts. (Source: after Eurostat 2009)

For this report, basic material flow accounts have been established for individual Asia-Pacific countries using the international datasets of the Food and Agriculture Organization (FAO), the International Energy Agency (IEA), the United States Geological Survey (USGS), and the United Nations Trade database (COMTRADE).[2] Ideally, international data should be complemented by data available from within countries, which often offers more detail and allows specific characteristics of a country's material flows to be considered.

The basic accounts can be complemented by data on further aspects of material use such as

- flows within the economy (using physical input/output tables)
- embedded (upstream and downstream) flows related to imports and exports, calculated by accounting for the raw material equivalents (RMEs) of imports and exports
- unused extraction covering material flows that do not enter the economic process but have nevertheless considerable environmental impact (such as overburden in mining or by-catch and by-harvest in fishing and agriculture)
- detailed accounts of physical stocks.

2 A concise technical annex and data and indicators are available online at www.csiro.au/AsiaPacificMaterialFlows

National material efficiency is expressed as material productivity (GDP per unit of DMC) or material intensity (DMC per unit of GDP) based on real GDP and exchange values.

Energy use and energy efficiency

A national energy use and energy intensity indicator depends on energy flow accounts and energy balances, and takes into account all relevant aspects of energy conversion from primary energy sources to final use in economic activities, to useful energy (the amount of final energy that is put to use in the form of heat, motion, and light). The level of data harmonization for energy flows is much greater than for material flows, because of the comprehensive dataset available from the International Energy Agency (IEA), which is complemented by a detailed guidebook: the *Energy Statistics Manual* (OECD/IEA/Eurostat 2005).

Energy flow accounts and balances take account of all relevant energy flows starting from primary sources (coal, natural gas, oil, nuclear, wind, and water), and allocating these energy sources to major users including the primary sector, manufacturing, transport, construction, services, and households. There is further and more complicated data analysis involved in establishing useful energy accounts, as has been demonstrated by Ayres and Warr (2009) whose work covers the United States and Japan.

National energy efficiency is expressed as energy productivity (GDP per unit of total primary energy supply, TPES) or energy intensity (TPES per unit of GDP) based on real GDP and exchange values. Sectoral energy intensities may be calculated based on final energy consumption by economic sectors and the added value of those sectors, and these have the potential to complement national indicators by explaining the effect of different sectors' energy intensities on national results.

Carbon and emission efficiency

National carbon dioxide emissions intensity usually focuses on carbon emissions from energy use and ignores other forms of carbon emissions from industrial processes and land use change. National emissions data from burning fossil fuels is established by the IEA using a standardized methodology (IEA 2009). Data for other emitted air pollutants is usually scarce and only exists for certain years. If there is data available, it is usually disaggregated by economic activities following the National Accounting Matrix including Environmental Accounts (NAMEA) for air emissions guidelines (Eurostat 2009).

Water use efficiency

Calculating national water use intensity is difficult because of large data gaps. Water use statistics usually distinguish water supply from different sources such as groundwater and surface water, and the water demands of major economic sectors such as agriculture, manufacturing, and households.

Land use efficiency

The assessment of national land use intensity is far from being a straightforward process. Firstly, statistical datasets and data from areal assessment need to be harmonized to identify different land use categories such as agriculture, forestry or urban industrial land. There is little data available on urban/industrial land and no consistent dataset for other land use categories. In a next step, it is necessary to identify intensive land use categories such as cropland, plantations, managed forests, and urban/industrial land to account for total land in use. Combined with national GDP, a land use intensity indicator may be derived. Subsequently, sectoral indicators for agriculture, forestry and manufacturing, and service sector activities may be established. Despite many conceptual issues, the availability of data will be a main constraint.

Modelling

Scenarios are exploration of possible futures. They are not predictions, but explore what may constrain future developments and assess the potential impact of different policy interventions at a systems level. If properly done, they make synergies and trade-offs obvious in order to help decision makers be aware of and rethink what is achievable or what needs to be avoided. For the REEO report, two independent models were employed to explore future resource use and economic development and their interdependency.

The Asia-Pacific Stocks and Flows Framework (APSFF) is the main component of the modelling approach, linking population, production, consumption, technologies, and lifestyles within one integrated accounting scheme, thus allowing tensions between resource requirements and available resources in the future to be modelled (Figure 1.6).

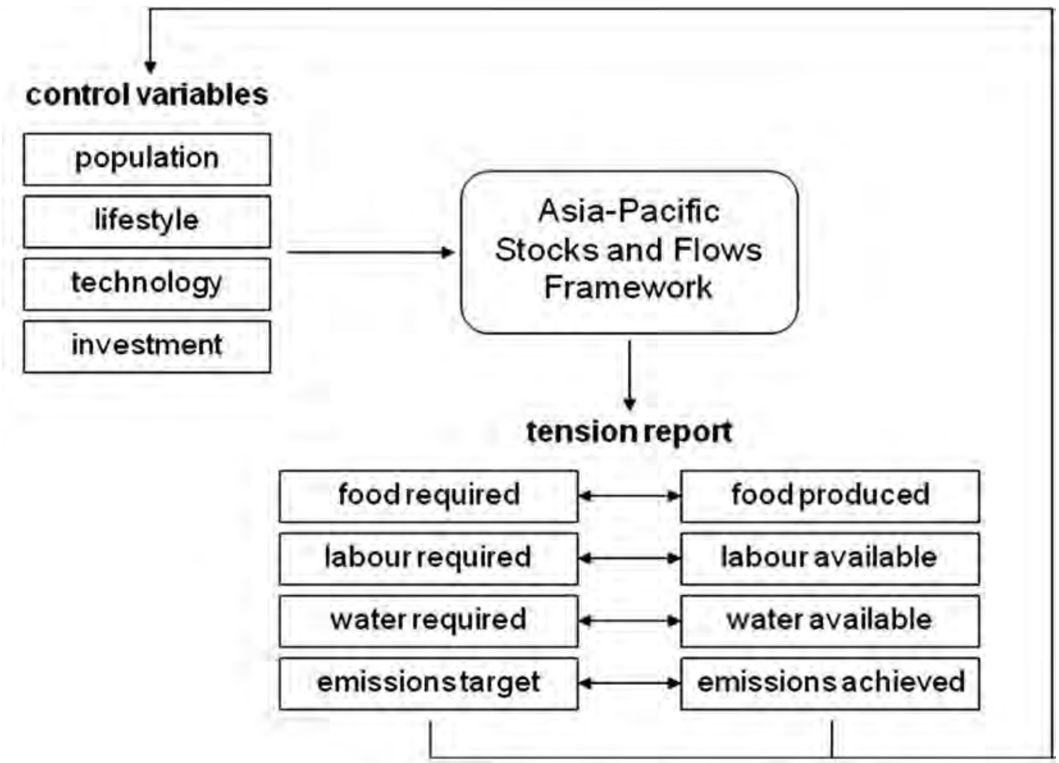


FIGURE 1.6.
The Asia-Pacific Stocks and Flows framework. (Source: after Foran and Poldy 2002)

The details of the APSFF modelling framework and the link to the economic model are explained in much greater detail in Chapter 7 of this report. The model integrates the accounts for materials, energy, water, land use, and emissions (Chapters 2–6) within one integrated assessment framework to test different policy options for their environmental and sustainability outcomes.

Why should Asia and the Pacific care about resource efficiency?

Most countries in the Asia-Pacific region have experienced large improvements in material standards of living over the past two decades. However, there is still prevailing disadvantage and poverty, and aspirations and resources often do not match. Economic development in the Asia-Pacific region will continue at a fast pace and will build more manufacturing capacity, modern buildings, infrastructure, and transport systems, and will enable increased household consumption through higher incomes. The economic success of the region may, however, eventually slow down or stall because of supply shortages of strategic resources and related price surges. Countries are facing constraints in regard to the capacity of landfills, waste incineration and ecosystems' absorptive capacity more generally. Such developments will negatively impact on social progress and will make the objective of reducing poverty much harder to achieve. This may eventually lead to socio-political instability and conflicts for resources.

To ensure future economic viability, the region needs to increase its capacity to use resources in a sustainable way. This means ensuring the availability of supplies at reasonable cost, and managing the environmental impact of resource use.

A focus on improving resource efficiency will help in tackling a number of urgent issues that are relevant for the Asia-Pacific region's future sustainability. Enhancing resource efficiency will:

- improve economic competitiveness and create new business opportunities
- preserve natural capital and local environmental quality
- ensure energy security and supply security of strategic materials
- tackle climate change, air pollution and waste problems
- help avoid social conflicts about resources
- pursue social benefits and improve living standards.

It is critical to identify the resource levels available, per capita, for sustainable lifestyles in the Asia-Pacific region and globally. This will involve reducing or avoiding environmentally unsustainable overconsumption in high-income households, which are potentially 'socially unsustainable' in a situation of growing aspirations, yet ensuring all people have access to sufficient resources.[3] In other words, policy frameworks need to guide Asia-Pacific economies toward sustainable lifestyles within the environmental space available (Spangenberg 2002) (Figure 1.7).

The challenge of enabling sustainable resource use in a situation of exponential growth is enormous. It will require a combination of resource efficiency measures (improvements in existing systems) and

3 Societies have seemed to function despite the economic poverty of parts of their population. Conflicts will be accentuated, however, because of the loss of traditional livelihoods, increasing reliability on market-based services, and growing income disparities, which are more obvious and visible at the same time.

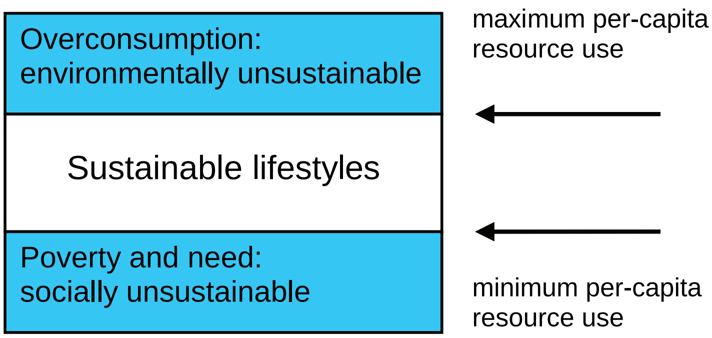


FIGURE 1.7.
Sustainable resource use (after Spangenberg 2002)

systems innovation (switching to new ways of providing services) in building, transport, energy, and water and sewerage systems to put the region on a trajectory toward sustainable resource use. The following chapters of this report explore ways in which this may be achieved.

Information will play an important role in the development of policies to achieve economic prosperity, poverty reduction, and sustainable environmental and natural resource outcomes simultaneously. Countries need to invest in the knowledge base and institutional capacity to establish integrated environmental information systems, to develop and update the relevant datasets and indicators to inform policy and review progress of sustainable development in Asia and the Pacific.

References

Ayres RU and Simonis UE (1994) *Industrial Metabolism. Restructuring for Sustainable Development*. UN University Press: Tokyo.

Ayres RU and Warr B (2009) *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Edward Elgar: Cheltenham.

Barnett H and Morse C (1963) *Scarcity and Growth: The Economics of Natural Resource Availability*. Johns Hopkins University Press for Resources for the Future: Baltimore.

Bauman Z (1998) *Globalization: The Human Consequences*. Polity Press: Cambridge, UK.

Blinder AS (1998) *Asking about Prices: A New Approach to Understanding Price Stickiness*. Russell Sage Foundation: New York.

Brookes L (2000) Energy efficiency fallacies revisited. *Energy Policy* **28**(6–7): 355–366.

Cobb CW and Cobb JB (1994) *The Green National Product: A Proposed Index of Sustainable Economic Welfare*. University Press of America: Lanham.

Crutzen PJ and Stoermer EF (2000) The Anthropocene. *Global Change Newsletter* **41**: 17–18.

De Bruyn SM, van den Bergh JCJM and Opschoor JB (1998) Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves. *Ecological Economics* **25**(2): 161–175.

Ehrlich PR and Holdren JP (1971) Impact of population growth. *Science* **171**(3977): 1212–1217.

ESCAP (2008) 'Greening growth in Asia and the Pacific'. Follow-up to the World Summit on Sustainable Development. Economic and Social Commission on Asia and the Pacific: Bangkok.

Eurostat (2001) *Economy-wide Material Flow Accounts and Derived Indicators – A Methodological Guide*. Eurostat: Luxembourg.

Eurostat (2007) *Economy-wide Material Flow Accounting – A Compilation Guide*. Eurostat: Luxembourg.

Eurostat (2009) *Manual for Air Emission Accounts*. Eurostat: Luxembourg.

Fischer-Kowalski M (1997) Dynamik und Selbststeuerung industrieller Gesellschaften. In: Fischer-Kowalski, M, H. Haberl, W. Hüttler, H Payer, H Schandl, V Winiwarter and H Zangerl-Weisz. *Gesellschaftlicher Stoffwechsel und Kolonisierung von Natur. Ein Versuch in Sozialer Ökologie*. Gordon and Breach: Amsterdam.

Fischer-Kowalski M and Haberl H (Eds) (2007) *Socioecological Transitions and Global Change: Trajectories of Social Metabolism and Land Use*. Edward Elgar: Cheltenham.

Foran B and Poldy F (2002) 'Future dilemmas: options to 2050 for Australia's population, technology, resources and environment'. Report to the Department of Immigration and Multicultural and Indigenous Affairs. CSIRO Sustainable Ecosystems: Canberra.

Galbraith JK (2009) Inequality, unemployment and growth: new measures for old controversies. *Journal of Economic Inequality* **7**(2): 189–206.

Grübler A (1998) *Technology and Global Change*. Cambridge University Press: Cambridge, UK.

Halada K, Ijima K, Shimada M and Katagiri N (2009) A possibility of urban mining in Japan. *Journal of the Japan Institute of Metals* **73**(3): 151–160.

Hamilton C and Denniss R (2005) *Affluenza: When Too Much Is Never Enough*. Allen & Unwin: Sydney.

Hinterberger F and Schmidt-Bleek F (1999) Dematerialization, MIPS and factor 10. Physical sustainability indicators as a social device. *Ecological Economics* **29**: 53–56.

Homer-Dixon T (2006) *The Upside of Down-Catastrophe, Creativity and the Renewal of Civilization*. Island Press: Washington DC.

IEA (2009) *CO_2 Emissions from Fuel Combustion*. International Energy Agency: Paris.

Jaenicke M and Weidner H (1995) *Successful Environmental Policy: A Critical Evaluation of 24 Cases*. Edition Sigma: Berlin.

Koning NBJ, Ittersum MKV, Becx GA, van Boekel MAJS *et al.* (2008) Long-term global availability of food: continued abundance or new scarcity? *NJAS – Wageningen Journal of Life Sciences* **55**: 229–292.

Krausmann F, Fischer-Kowalski M, Schandl H and Eisenmenger N (2008) The global sociometabolic transition. *Journal of Industrial Ecology* **12**(5–6): 637–656.

Laitner JA (2000) Energy efficiency: rebounding to a sound analytical perspective. *Energy Policy* **28**(6–7): 471–475.

Meadows DH, Meadows DL, Randers J and Behrens III WW (1972) *The Limits to Growth*. Universe Books: New York.

OECD (2008) 'Measuring material flows and resource productivity: synthesis report'. OECD: Paris.

OECD/IEA (2010) 'Oil market report'. International Energy Agency: Paris.

OECD/IEA/Eurostat (2005) *Energy Statistics Manual*. OECD/IEA/Eurostat: Paris.

Polimeni JM and Polimeni RI (2006) Jevons' Paradox and the myth of technological innovation. *Ecological Complexity* **3**(4): 344–353.

Roberts MC (2009a) Synchronization and co-movement of metal prices. *Minerals and Energy: Raw Materials Reports* **23**(3): 105–118.

Roberts MC (2009b) Duration and characteristics of metal price cycles. *Resources Policy* **34**: 87–102.

Saunders HD (2000) A view from the macro side: rebound, backfire, and Khazzoom-Brookes. *Energy Policy* **28**(6–7): 439–449.

Schipper L (2000) On the rebound: the interaction of energy efficiency, energy use and economic activity. An introduction. *Energy Policy* **28**(6–7): 351–353.

Schor J (1998) Time, labour and consumption: guest editor's introduction. *Time & Society* **7**: 119–127.

Schor J (2004) *Born to Buy*. Scribner: New York.

Selden TM and Song D (1994) Environmental quality and development: is there a Kuznets Curve for air pollution emissions? *Journal of Environmental Economics and Management* **27**: 147–162.

Smith VK (1979) *Scarcity and Growth Reconsidered*. Johns Hopkins University Press for Resources for the Future: Baltimore.

Spangenberg JH (2002) Environmental space and the prism of sustainability: frameworks for indicators measuring sustainable development. *Ecological Indicators* **2**: 295–309.

Spangenberg JH, Omann I and Hinterberger F (2002). Sustainable growth criteria: minimum benchmarks and scenarios for employment and the environment. *Ecological Economics* **42**: 429–443.

Sraffa P (1960) *Production of Commodities By Means of Commodities: Prelude to a Critique of Economic Theory*. Cambridge University Press: Cambridge, UK.

Taylor J (1993) The growing abundance of natural resources. In *Market Liberalism: A Paradigm for the 21st Century*. (Eds D Boaz and EH Crane) pp. 363–378. Cato Institute: Washington DC.

UNEP (2010) ‘The green economy initiative’. Retrieved 19 May 2010, from http://www.unep.org/greeneconomy/.

US Energy Information Administration (2010) Independent statistics and analysis: petroleum navigator. Washington DC. Retrieved 10 December2010, from http://tonto.eia.doe.gov/dnav/pet/pet_sum_top.asp.

Victor PA (2008) *Managing Without Growth: Slower by Design, Not Disaster*. Edward Elgar: Cheltenham.

Von Weizsäcker E, Hargroves K, Smith MH, Desha C and Stasinopoulos P (2009) *Factor 5. Transforming the Global Economy through 80% Improvements in Resource Productivity*. Earthscan: London.

Von Weizsäcker E, Lovins AB and Lovins LH (1997) *Factor Four: Doubling Wealth, Halving Resource Use*. Earthscan: London.

Warr B, Ayres RU, Eisenmenger N, Krausmann F and Schandl H (2010) Energy use and economic development: a comparative analysis of useful work supply in Austria, Japan, the United Kingdom and the US during 100 years of economic growth. *Ecological Economics* **69**(10): 1904–1917.

Weisz H, Krausmann F, Amann C, Eisenmenger N, Erb KH, Hubacek K and Fischer-Kowalski M (2006) The physical economy of the European Union: cross-country comparison and determinants of material consumption. *Ecological Economics* **58**(4): 676–698.

Wit A and Wilke H (1998) Public good provision under environmental and social uncertainty. *European Journal of Social Psychology* **28**(2): 249–256.

Chapter 2: **Materials**

Heinz Schandl and James West

Main messages

- At the beginning of the 21st century, the Asia-Pacific region has overtaken the rest of the world to become the single largest user of natural resources. Total resources consumed in 2005 – including biomass, fossil fuels, metals, and industrial and construction materials – amounted to around 32 billion tonnes, or 8.6 tonnes per capita. While resource use in the Asia-Pacific region has grown strongly over the last three decades, there is still huge potential for future growth. In coming decades, the Asia-Pacific region will be the most important driver of global resource use and related environmental impacts, including resource scarcity, pollution, and climate change.

- In 2005, the subregions of the Asia-Pacific showed stark differences in domestic material consumption, ranging from very low material consumption in South Asia and South-East Asia of between 5 and 7 tonnes per capita, to moderate material consumption of 10 tonnes per capita in the Pacific, 12 to 13 tonnes per capita in Central Asia and North-East Asia, and high material consumption in Australia and New Zealand of above 47 tonnes per capita.

- Whilst the region is diverse, with both large material exporters and importers, the Asia-Pacific region overall will become increasingly dependent on imported materials to enable continued manufacturing growth and increasing material standards of living. While Australia and New Zealand, and to a lesser extent Central Asia, were net exporters of materials, all other regions were either only marginally integrated in world resources markets, or on a trajectory to become reliant on imported resources, following the example of North-East Asia.

- Over the last three decades, the Asia-Pacific region has shifted from a biomass-based to a minerals-based economy. Construction materials were the fastest growing component of domestic material extraction. Fossil fuels, metal ores and biomass were the major net imports.

- Continuing improvements in material efficiency seem to be an endogenous trend in economic development and, on a global scale, material efficiency has improved over the last century. Material efficiency in the Asia-Pacific region, however, was stagnant between 1970 and 1990 and, since then, the region has lost efficiency owing to shifts in economic activity from very efficient producers (e.g. Japan) to less efficient producers (e.g. China). In 2000, this trend reversed global material efficiency for the first time in a century, and the world today is using resources increasingly less efficiently.

- The history of resource use has put different countries on different trajectories and therefore created very specific sustainability problems for each country. This report looks in greater detail at a group of 10 countries that are typical of different resource use pathways in the region. Trends for China and India, especially, are very important because they currently account for 60% and 20% respectively of all materials consumed in the region, and both countries show huge potential for further growth.

- Material use over the last three decades was driven mainly by rising wealth and per-capita income and, to a much lesser extent, by growing populations. Crucially, while advances in technology and innovation are often assumed to strongly moderate growth in materials use and emissions, this dynamic does not appear to have contributed much to mitigating the environmental impacts of production and consumption in the Asia-Pacific region over the last three decades. This was especially the case in North-East Asia for the period 1985–1995, and puts a question mark over how well justified this assumption is.

- The speed and magnitude with which new infrastructure and productive capacity is being established in the Asia-Pacific region presents both a huge challenge, and a great opportunity for innovation and to introduce new and more sustainable technologies and systems. The choices being made now will have long lasting effects, for decades to come. It would be unwise to rely on the right choices for the longer term sustainability being made entirely spontaneously. Ensuring that this opportunity is exploited will require well-designed policies that take an integrated view of economic, social, and environmental imperatives.

Material use patterns and material efficiency in Asia and the Pacific

The use of natural resources (materials, energy, water, and land) underpins all of humanity's economic and social activities. Natural resources are extracted, concentrated, and transformed to enhance their value for a vast range of consumptive activities. Some natural resources are used up in the process of consumption (e.g. food, feed, and fuels) while others are transformed into durable artefacts (e.g. buildings, infrastructure, machinery, and consumer goods), which last much longer. Waste and emissions occur at all stages of the production–consumption process and, ultimately, at the end of its useful lifetime, every primary resource is discharged into the environment as a waste or an emission.

Throughout world history, humanity has consumed ever greater amounts of natural resources, assisted by advancing technologies and driven by new, material- and energy-intensive lifestyles. Most of the global growth in resource use has occurred in high-income OECD countries, but recently the Asia-Pacific region has emerged as a major global resource consumer and had, by the end of the 20th century, overtaken the rest of world in overall material use. Since the 1970s, the Asia-Pacific region has been characterized by significantly higher rates of growth in materials use than any other region of the world. As a consequence, it is rapidly catching up with the world average in per capita material use, and retains a considerable potential for further growth relative to OECD countries (Krausmann *et al.* 2008). This very strong growth in resource use has been driven to a large extent by massive construction of new infrastructure and buildings in fast-growing cities and the emergence of major Asia-Pacific region economies as centres of global manufacturing, as well as the emergence of new consumers (Myers and Kent 2004). These developments, while they have enabled fast economic growth and a higher standard of living for part of the Asia-Pacific population, have also had a negative impact on the region's material efficiency (i.e. the efficiency of materials used per unit of economic output), because natural resources use has grown more rapidly than economic output.

Figure 2.1 shows that domestic materials consumption (DMC) by the Asia-Pacific region grew from 7.7 billion tonnes in 1975 to 32.1 billion tonnes in 2005, which is a more than fourfold increase. Although growth in global DMC doubled over the period 1971–2002, reference to the two components of this growth (Asia-Pacific and the rest of the world (ROW)) shows that growth in world DMC is dominated by expansion in the Asia-Pacific region, with the total increase in the ROW DMC for the period contributing less than 20%. In short, the Asia-Pacific region accounted for 80% of the growth in world material use over the 35 years to 2005.[1]

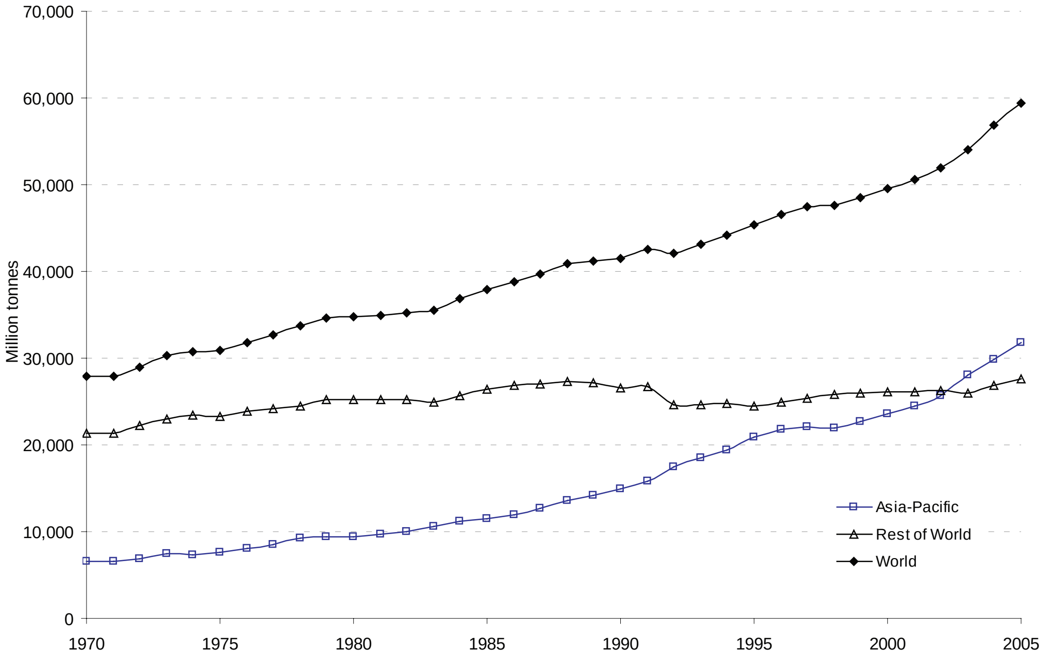


FIGURE 2.1.
Domestic materials consumption for the Asia-Pacific region, rest of the world, and world, for the years 1970–2005

Around 2002, two important new features of global resource use become apparent. Firstly, DMC for the Asia-Pacific region overtook that for the ROW, having started out three decades earlier at around one third of the ROW level. The second feature is a marked increase in the rate of growth for the world overall from 2002 on, again propelled mainly by the Asia-Pacific region, but coinciding with a period of stronger growth for the ROW as well. From 2000 on, the combined world curve appears to switch to a higher growth regime. The growth curve for the Asia-Pacific region for much of the period 1970–2005 appears more exponential than linear, approximating a compounding annual rate of growth of 4.6% from 1970 to 1997 (i.e. prior to the 1997 Asian economic crisis), and 5.0% in the rebound period from 1999–2005 following that event, or 4.8% for the entire 1970–2005 interval. With the increasingly dominant role of the Asia-Pacific region in global DMC, it is probable that world DMC will come to reflect the past trajectory of the Asia-Pacific region more closely.

1 Note that the marked decline in the ROW DMC apparent in 1991–1992 is associated with the breakup of the USSR and the subsequent re-allocation of some of the successor states to the Asia-Pacific region. Data are in the Asia-Pacific material flows database, at www.cse.csiro.au/forms/form-mf-start.aspx.

Figure 2.2 shows a trend towards convergence in per capita DMC between the Asia-Pacific and the ROW. A strong trend towards higher levels of per capita DMC in the Asia-Pacific region over most of the period 1970–2005 stands in direct contrast to the downward trend that characterizes the ROW for most of this period. Whereas DMC for the Asia-Pacific region in 1970 stood at less than 3.2 tonnes per capita and was approximately 25% of the contemporary figure for ROW, by 2005 it had risen to more than 8.6 tonnes per capita, over 87% of the corresponding ROW figure.[2]

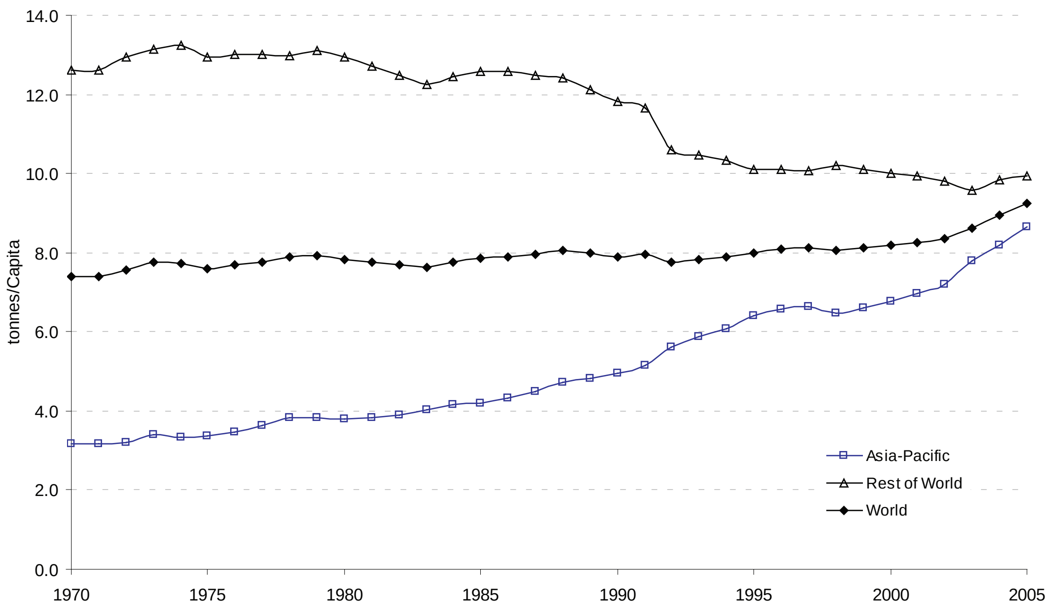


FIGURE 2.2.
Domestic materials consumption per capita for the Asia-Pacific region, rest of the world, and world, for the years 1970–2005

The trend towards higher levels of per capita DMC for the Asia-Pacific region is readily explained as a consequence of large sections of the region's population becoming increasingly affluent over the period, so acquiring the means to consume more.

A less expected and potentially more disturbing feature of Figure 2.2 is the acceleration upwards of the per capita DMC for the Asia-Pacific region in recent years, at a time when the ROW per capita consumption of materials was reversing strongly. It appears that, rather than converging towards some static DMC per capita figure, which might have been expected by projecting the trends up to the end of the 20th century, convergence may actually be to an upward trending line – in other words, the world's citizens as a whole are consuming more, leading to emerging shortages for many critical materials. If it persists, this trend will undermine the hope that societies may 'dematerialize' above a certain level of wealth through deliberate environmental policy efforts (Grossman and Krueger 1995), at least for any level of wealth currently being experienced by a significant proportion of the world's population. While there was a clear trend towards dematerialization for the ROW, viewed in isolation, the trend for the world overall continued to show a modest but accelerating increase. This suggests that, rather than any fundamental dematerialization taking place, the trend observed at national and regional levels was largely due to the displacement of production from wealthier nations in the ROW to the Asia-Pacific region.

2 Note that values for the ROW should not be interpreted as approximating averages for developed countries. The ROW grouping includes some of the poorest regions on Earth, but also includes some of the richest countries.

The overall trajectory in per capita DMC for the Asia-Pacific region between 1971 and 2005 means that the region's citizens have been consuming materials at a compounding annual rate of growth of around 3.0%.

Figures 2.3 to 2.5 provide a more detailed view of how material flows per capita are distributed among subregions of the Asia-Pacific region, and how levels of these flows changed between three specific points in time (1975, 1990 and 2005).

Figure 2.3 shows a very high rate of domestic extraction (DE) in the Australia and New Zealand subregion, on a per capita basis, relative to the other subregions. At around 68 tonnes per capita, this rate of DE is around five times the next highest (Central Asia at approximately 14 tonnes per capita). The disparity is such that the growth component alone in DE per capita for Australia and New Zealand between 1990 and 2005 was greater than total DE per capita for the next highest region. The compounding growth rate for Australia and New Zealand from 1975–2005 was around 2.1%. Such high natural resource extraction is explained by the importance of the primary export industries (mining and agriculture) in Australia and New Zealand, enabled by rich resource endowment and very low population density (see Schandl *et al.* 2008 for a detailed picture of Australia's resource use trajectories).

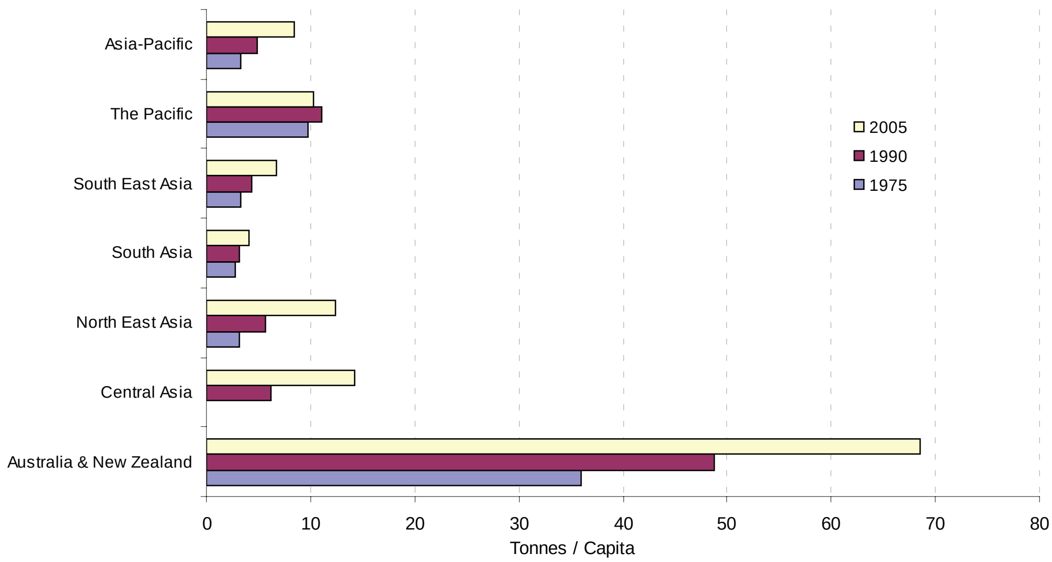


FIGURE 2.3.
Domestic extraction of primary materials per capita for the Asia-Pacific region and its constituent subregions for the years 1975, 1990, and 2005

Less immediately apparent, because it starts from a much lower base, is the very rapid rate of growth in DE in North-East Asia. From a little over 3.2 tonnes per capita in 1975, DE nearly doubled to 5.7 tonnes per capita in the 15 years to 1990, and then more than doubled again to over 12.3 tonnes per capita by 2005. This corresponds to an average compounding growth rate in DE of around 4.6% p.a., sustained over three decades, and was a key factor in the 'economic miracle' of China (Wu 2004).

Despite the very large per capita DE values for Australia and New Zealand, the overall DE per capita value for the region as a whole is clearly dominated by, and intermediate between, the values for North-East Asia and South Asia (including India and Pakistan). This is a result of their much larger populations: in 2005, North-East Asia and South Asia each held over 41% of the region's total population, while Australia and New Zealand accounted for less than 0.7%.

Figure 2.4 shows the physical trade balance (PTB) – that is, imports minus exports – for the same set of subregions and provides an indication of which subregions serve as net sources of (predominantly[3]) primary materials, which subregions require net inputs from areas outside of their domestic territories, and which are largely self sufficient in materials (in net tonnage terms).

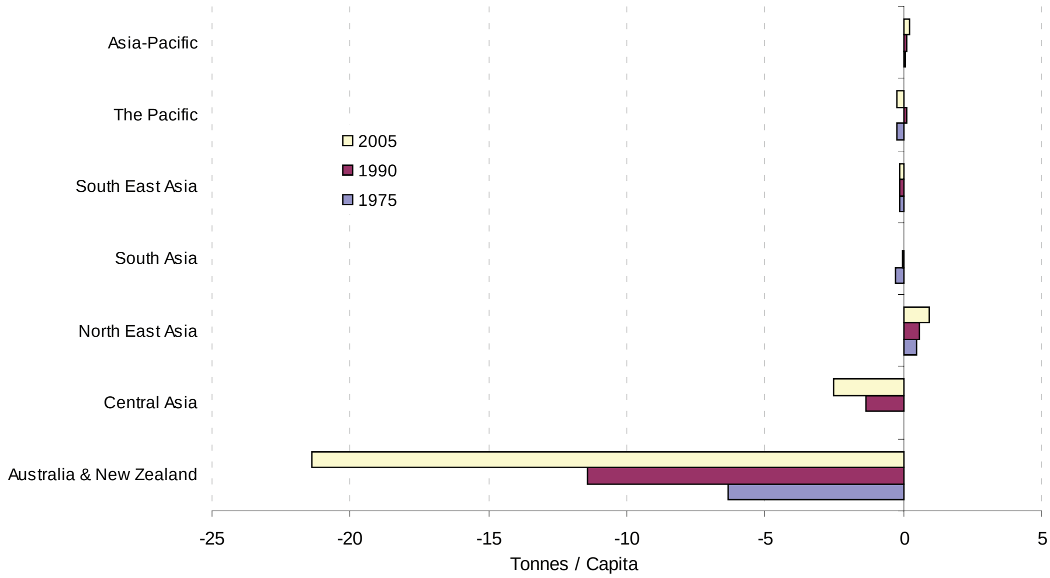


FIGURE 2.4.
Physical trade balance per capita for the Asia-Pacific region and its constituent subregions for the years 1975, 1990 and 2005

Australia and New Zealand are again prominent in Figure 2.4, with a strongly negative PTB (i.e. exports exceed imports), growing from –6.3 tonnes per capita in 1975 to –21.4 tonnes per capita by 2005: an average compounding growth rate of 4.2% p.a. Not only is this subregion's level of net exports over eight times higher than the next highest exporter (Central Asia at –2.5 tonnes per capita in 2005), but this level of exports is over 50% higher than the highest level of domestic extraction per capita elsewhere in the region (refer back to Figure 2.3). The material flows characterizing this subregion's economy are quite anomalous within the region, and identify it as a strategic source region for primary materials used elsewhere. The nearest parallel within the region on this measure is Central Asia.

Three of the other subregions (the Pacific, South-East Asia, and South Asia) are characterized by small PTB per capita, indicating a large degree of self sufficiency in materials in net tonnage terms. Within this group of three subregions, the trend for South Asia is of most importance. Although the per capita quantities involved are small, going from –0.27 tonnes per capita in 1975 to 0.04 tonnes per capita in 2005, it is significant that South Asia has moved from being a net exporter of materials to requiring net material inputs from outside. If this trend is sustained into the future, combined with the large population of South Asia, it will require either a major expansion in domestic extraction elsewhere or a significant redirection of existing international trade flows.

3 The physical trade balance established for this report focuses on primary materials, but also includes some processed materials such as iron, steel, non-ferrous concentrates, refined petroleum products, and so on, for which data were available, and that could be fitted well into a category and maintained a significant portion of the initial mass.

For North-East Asia, the PTB rose from 0.47 tonnes per capita in 1975 to 0.93 tonnes per capita in 2005, consistent with a compounding growth rate of 2.3%. Although the per capita numbers are modest, the high population of this subregion results in total net imports for North-East Asia being over twice the size of the trade flows for any of the other subregions. Most of this growing dependency on foreign resources can be attributed to China's economic and manufacturing growth, and this has implications for resource scarcity and commodity prices, which rose rapidly during the year 2008 owing to supply shortages. It will be essential for China's competitive position as a global producer to reduce its international resource dependence through policies that foster the effective and efficient use of raw materials for production.

Figure 2.5 reflects actual consumption of primary materials within each subregion for 1975, 1990, and 2005. The main features and observations from this diagram are broadly the same as those for Figure 2.3 but there is less contrast between the different subregions.

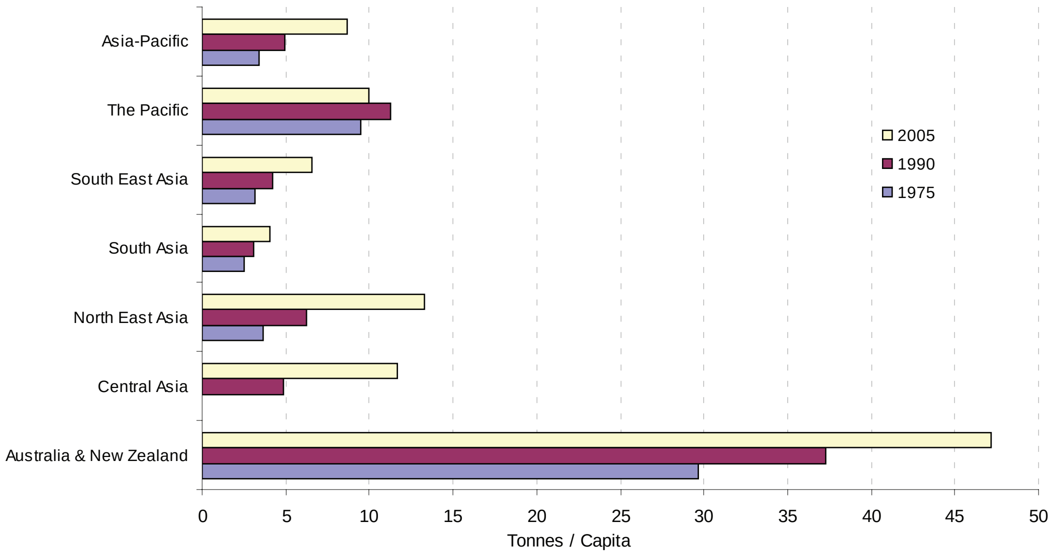


FIGURE 2.5.
Domestic materials consumption per capita for the Asia-Pacific region and its constituent subregions for 1975, 1990, and 2005, tonnes per capita

The observed narrowing in disparities between different subregions after trade is accounted for raises the further issue of which activities are classed as 'consumption'. Here, with the limited exceptions outlined previously, a primary material is considered to have been consumed at its first point of transformation. The implications of this approach, and the effect it has on the material flow accounts of countries with different economic structures, are discussed in Box 2.1. It is sufficient to say that if consumption of a primary material were allocated instead to the point at which the final material of value reaches the end consumer, the DMC profiles of some of these subregions would change quite radically.

Box 2.1: 'Who is the consumer?'

As production systems become more globalized, objectively attributing consumption of natural resources to individual countries becomes more difficult. The problem is well illustrated in the production and use of metals. Using copper as an example, the initial ore from which metal is extracted is typically only around 1% copper, with 99% waste minerals. The bulk of the waste is removed early in the production process, to reduce transport costs. International trade in copper is thus mainly in the form of concentrates (which typically preserve less than 10% of the initial ore mass) or refined metal (preserving 1%). Even if none of the actual metal is retained in the source country, it will be credited with having 'consumed' between 0.9 and 0.99 tonnes of metal ores and concentrates. The country that imports the concentrated product will only be credited with consumption of 0.1 to 0.01 tonnes of metal ores and concentrates, even if all of the material of economic value is used there in long-lived infrastructure such as wiring or pipes.

A similar situation occurs when attributing energy consumption. Most of the energy embodied in an aluminum product will generally be attributed to the country where the aluminum was refined, regardless of where the final product is used.

This mechanism helps explain why some highly affluent countries exhibit relatively low apparent consumption of materials and energy. By importing their resource requirements in highly concentrated forms, they transfer the bulk of their primary materials and energy footprint to source countries. Those source countries exhibit a corresponding inflation in their materials and energy consumption.

Figure 2.6 shows how domestic extraction (DE) of five major primary materials within the Asia-Pacific region has changed over time: for biomass, construction minerals, fossil energy carriers, industrial minerals and metal ores in separation. The most obvious development over the period has been the degree to which construction minerals have replaced biomass as the largest category. From accounting for less than 27% of total DE in 1975, construction minerals grew to over 52% by 2005.

Over the same period, total biomass DE continued to grow quite strongly, from 3.8 billion tonnes in 1975 to 8.8 billion tonnes in 2005: a compounding growth rate of 2.8% p.a. However, the extremely rapid rate of DE growth in construction minerals (7.2% p.a.) resulted in biomass's share falling from around 50% of the total in 1975 to 27% by 2005. This decrease in the relative importance of biomass was expected, because it is characteristic of societies transitioning from agrarian to more industrialized economies and reflects the related change in the structure of material and energy flows (Krausmann *et al.* 2008; Schandl and Turner 2009).[4]

4 A detailed breakdown of the change in shares for each major category is provided in Figure 2.9.

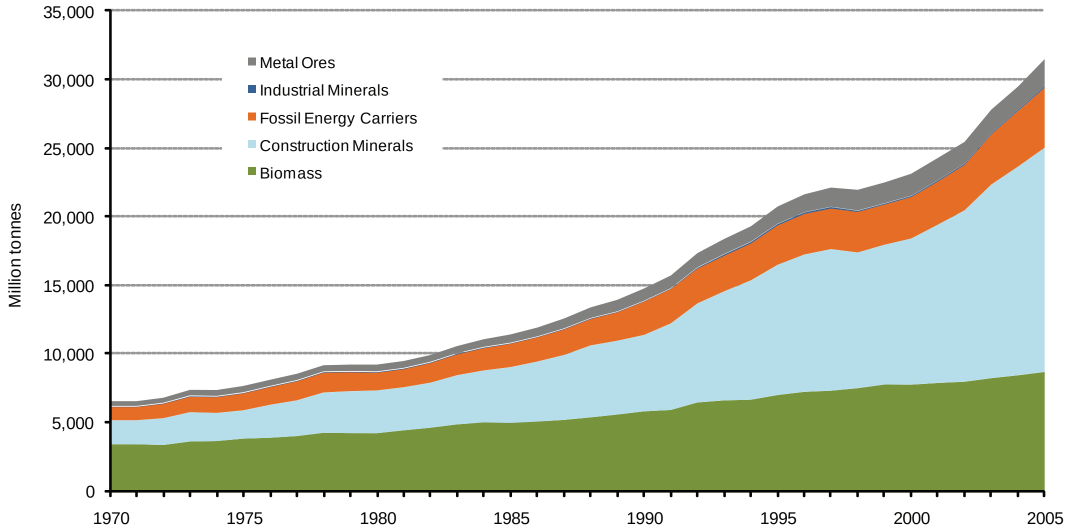


FIGURE 2.6.
Domestic extraction in the Asia-Pacific region by major category of material for the years 1970–2005

Figure 2.7 shows how PTB has developed, using the same breakdown into five major materials categories. The overall pattern has been a reasonably steady increase in net imports for most categories of primary materials for the region as a whole. One persistent exception seems to be construction minerals, for which the region has generally maintained modest net exports since around 1980. A brief period where the Asia-Pacific region became a net exporter of metal ores – around the time of the Asian financial crisis of 1997 – returned to deficit by the turn of the millennium and grew steadily thereafter.

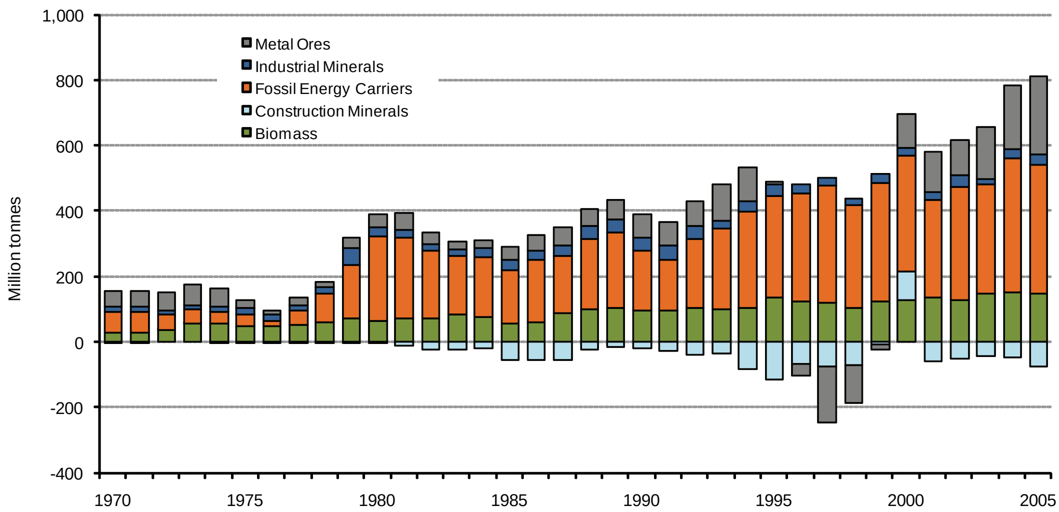
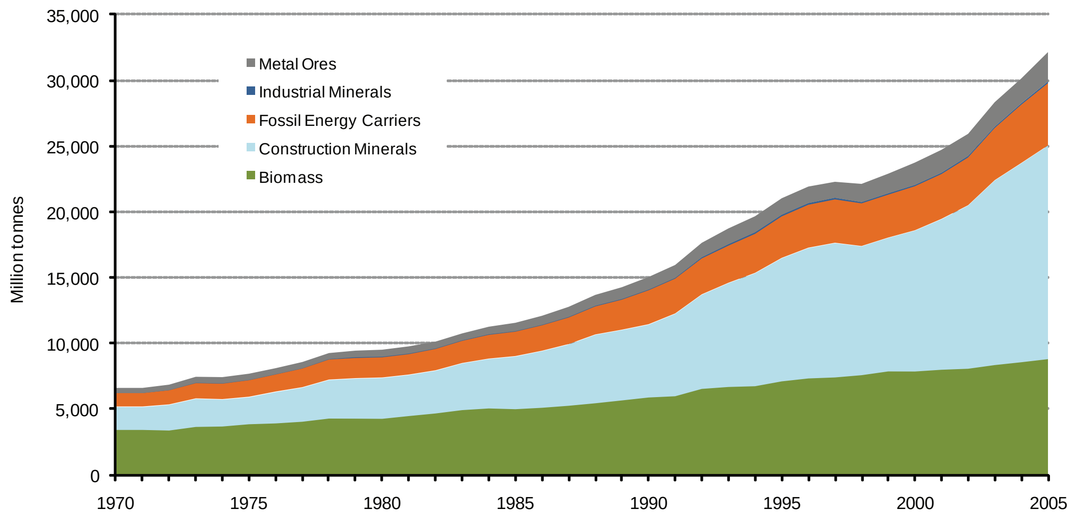


FIGURE 2.7.
Physical trade balance for the Asia-Pacific region by major category of material for the years 1970–2005

The relative size of PTB to DE is generally small for most of the main material categories. This is especially true for the largest categories of construction minerals and biomass, because some of the larger components in these categories are of relatively low value per unit of weight and/or volume, and so cannot usually be profitably traded over long distances. Examples of such materials include construction aggregates (by far the largest component of construction minerals), grazed biomass and crop residues. As a consequence, results for DMC (in Figure 2.8, calculated as DE + PTB) are very similar to results for DE (in Figure 2.6).

FIGURE 2.8.

Figure 2.8. Domestic materials consumption for the Asia-Pacific region, by major category of material for the years 1970–2005.



It is important to emphasize that the relative insignificance of trade, in gross tonnage terms, should not be taken as an indicator of its real significance in determining material flows. As has been discussed earlier (see Box 2.1) the implications of trade flows for material flows accounting are considerable because of the potentially large indirect (embodied) resources flows that are associated with trade flows.

Figure 2.9 shows the change in relative proportions of DMC for the five main materials categories between 1975 and 2005. The relative shares of all categories, except construction minerals, shrank, as a result of the extremely rapid growth in the latter. Although relative shares for all categories other than construction minerals declined, total tonnages of DMC in each individual category nonetheless continued to grow strongly, with biomass growing the least (128%) and metal ores growing the most (334%) over the period.

FIGURE 2.9.

Change in relative shares of domestic material consumption in the Asia-Pacific region by major material categories between 1975 and 2005

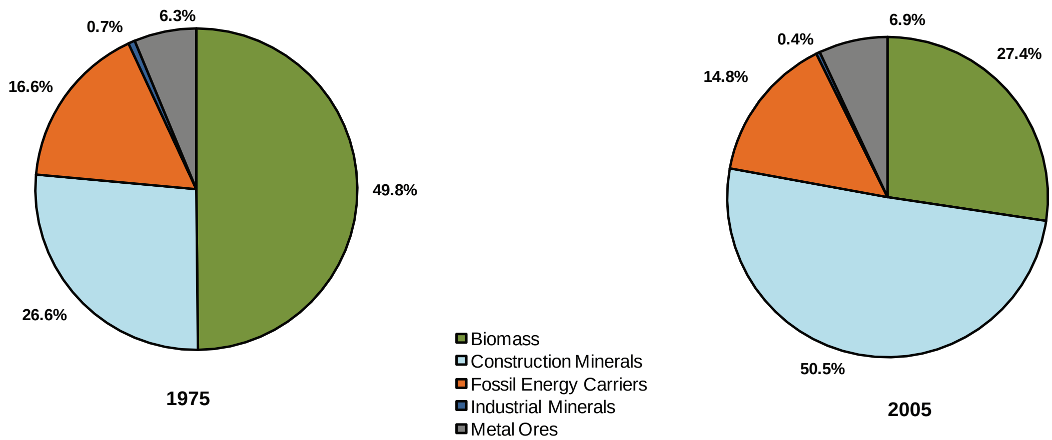


Table 2.1 provides a breakdown of the major material categories into 12 sub-categories, and details the percentage of each category accounted for by each for 1975, 1985, 1995 and 2005.[5]

Table 2.1. Changes in domestic material consumption in the Asia-Pacific region over three decades				
	1975	**1985**	**1995**	**2005**
Biomass (Mt)	3,849	4,999	7,117	8,809
Primary crops	36%	37%	37%	37%
Crop residues	32%	32%	30%	29%
Grazed biomass	17%	18%	23%	25%
Wood products	16%	14%	10%	9%
Fossil energy carriers (Mt)	1,283	1,884	3,184	4,762
Coal	61%	67%	63%	65%
Petroleum products	37%	29%	29%	26%
Natural gas	2%	4%	8%	9%
Metal ores and concentrates, processed metals (Mt)	514	658	1,156	2,267
Iron ores and concentrates, iron and steel	41%	42%	37%	39%
Non-ferrous metal ores and concentrates, processed metals	59%	58%	63%	61%
Industrial minerals (Mt)	51	63	132	121
Construction minerals (Mt)	2,054	3,948	9,255	16,184
Cement related	60%	64%	69%	74%
Non-cement related	40%	36%	31%	26%
Total	7,750	11,552	20,844	32,143

The overall picture shows a twofold increase in biomass due to population growth, increased food and feed requirements and changes in lifestyle and the diets of urban households. The increase in grazed biomass relative to primary crops may reflect increasing consumption of animal products, especially meat and milk of ruminant animals, as per capita spending power increases. This has important implications for the area of arable land required to meet the region's demand for food, because animal products generally require much larger inputs of biomass per calorie (delivered to the end consumer), compared with using primary crops directly.[6] The growing importance of livestock production will also increase greenhouse gas emissions from agriculture in the region.

5 The dataset that has been established for this report provides much greater detail on material flows, beyond the five and twelve major material categories used in this section (and the four and eleven category disaggregations used in the updated online database, and in the individual country assessments below). Information summarized by major material categories is underpinned by about 250 to 300 more detailed material flow categories, which could be further analysed in regard to more specific resource use and environmental impact issues.

6 Comparing nutritional equivalencies between primary crops and animal product systems can be complex and subject to great variation. Some indication of the direct energy conversion costs of converting crops to animal products can be ascertained from Table 3.10 in Wirsenius (2000). There, gross energy losses in converting maize grain to animal products range from around 80% in the most efficient cases (milk plus cattle carcasses from dairy production systems in western nations) to worse than 99% for some beef cattle systems. This only takes into account the gross energy content of the feed and the gross energy content of products.

The use of fossil energy carriers has increased fourfold owing to increased economic activity, transport, and mobility, as well as new appliances acquired by urban households and the related electrification of households and businesses, which is mainly powered by coal-fired power stations. Natural gas has gone from being a marginal and little-exploited source of fossil energy in 1975, to a significant and increasing component of the overall energy mix in the region. Its growth in share has come mainly at the expense of (liquid) petroleum products, although total consumption of petroleum products continued to increase rapidly, growing from 0.48 billion tonnes to 1.24 billion tonnes p.a. in 2005, a compounding growth rate of 3.2% p.a. resulting from mass motorization and increased freight transport.

Most notably, there was an eightfold increase in use of construction materials over three decades, based on the share of construction minerals associated with cement for the Asia-Pacific region.[7] This indicates a vast and growing investment in durable infrastructure. Use of metal ores and industrial minerals grew fourfold, owing to a massive increase in manufacturing capacity. China especially has become the 'workshop of the world' during the last two decades (Wu 2004).

Figure 2.10 shows how material intensity (MI) has changed over time for the Asia-Pacific region, the ROW, and the world as a whole. MI indicates whether economies are using progressively more or less material per unit of wealth (as measured by GDP) they generate. Declining MI over time is an indication of 'doing more with less', and is a pre-requisite for achieving continued growth without placing ever-heavier demands on the environment.

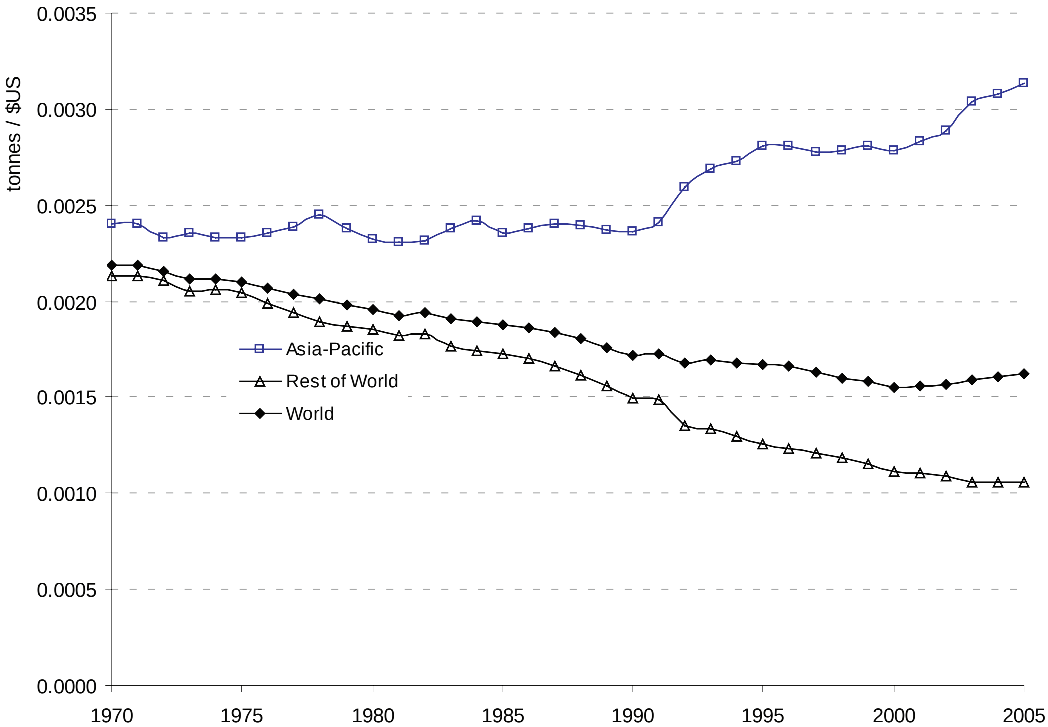


FIGURE 2.10.
Material intensity for the Asia-Pacific, rest of the world (ROW) and world, for the years 1970–2005. (Materials are total domestic material consumption, dollars are constant year 2000 $US, exchange rate based)

7 Construction minerals are subject to large scale and widespread under-reporting in most national materials accounts. Consequently, construction minerals tonnages were calculated by applying a factor to reported cement DMC for each country, as this tends to be relatively well reported. This gave the 'cement associated' component, representing aggregates mixed into concrete. A second component was then calculated as varying ratio of this. The ratio applied to achieve this was derived from Krausmann et al. (2009), varies over time, and is a global figure rather than specific to the Asia-Pacific region.

Globally, material efficiency has been steadily improving in the three decades since the 1970s. This growth in efficiency (i.e. a decline in MI of production) was enabled by efficiency gains in the rest of the world, while material efficiency in the Asia-Pacific region remained stagnant until 1991. Since then, two periods of decreasing material efficiency in the Asia-Pacific region can be observed, from 1991 to 1995, and from 2000 onwards. During these periods, resource use grew faster than economic activity owing to massive infrastructure development, rapid urbanization, enhanced transport capacity, and the establishment of energy production infrastructure, as well as lifestyle changes and new consumption and mobility patterns among higher-income urban households.

Previous studies e.g. Krausmann *et al.* (2009), have demonstrated that global resource efficiency improved over the whole of the 20th century. Since the year 2000 however, this ongoing trend at the global level towards increased efficiency has reversed. For the first time in a century, the world is using natural resources less efficiently. One underlying factor driving decreased material efficiency is a net shift of economic activity away from efficient producers to less efficient producers. If resource efficiency is examined on a country by country basis, most economies are becoming more efficient (i.e. less material intensive over time). However, the relative share of economic activity taking place in high efficiency economies has been increasingly displaced to economies of much lower efficiency. To illustrate this, in 1970 Japan had a 73% share of all economic activity in the Asia-Pacific region, and an MI of less than 0.8 kg per US$, while China accounted for 4%, at an MI of over 16 kg per US$. By 2005, Japan's share of the Asia-Pacific region's economy had decreased to around 50%, at an MI of less than 0.3 kg, while China's economic share had grown to 19% at an MI of 9.4 kg per US$. The weighted average MI for these two countries combined thus increased from 1.2 kg per US$ in 1971 to 1.9 kg per US$ in 2005.

If this trend continues, extractive pressures on the environment will increase even faster than the rapid rates of economic growth that have characterized the Asia-Pacific region in recent decades. As shown in Figure 2.1 and Figure 2.2, the rapid growth of resource use in the Asia-Pacific region relative to the ROW means that trends for the world are now heavily influenced by trends for the Asia-Pacific region. As a result, even as the MI of the ROW continued to decline or remained static through the early years of the 21st century, the MI for the world as a whole established a steady trend upwards. Humanity as a whole is now consuming more resources and producing more emissions to maintain economic growth than was the case at the close of the 20th century. The Asia-Pacific region has become the main motor of this growth in resource use and emissions.

Material use patterns and material efficiency for selected countries

In this section, material use patterns and material efficiency are reviewed for a number of individual countries. These countries were selected to be representative of major patterns of resource use in the Asia-Pacific region, and consistent with a recent classification system set out by Krausmann *et al.* (2008). That system classifies countries by development status and population density, the rationale being that these variables are linked to a country's metabolic profile. Six major types were defined in Krausmann *et al.* (2008), and these are shown in Table 2.2.

Table 2.2. Country typology following Krausmann *et al.* 2008	
Cluster Type	**Countries**
High population density industrialized countries (HDI)	**Japan, Republic of Korea**
Low population density industrialized countries of the New World (LDI-NW)	**Australia**, New Zealand
Low population density industrialized countries of the Old World (LDI-OW)	**Kazakhstan**, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
High population density developing countries (HDD)	Bangladesh, Brunei Darussalam, Cambodia, **China, India, Indonesia**, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Samoa, Sri Lanka, **Thailand**, Viet Nam
Low population density developing countries of the New World (LDD-NW)	Fiji, **Papua New Guinea**, Solomon Islands, Vanuatu
Low population density developing countries of the Old World (LDD-OW)	Afghanistan, Bhutan, Iran, Lao People's Democratic Republic, Mongolia, Timor-Leste

Only Pacific Island nations greater than 100,000 people are represented in the table. For the following analysis, a group of 10 countries was selected (in bold type in table) including at least one representative for each cluster type. This group represents 75% of Asia-Pacific population, 80% of economic activity and 50% of land area.

Figure 2.11 shows the contribution of the 10 countries to domestic material consumption over time. In 1970, China, India, and Japan dominated regional materials consumption, with broadly comparable shares. Since then China has become by far the largest consumer of materials in the Asia-Pacific region, followed by India and Indonesia. By 2005, 60% of all materials consumed in the Asia-Pacific region were used in China and 20% in India.

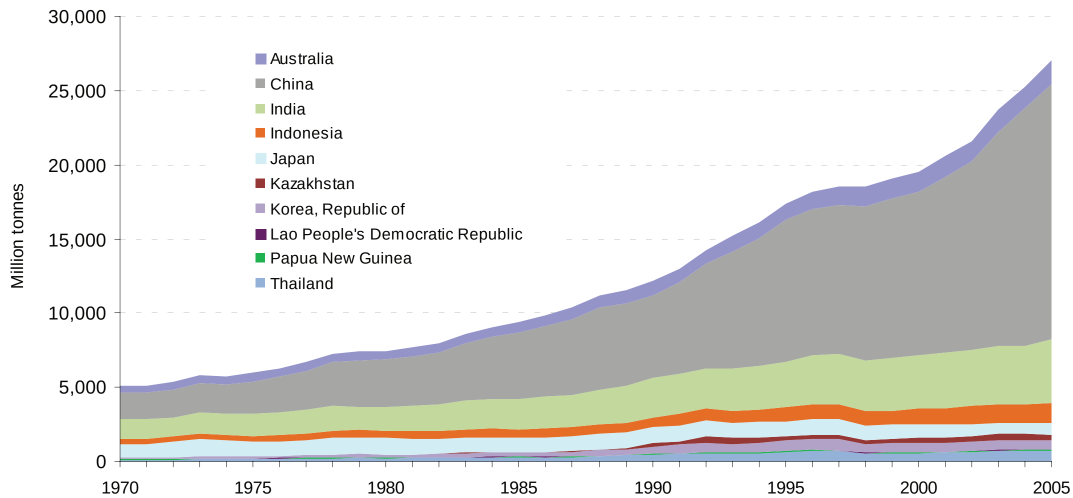


FIGURE 2.11.
Total Domestic material consumption for each of the 10 focus countries

Japan and the Republic of Korea are representative of the group of high population density industrialized countries (HDI) within the Asia-Pacific region. Countries in this group have a long history of agricultural development and industrialization, have high population densities, they face relative scarcity of natural resources, and have few natural undisturbed ecosystems as a result. Dependence on imports of raw materials is very high. Both countries are advanced economies with a high level of income. Their use of iron and steel, cement, fertilizer, animal-based diets, and electricity are among the highest in the world. Despite a standard of living similar to that of low population density industrialized countries of the New World (LDI-NW), natural resources are used more efficiently and per capita material and energy use are relatively low. Because of their scarce resource endowment and limited land, these countries have long made efforts to use resources more effectively and efficiently, and to establish recycling as a major activity so as to decrease dependence on imported raw materials.

In 2005, the Japanese economy used less than 12 tonnes of materials per capita, half of which were imported. Total materials use declined in the decade to 2005, while MI improved from 0.75 kg per US$ in 1970 to less than 0.3 kg per US$ by 2005. Construction materials became progressively less important over the three decades to 2005, while fossil fuels became relatively more important in Japan's material use (see Figure 2.16). The high material efficiency standards in Japan may have been achieved in large part by externalizing many materials intensive production functions to other countries. On the other hand, Japan still has a very large and export oriented manufacturing sector, which should offset some of the gains achieved by externalizing many heavy industrial processes.

The Republic of Korea, in comparison, has been less successful in enabling resource-efficient production and has operated with much higher per capita material use than Japan. DMC was around 19 tonnes per capita in 2005, while MI showed high volatility but improved overall from 2.1 kg per US$ in 1970 to less than 1.5 kg per US$ in 2005. The Republic of Korea, like Japan, also imports a significant share of its material requirements (around 30%). The share of construction minerals in DMC increased over the last three decades, as did that of metal ores, while the share of biomass decreased, although it still more than doubled in absolute tonnage terms. In 2005, Japan consumed around 1.4 billion tonnes of resources, and the Republic of Korea just over 900 million tonnes (Figure 2.18).

Australia represents the group of low population density industrialized countries of the New World (LDI-NW). These economies have large endowments of natural resources, including large available land areas, and low population densities. They typically experienced rapid industrialization in the late 19th and early 20th centuries, and are among the most advanced economies, as is apparent from their high material standards of living. Average per capita incomes are among the worlds highest. The per capita levels of material (and energy and water) use in this group of countries are usually the highest of the six country classes. Australia in particular has a relatively small domestic market and manufacturing sector,and a very large (in tonnage terms) export-oriented primary sector. Materials such as coal, iron, aluminium, wheat and beef, are sold to the global market without elaborate transformation.

This economic pattern has resulted in a DE of around 70 tonnes per capita in 2005, with a large negative physical trade balance of over 25 tonnes per capita. MI did not improve over the entire period from 1970–2005, stagnating at around 1.9 kg per US$, and somewhat higher than the world average of 1.6 kg per US$ in 2005. Metal ores and industrial minerals dominate Australia's DMC, accounting for nearly 42% of all flows in 2005 (Figure 2.12). In 2005, the Australian economy used around over 900 million tonnes of primary materials, a similar magnitude to Japan and the Republic of Korea.

Kazakhstan is an example of the group of low population density industrialized countries of the Old World (LDI-OW). Within the Asia-Pacific region these are largely countries that were part of the former Soviet Union. These countries are special in that they combine characteristics of both high and low population density areas. Their history of agricultural development shares similarities with the New World countries, in that agriculture only gradually extended into the periphery of European Russia in the 20th century, facilitated by the extension of railroads and irrigation systems. The region experienced rapid industrialization in the 20th century through the political and economic policies of communism and a planned economy. The 1980s saw a period of severe economic and political crisis going hand in hand with sharp economic decline following collapse of the political system. By 2000, this once-advanced region was still dealing with the aftermath of economic breakdown and political restructuring, while experiencing a spurt of economic growth. All this is reflected in a mix of characteristics of both industrial and developing patterns and attributes.

These countries usually feature large heavy industry sectors and a highly industrialized agricultural sector, resulting in very high per capita material and energy use levels, only slightly lower than those of high population density industrialized countries (HDI) countries. Per capita GDP, however, is typically low, and the proportion of the population involved in agriculture is usually high. Countries in this group are sparsely populated, often command large resource endowments, and provide resources to the global market.

Reliable data for this group starts around 1992 and shows a per capita DMC of 21 tonnes for Kazakhstan in 2005, with a steep upward trend coming off a low of just over 11 tonnes per capita in 1997 (Figure 2.17). The physical trade balance of Kazakhstan is negative, exporting nearly 7 tonnes per capita to the world, mainly fossil fuels and ores. Material efficiency has improved greatly over the last decade, from an MI of 19 kg per US$ in 1992 to less than 11 kg per US$ in 2005. Time will tell if rapid exploitation of the natural resources base will be accompanied by value adding in the manufacturing sector and further improvements in the efficiency of resource use.

China, India, Indonesia and Thailand are examples of high population density developing countries (HDD). These countries share a long history of continuous agrarian development, leading to high population densities and sustained social development. This cluster also has a high level of heterogeneity, including many of the least developed as well as rapidly industrializing countries, among them the world's most densely populated and poorest countries. Per capita material and energy use is still relatively low, but is growing rapidly in some instances owing to unprecedented growth in economic development. These countries have large agricultural sectors and populations that are undergoing transition to urban centres at high rates. Some of the most densely populated countries in this group appear to be close to the limits of the productive and absorptive capacity of their ecosystems. Despite considerable net imports of biomass, the metabolic pattern of this group of countries remains much closer to an agrarian than to an industrial metabolic pattern.

India has the lowest per capita income country in this group, despite the accumulation of considerable wealth in its urban centres in recent decades. India is characterized by large inequalities, and its low average income is reflected in a low DMC per capita of around 4 tonnes, of which biomass accounted for almost 50% in 2005. India's physical trade balance suggests that the country is only starting to integrate into world resource and commodity markets. Currently its major net imports are of petroleum, largely for transport systems. MI improved from around 11.5 kg per US$ to less than 7 kg per US$, which is in part a result of increased incomes generated by the services sector, which tends to be relatively resource efficient. The Indian economy grew rapidly in the decade to 2005, and there is huge potential for further growth in materials use as the country continues to urbanize, industrialize, and achieve better incomes and adopt higher consumption lifestyles for its very large population. India, in 2005, accounted for just over 4.4 billion tonnes of the world's materials consumption (Figure 2.14).

Indonesia had a DMC of about 6 tonnes per capita in 2005, and a negative PTB, largely due to exports of fossil fuels (overwhelmingly coal, with some natural gas, as Indonesia became a net importer of petroleum from 2004). Since 1975, the metabolic profile of Indonesia has changed rapidly from an agrarian and biomass-based economy – 80% of all materials used were biomass based – to a more industrial metabolism involving substantial shares of construction materials, metal ores, and, increasingly, fossil energy. Material efficiency has improved – MI decreased from over 10 kg per US$ in 1971 to 4.7 kg per US$ in 1997 – but since then this has increased again, to 5.7 kg per US$ by 2005. This can be explained by the rapid industrial transformation taking place and the growth in resource use which typically accompanies this transition. Krausmann *et al.* (2008), based on historical material, and Schandl *et al.* (2009), in a study of metabolic profiles of Asian developing economies, found that the industrial transition corresponded with a two- to fourfold increase in demand for raw materials and energy (Figure 2.15).

Thailand is on a similar path to Indonesia, undergoing the transition from an agriculture and biomass-based economy to a modern, industrial economy, but is further advanced. Thailand's DMC was nearly 12 tonnes per capita in 2005, having resumed growth after a sharp decline following the Asian economic crisis in 1997. Since 1975, the share of biomass in Thailand's material use has fallen from 64% to just 33% in 2005. Construction materials and fossil fuels have gained in importance and the country has become a significant net importer of fossil fuels and metal ores. Because of a highly diversified economic structure, with significant incomes being generated in low material-intensity sectors, Thailand was able to improve its resource efficiency from just under 6.7 kg per US$ in 1970 to around 4.8 kg per US$ in 2005. Thailand consumed a total of nearly 750 million tonnes of materials in 2005, and there is potential for further rapid growth as peripheral areas modernize (Figure 2.21).

China has been the 'powerhouse' of economic development, industrialization, and urbanization in Asia over the past decade and this is clearly reflected in its resource use profile. DMC reached almost 14 tonnes per capita in 2005, up from 2.4 tonnes per capita in 1975. China's net imports of resources have increased very rapidly, especially since the late 1990s, with growth in imports of ores being especially dramatic, due to the country's increasingly rapid industrial and infrastructure development. The aggregated figures are remarkable. In 1980, China's DMC was under 3.2 billion tonnes per annum, but by 2005 it had grown to nearly 18 billion tonnes per annum, making China the world's single largest resource consumer. Despite this massive growth, China has almost halved its MI since the 1970s, from over 16 kg per US$ to around 9.4 kg per US$ in 2005 (Figure 2.13).

Papua New Guinea is a low population density developing country of the New World (LDD-NW). These countries are sparsely populated and usually have rich endowments of natural resources, forming the basis for an extractive economy. As a result, they are often net exporters in one or more of the major materials categories. Per capita GDP is significantly below the level of that in industrialized countries, and this is reflected in their metabolic profiles, which show characteristics of both agrarian and industrial patterns. DMC per capita is relatively high, and the share of the population engaged in agriculture fairly low, however consumption of electricity, iron and steel, and cement is substantially lower than in HDIs and LDI-NWs.

On the data available, DMC in PNG was around 14 tonnes per capita in 2000, dominated by metal ores and biomass. MI for the same year was around 21 kg per US$. The statistics are very volatile over the two decades to 2005, due to both erratic availability of data, and because of real and major fluctuations in the output of PNG's primary export industries (Figure 20).

The Lao People's Democratic Republic is a low population density developing country of the Old World (LDD-OW). Population density in these countries is low and agricultural development has been hampered by geographical factors. Populations in this group are nonetheless usually increasing rapidly, as in the case of the Lao People's Democratic Republic. Per capita GDP levels are very low, with significant sections of the population typically near a subsistence level. The metabolic profile of these countries is characterized by very low levels of material and energy consumption, with a high proportion of the population involved in agriculture, and with biomass accounting for a large share of DMC. Per capita consumption of cement, iron and steel, electricity, meat, and dairy products are very low.

DMC in the Lao People's Democratic Republic was around 4 tonnes per capita in 2005, with a negligible PTB reflecting little integration into world resources markets. The country's metabolic profile has however changed from a near purely biomass-based agrarian economy in 1975 to one more reliant on inputs of construction minerals and ores (and presumably fossil fuels, although the available data was not adequate to determine this with certainty). Material efficiency improved during the period 1983 to 1997, with MI decreasing from from 10.3 kg per US$ to 6.8 kg per US$, but it subsequently reversed and reached 9.7 kg per US$ in 2005 (Figure 2.19).

The 10 countries highlighted in the resource use analysis represent major types, with different characteristic resource use trajectories and future potential for growth. The OECD countries in the Asia-Pacific region show very different resource use profiles, with Japan representing one of the most resource efficient economies globally and Australia being one of the biggest resource users and exporters of resources.

Regarding the non-OECD countries, the large industrializing nations such as China and India represent the greatest challenge for global sustainability. Their current low to moderate per capita material use has great scope for rapid future growth, which when realized will place an unprecedented level of demand on global resources. To minimize constraints on economic and social development resulting from this, such as shortages in supply of critical materials and related price surges, the Asia-Pacific region as a whole will need to implement policies aimed at increasing the effectiveness and efficiency of materials use.

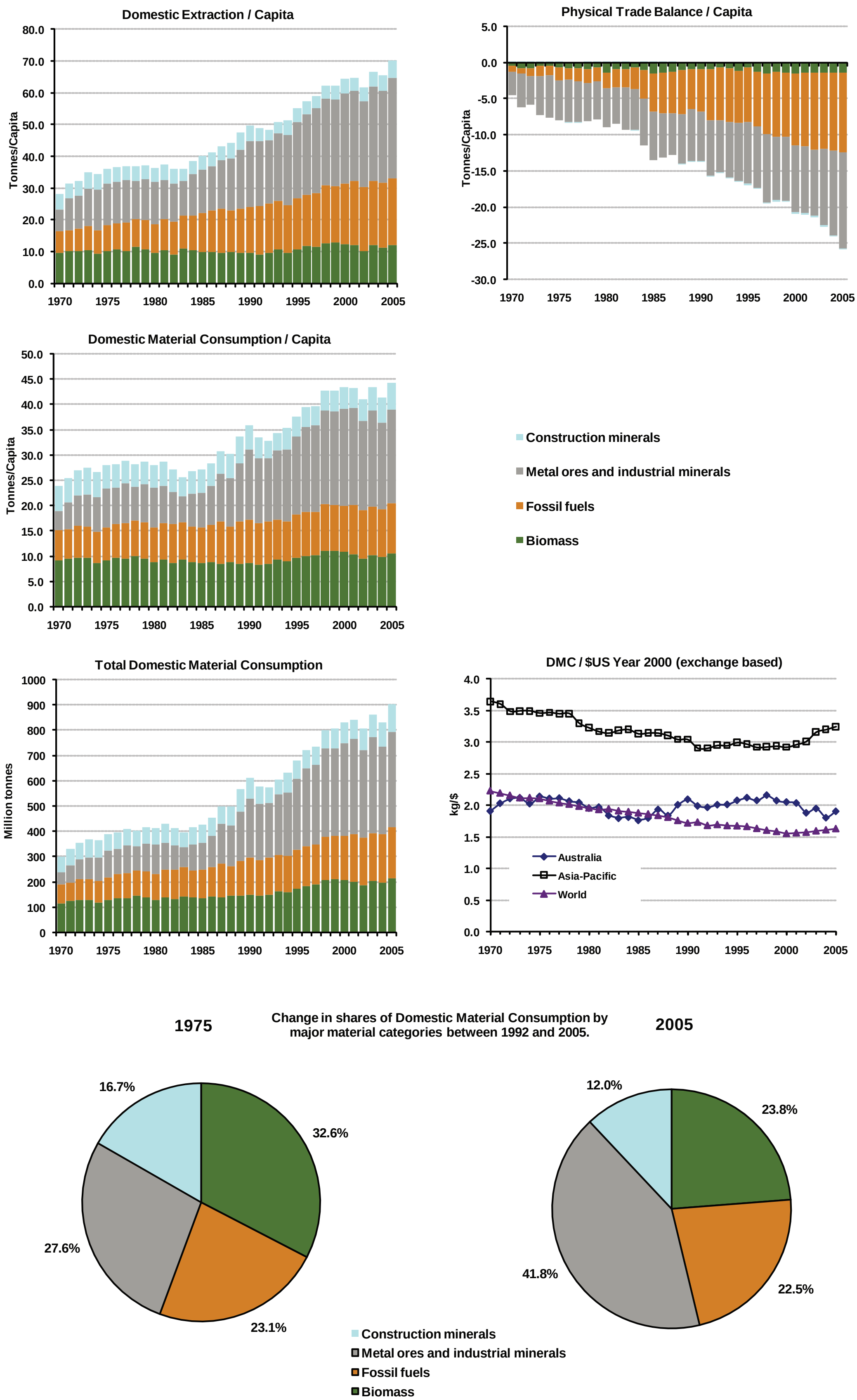


FIGURE 2.12.

Summary panel on material flows and materials intensity for Australia

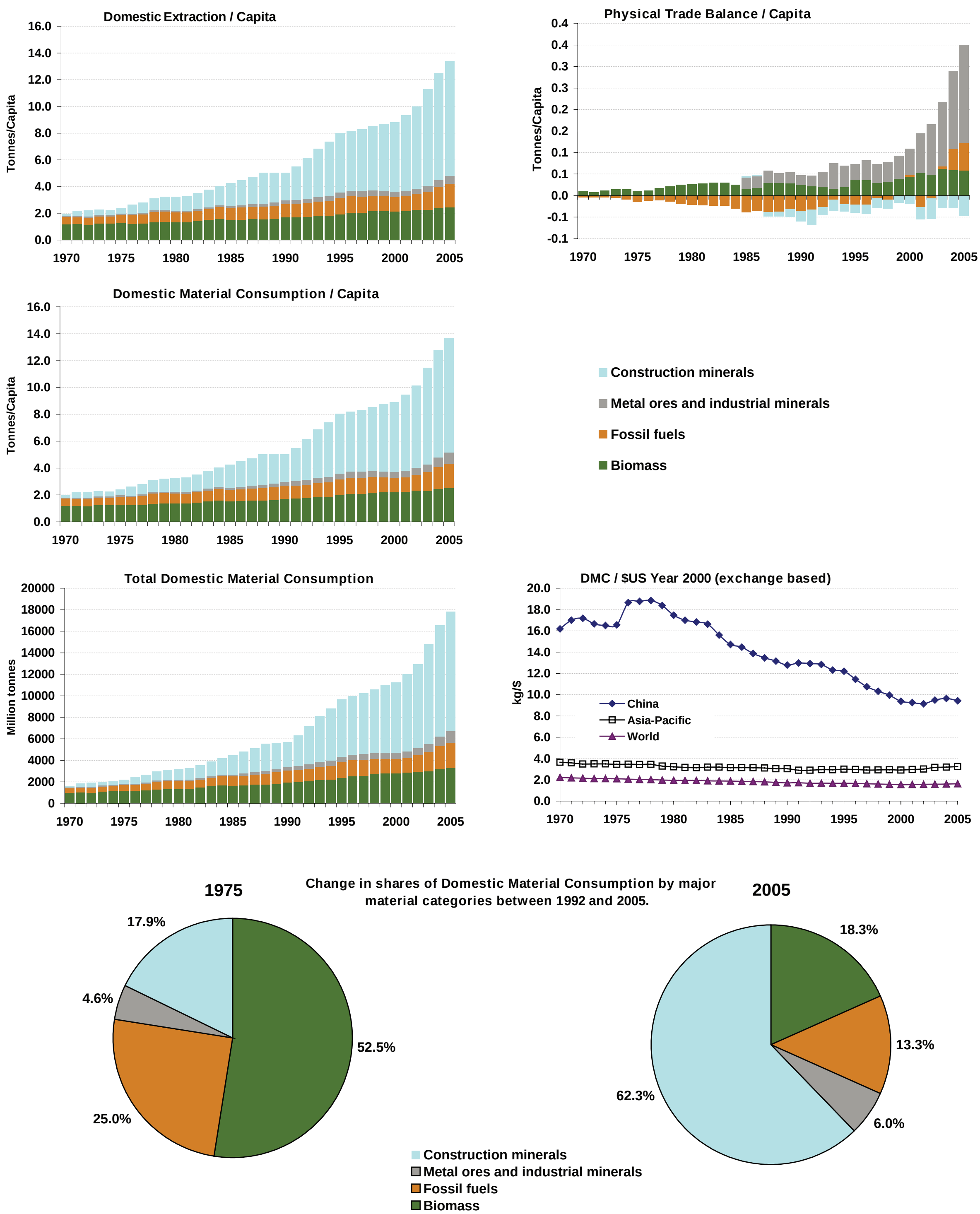


FIGURE 2.13.

Summary panel on material flows and materials intensity for China

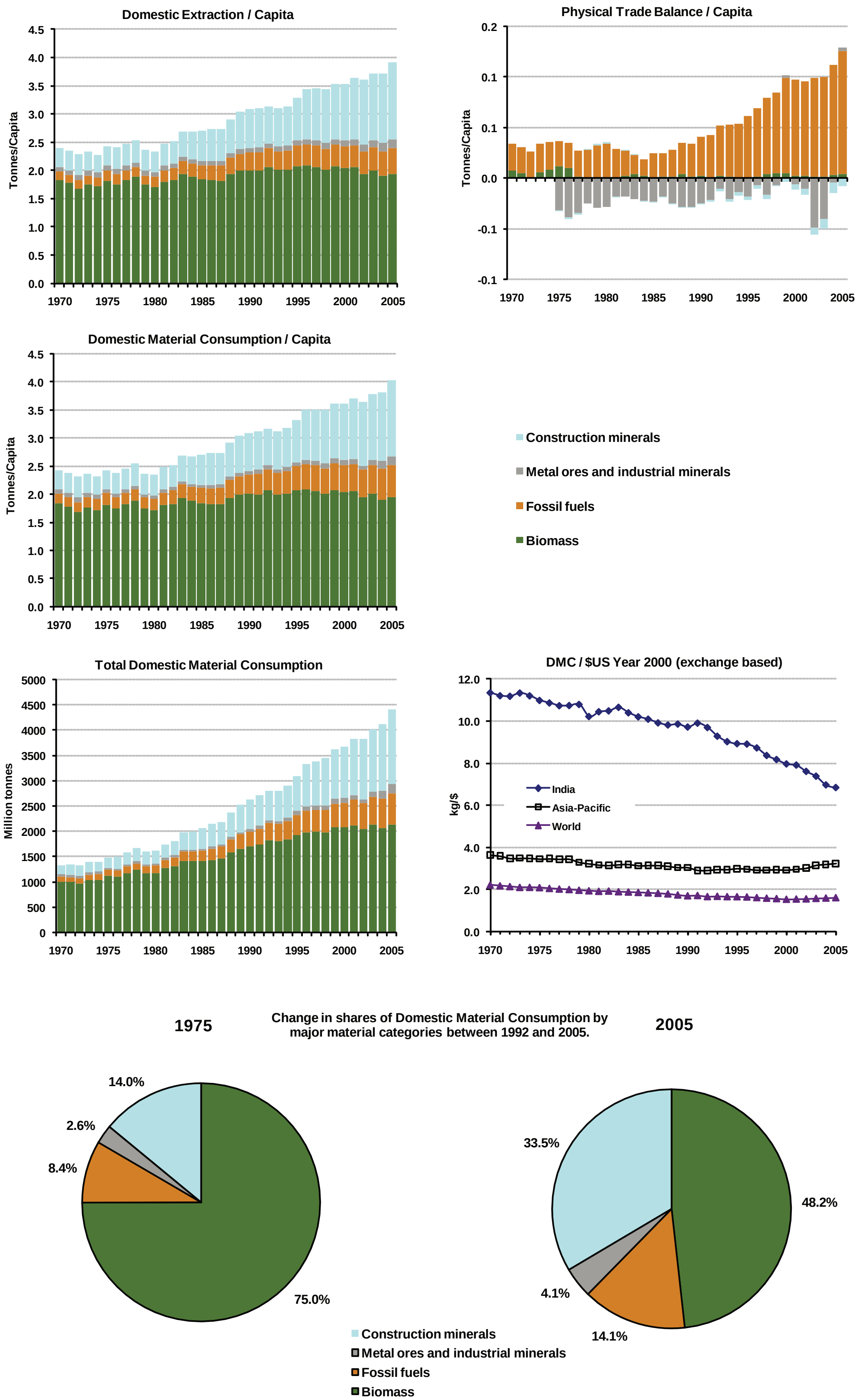


FIGURE 2.14.

Summary panel on material flows and materials intensity for India

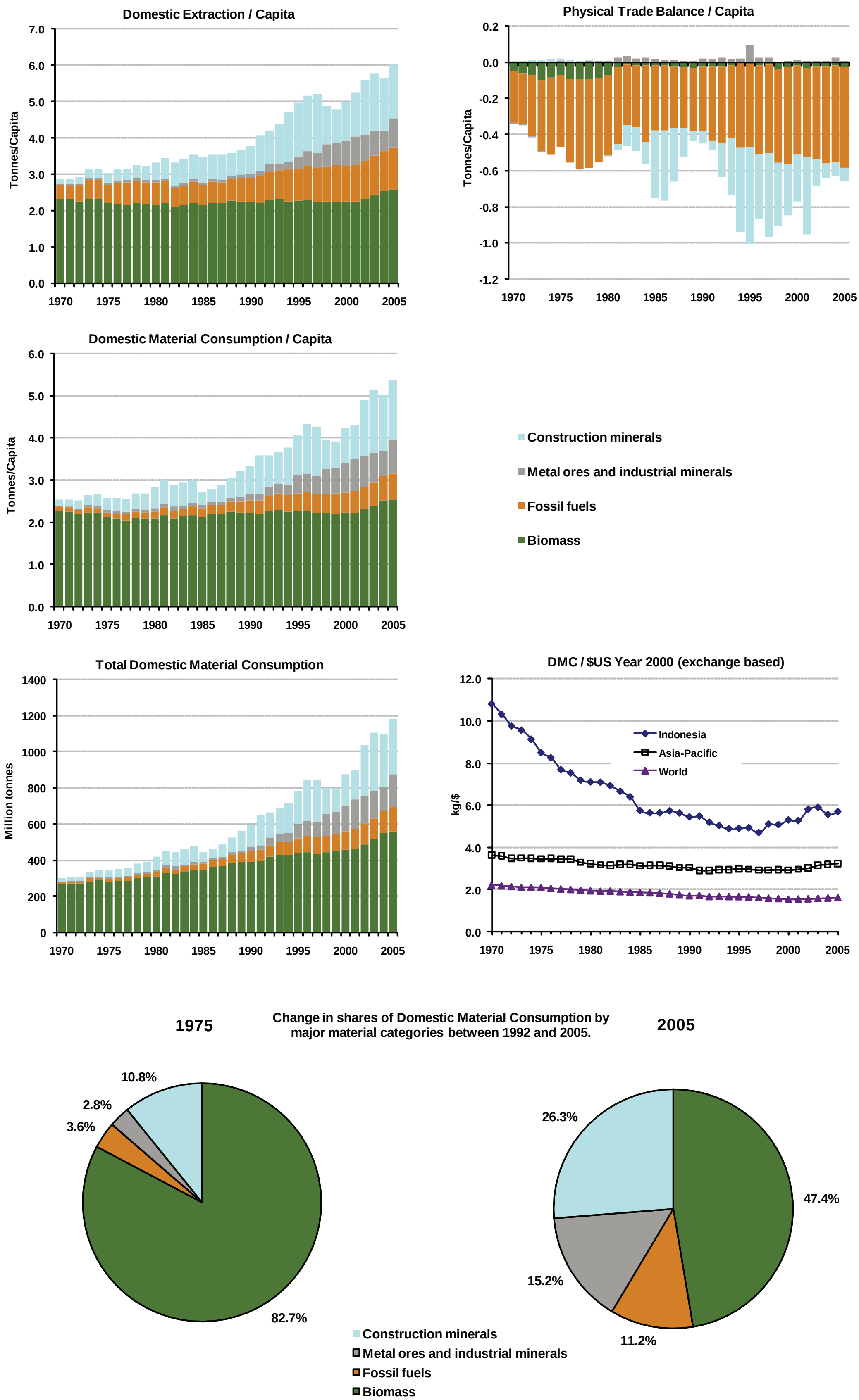


FIGURE 2.15.

Summary panel on material flows and materials intensity for Indonesia

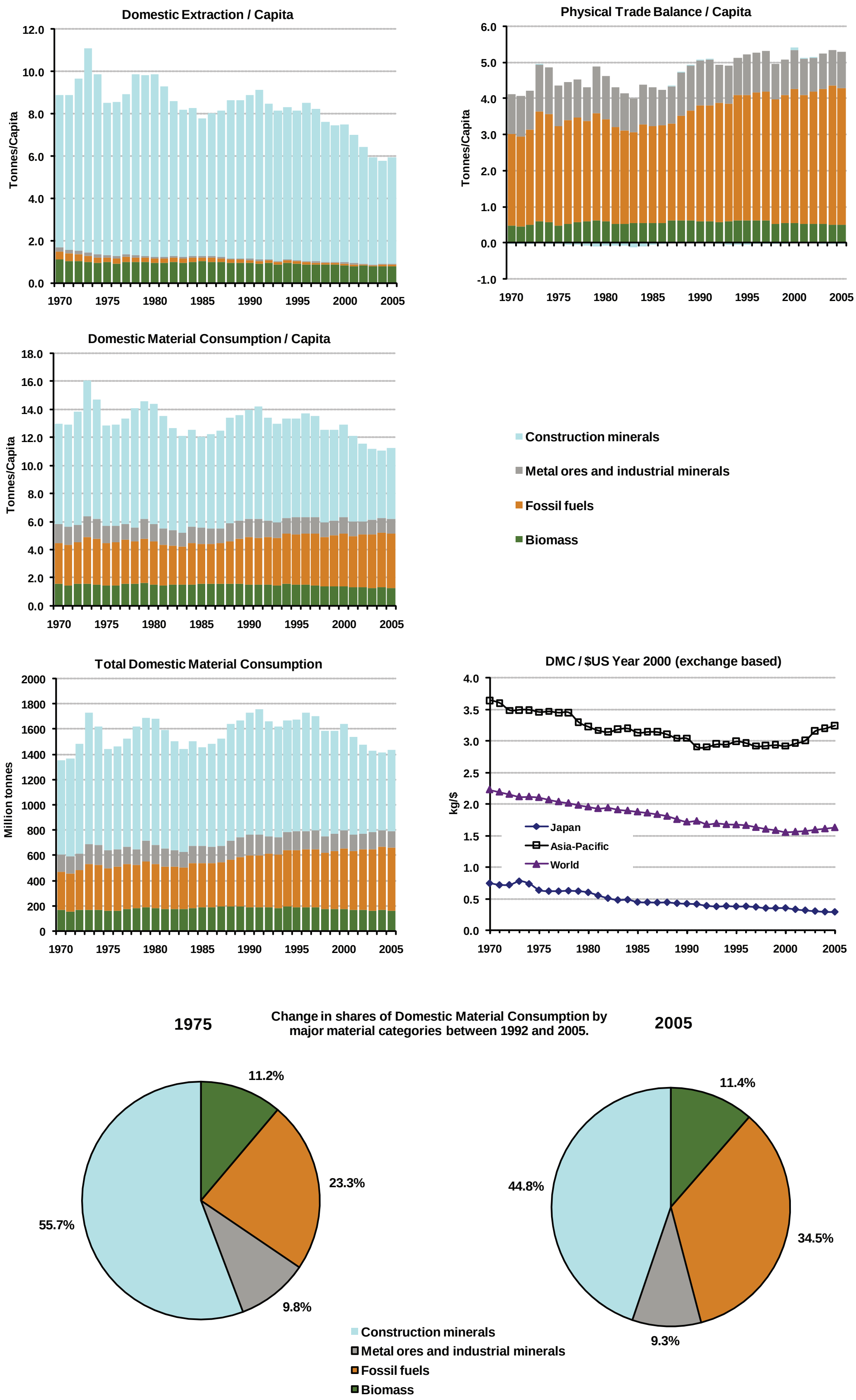


FIGURE 2.16.
Summary panel on material flows and materials intensity for Japan

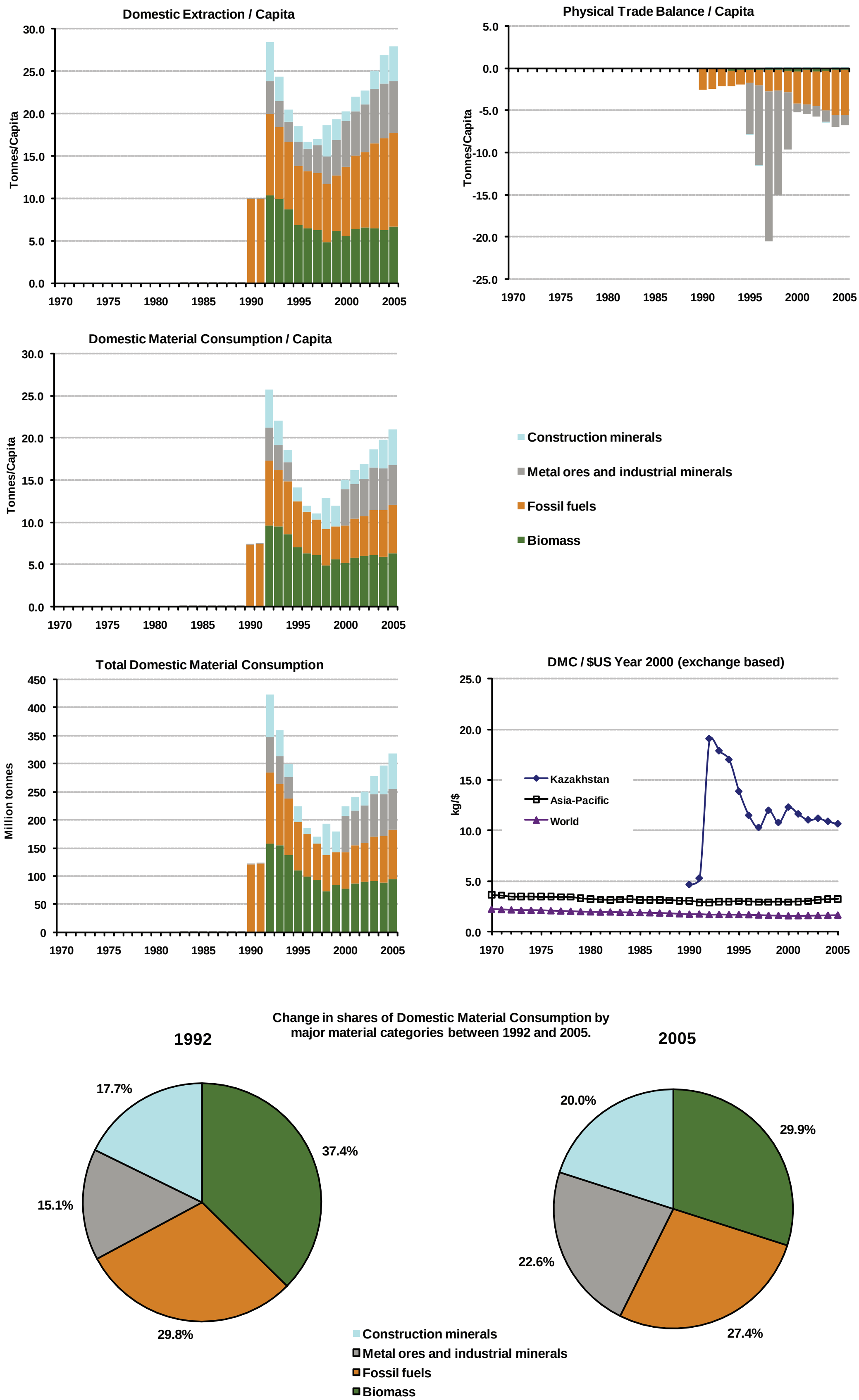


FIGURE 2.17.

Summary panel on material flows and materials intensity for Kazakhstan

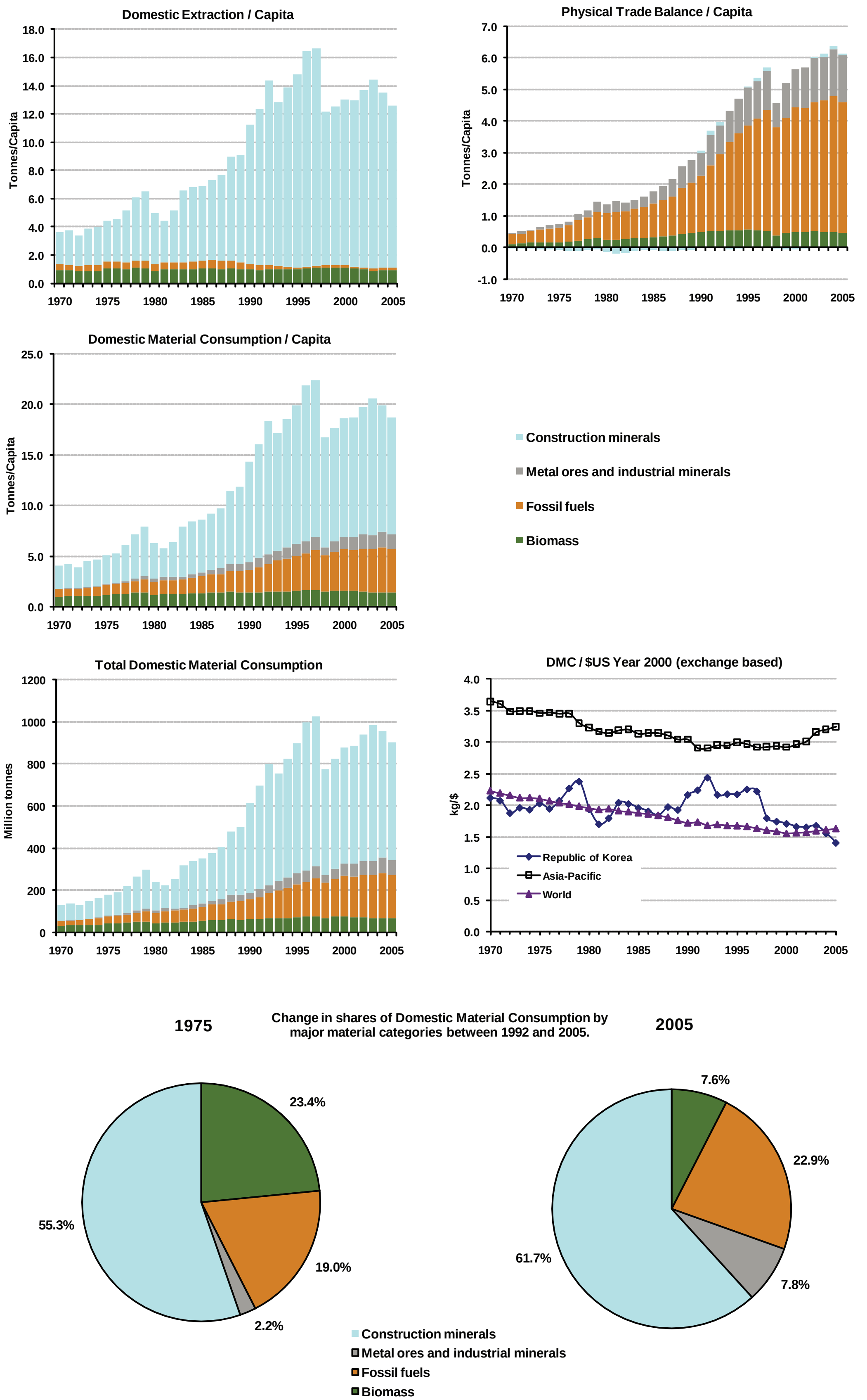


FIGURE 2.18.

Summary panel on material flows and materials intensity for the Republic of Korea

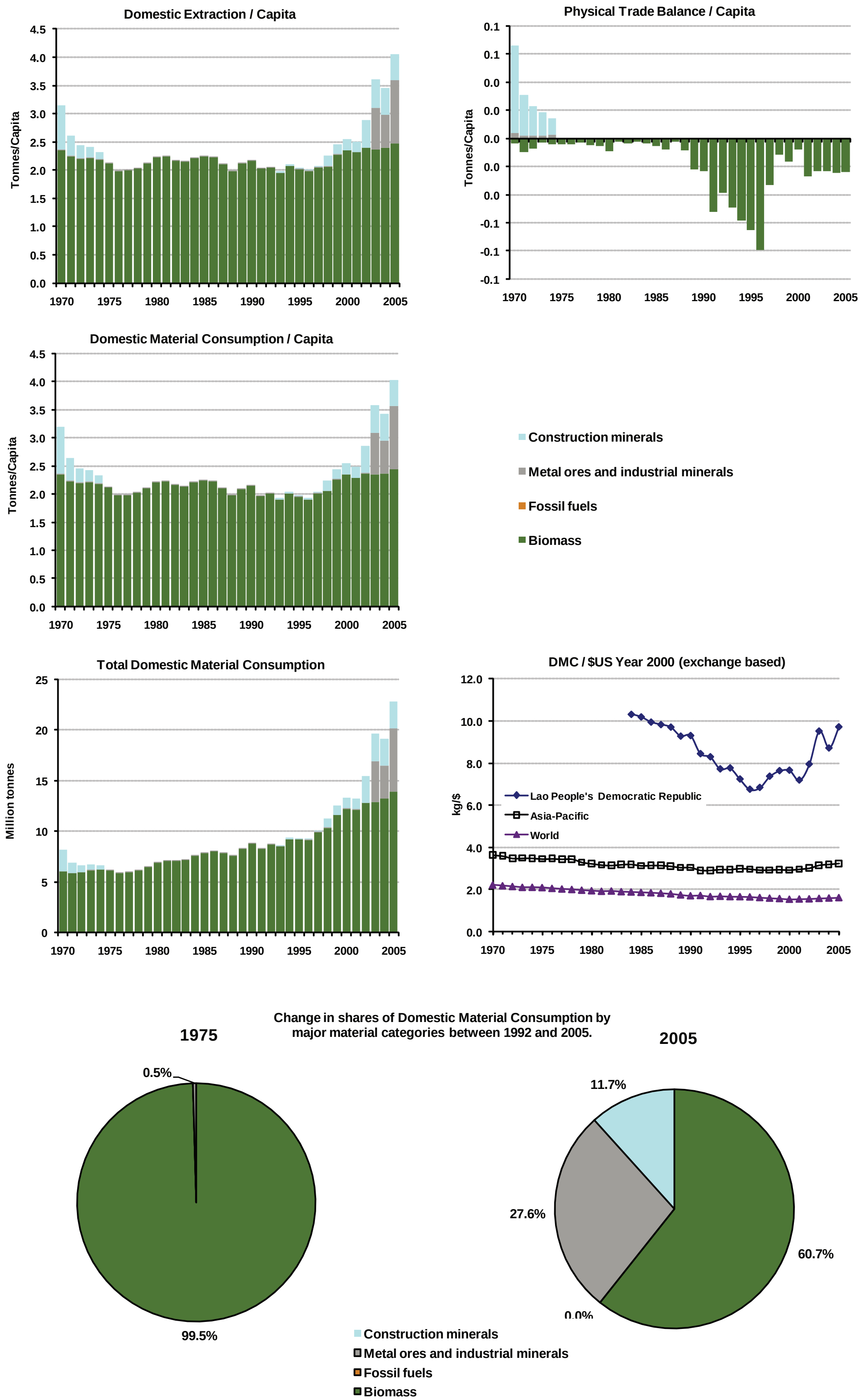


FIGURE 2.19.
Summary panel on material flows and materials intensity for the Lao People's Democratic Republic

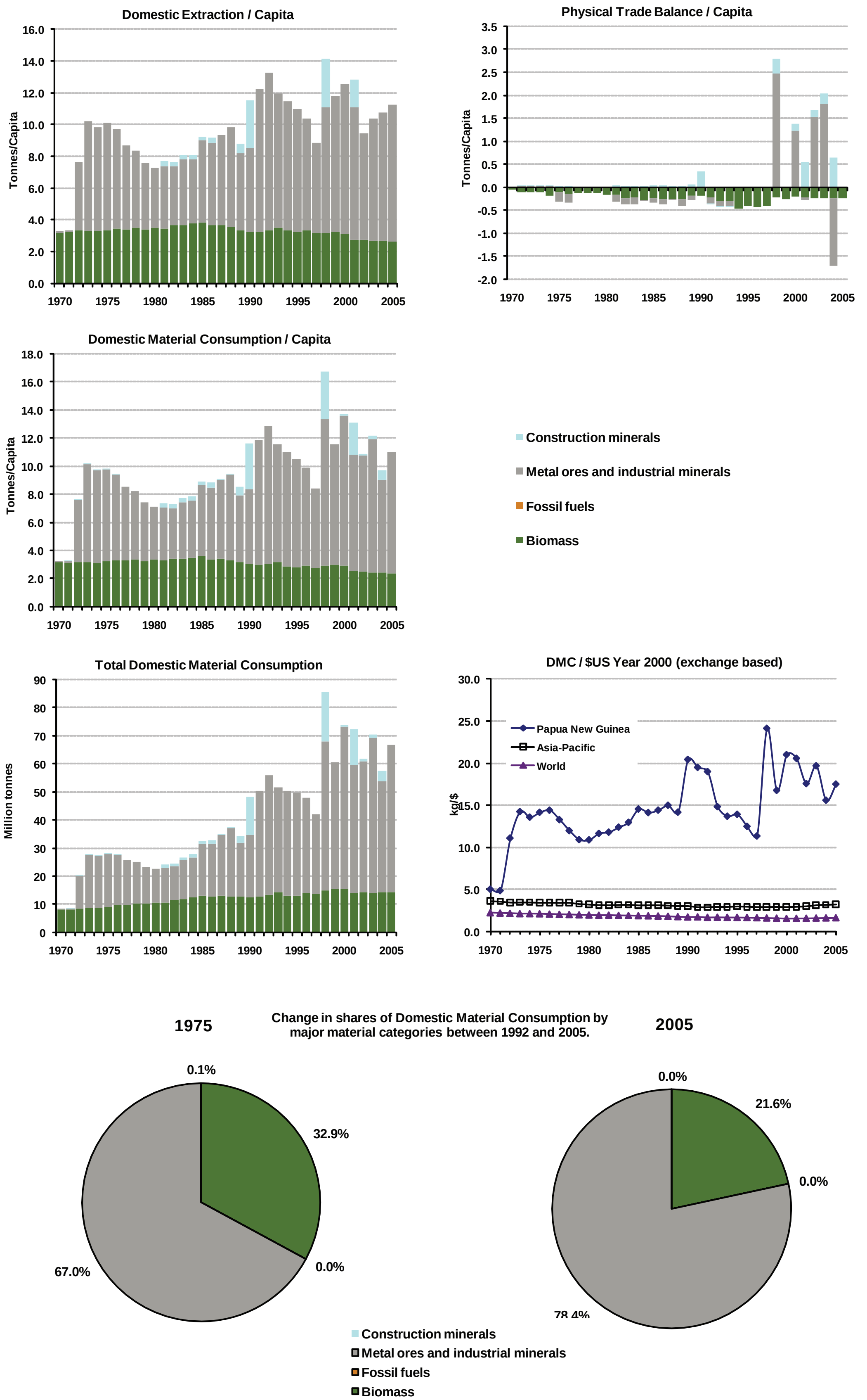


FIGURE 2.20.

Summary panel on material flows and materials intensity for Papua New Guinea

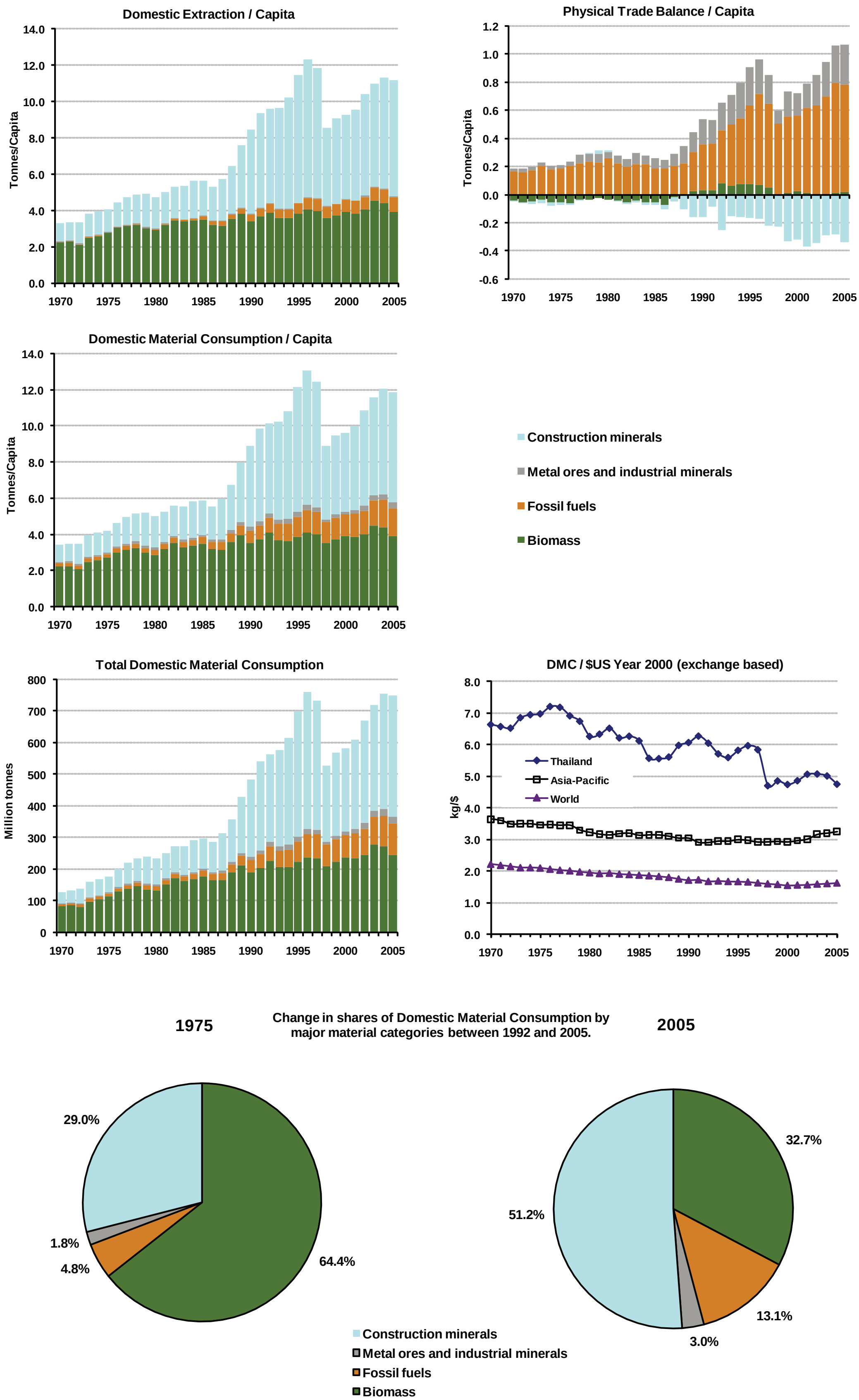


FIGURE 2.21.

Summary panel on material flows and materials intensity for Thailand

Drivers of material use patterns and material efficiency

The level of resource use in a region is driven by a number of factors. To better understand how resource use has developed to the present, and what trajectory it might take into the future, it can be helpful to identify and analyse key drivers independently. One widely used analytical framework to achieve this is the $I = P \times A \times T$ equation (*IPAT*). This equation in its original form proposed by Ehrlich and Holdren (1971) conceptualizes total impacts on the environment (*I*) as the product of population (*P*), multiplied by the level of affluence of that population (*A*), multiplied by a technological coefficient (*T*).

I might be defined as an emission of interest, such as CO_2, or an extractive pressure on the environment, such as DMC. *A* is often taken to be GDP/capita, and then *T* could be defined as the intensity of *I* per unit GDP generated. Here, I = DMC, A = GDP/capita, and T = DMC/GDP.

Using this framework in its original form, determining the effect on *I* of changing an individual driver in isolation is straightforward. A 10% increase in P will, all other things being equal, lead to a 10% increase in *I*. The situation becomes less clear where two or more of the drivers vary simultaneously, due to the multiplicative nature of the equation. A quick inspection of the percentage changes in drivers (ΔP, ΔA, and ΔT) in Table 2.3 shows that the change in impact (ΔI) cannot be calculated by adding these changes. More importantly, it is difficult to allocate proportional 'responsibility' for ΔI to the different drivers using IPAT in this form, and have the components add up to 100%.

One solution to this allocation problem is via a transformation of the IPAT factors to logarithmic form, giving an additive form of the IPAT equation, which is amenable to allocating percentage contributions to the different drivers, which will add up to 100%.[8] The results of applying this technique are shown in the last three columns of Table 2.3 to 2.5.

Tables 2.3 to 2.5 present the speed of growth in DMC during the last three decades. From 1975 to 1985, resource use in the Asia-Pacific region grew by 3.9 billion tonnes. Between 1985 and 2005 absolute growth was at 9.4 billion tonnes and during the years 1995 to 2005 another 11.1 billion tonnes were added. North-East Asia, including China, has been the single biggest contributor to this dramatic increase in resource use. The change over time in relative contributions to North-East Asia's DMC made by China, Japan and The Republic of Korea can be gauged by reference to Figure 2.11. Through all three decades, affluence (rising per capita income) was the main driver of growth in domestic resource consumption. Ever more households are integrated into the market and lifestyles in urban areas are changing rapidly, as is the economic structure in many of the Asian developing countries, requiring new infrastructure, buildings, mobility, and capital and consumer goods. Population growth contributed to growth in DMC, but to a much lesser extent and even less so over time.

8 Details on the formulation of the log transformation of IPAT and a discussion of some limitations of the technique can be found in Herendeen RA (1998) *Ecological Numeracy: Quantitative Analysis of Environmental Issues*. New York: John Wiley & Sons Inc. The values for Japan in Table 2.3 provide an illustration of one shortcoming. In cases where there have been large changes in drivers, of opposite signs, which have resulted in a small net change in *I*, we end up with very large percentage changes of opposing signs (which still add to 100%) to explain the small ΔI. In such cases, the raw percentage changes in *P*, *A*, and *T* provides a clearer representation of the dynamics over the period.

Technology is often seen as a moderating factor which yields reduced resources use through increased efficiency. Unfortunately, the observed contribution of *T* to reducing resource pressure has actually been very small over the last three decades. In the period 1985 to 1995 the change in MI of technologies being used actually contributed to DMC growing, and in the other two decades efficiency gains from *T* were relatively small.[9]

The IPAT assessment suggests the hope that improved technology will spontaneously arise, and largely resolve resource constraint issues via improved efficiency, is not well justified in the current context. It appears that more radical changes in how housing, mobility and energy needs are met may be required to adequately counter the combined effects of growing populations and growing affluence.

This regional trend is representative for the major subregions with the exception of South Asia during 1975 to 1985, where population was the main driver, and the Pacific, where population growth was the main contributing factor to growth in DMC during all three decades. Especially in North-East Asia, *T* did not contribute at all to decreasing DMC. On the contrary, *T* for this subregion increased over each of the three periods covered; that is, resource efficiency deteriorated. This reflects the fact that the proportion of North-East Asia's aggregate GDP accounted for by countries with higher materials intensities increased over time (as discussed previously for the Asia-Pacific region as a whole).

While the moderating effect of *T* has been disappointingly small to date, the rapid transition of the region currently underway presents the opportunity to greatly increase the role of technology and innovation in reducing environmental impacts. Over the coming decades, the region will experience further massive growth in infrastructure, and the type of investment made today will determine the resource use trajectories over the next 30 to 50 years. Investment in sustainable production and consumption technologies, sustainable infrastructure, and green jobs and skills, should be encouraged now – to secure ongoing competitiveness and to improve standards of living for the region's constituent societies.

9 It is important to re-emphasize here that the term 'Technology' (*T*) used in relationship to this IPAT analysis has the very specific definition of DMC/GDP i.e. materials intensity, *and is not simply connected to the more common concepts of (small t) technology*. This means that an 'advance' in technology, such as replacing bicycles with cars, may well lead to an increase in *T*, but if those cars are subsequently replaced with lighter and more fuel efficient cars (which we probably think of as an improvement in technology), *T* would actually decrease (because reduced steel and fuel requirements would lead to reduced DMC). Thus an improvement in *T* means only that *T* has decreased, *and does not necessarily imply that more 'advanced' technology is being used*. It is worth noting that fluctuations in exchange rates can have strong impacts on *T* even where the actual technologies employed remain unchanged.

Table 2.3. Major drivers of the change in domestic material consumption in the Asia-Pacific region over the period 1975–1985								
						Share contributions using log transforms		
	ΔI%	ΔI(tonnes)	ΔP	ΔA	ΔT	P	A	T
All Asia-Pacific	50.1%	3,867,811,662	20%	34%	–6%	44%	72%	–16%
Australia and NZ	10.8%	55,679,949	12%	16%	–14%	112%	141%	–153%
Central Asia	NA	41,850,000	NA	NA	NA	NA	NA	NA
North-East Asia	63.2%	2,538,422,710	14%	33%	7%	27%	59%	14%
South Asia	40.6%	870,442,129	26%	12%	0%	67%	33%	–1%
South-East Asia	35.2%	354,326,199	23%	49%	–27%	70%	133%	–102%
The Pacific	18.5%	7,090,675	26%	5%	–10%	134%	27%	–61%
Australia	10.2%	46,448,423	13%	17%	–17%	129%	158%	–187%
China	103.6%	2,259,239,976	15%	99%	–11%	19%	97%	–16%
India	38.8%	578,654,876	25%	20%	–7%	67%	56%	–24%
Indonesia	30.4%	103,463,451	23%	57%	–32%	78%	169%	–147%
Japan	0.9%	12,899,421	8%	34%	–30%	850%	3,266%	–4,016%
Kazakhstan	NA	41,850,000	NA	NA	NA	NA	NA	NA
Korea, Republic of	95.8%	173,214,235	16%	76%	–4%	22%	84%	–6%
Lao PDR	27.7%	1,708,115	21%	NA	NA	77%	NA	NA
Papua New Guinea	15.6%	4,397,601	27%	–11%	3%	164%	–82%	18%
Thailand	66.6%	118,460,093	20%	59%	–13%	37%	91%	–27%

I = DMC, ***P*** = Population, ***A*** = GDP*/ Population, ***T*** = DMC/GDP*
* GDP is denominated in exchange rate based, constant year 2000 $US

Table 2.4. Major drivers of the change in domestic material consumption in the Asia-Pacific region over the period 1985–1995								
						Share contributions using log transforms		
	ΔI%	ΔI(tonnes)	ΔP	ΔA	ΔT	P	A	T
All Asia-Pacific	81.4%	9,433,029,646	20%	47%	3%	30%	65%	5%
Australia and NZ	59.3%	339,825,023	14%	17%	19%	29%	34%	38%
Central Asia	973.1%	407,251,729	NA	NA	NA	NA	NA	NA
North-East Asia	91.4%	5,988,446,800	13%	34%	26%	19%	45%	36%
South Asia	47.0%	1,415,668,587	22%	30%	–7%	51%	69%	–19%
South-East Asia	92.7%	1,261,569,150	21%	70%	–6%	29%	81%	–10%
The Pacific	44.6%	20,268,356	29%	24%	–10%	69%	59%	–28%
Australia	67.0%	334,589,544	15%	18%	23%	27%	33%	40%
China	115.5%	5,126,852,177	15%	127%	–17%	18%	107%	–25%
India	49.9%	1,033,497,338	22%	40%	–12%	49%	84%	–33%
Indonesia	76.5%	339,784,377	18%	74%	–14%	29%	98%	–27%

Table 2.4. Major drivers of the change in domestic material consumption in the Asia-Pacific region over the period 1985–1995								
Japan	15.1%	219,409,606	4%	31%	–16%	27%	193%	–120%
Kazakhstan	308.5%	129,105,448	NA	NA	NA	NA	NA	NA
Korea, Republic of	157.6%	557,863,346	11%	109%	12%	11%	78%	12%
Lao PDR	17.9%	1,410,387	34%	25%	–29%	176%	134%	–210%
Papua New Guinea	53.9%	17,588,336	29%	23%	–4%	60%	49%	–9%
Thailand	137.1%	406,236,442	13%	118%	–4%	14%	90%	–5%

I = DMC, ***P*** = Population, ***A*** = GDP*/ Population, ***T*** = DMC/GDP*
* GDP is denominated in exchange rate based, constant year 2000 $US

Table 2.5. Major drivers of change in domestic material consumption the Asia-Pacific region over the period 1995–2005

						Share contributions using log transforms		
	Δ*I*%	**Δ*I*(tonnes)**	**Δ*P***	**Δ*A***	**Δ*T***	***P***	***A***	***T***
All Asia-Pacific	52.9%	11,113,337,115	13%	46%	–7%	29%	88%	–18%
Australia and NZ	28.5%	260,169,446	13%	27%	–10%	48%	96%	–44%
Central Asia	56.2%	252,242,380	9%	47%	–2%	19%	86%	–5%
North-East Asia	61.1%	7,658,586,708	8%	24%	21%	15%	45%	40%
South Asia	43.5%	1,924,286,813	19%	48%	–18%	48%	109%	–56%
South-East Asia	38.2%	1,002,339,806	15%	26%	–5%	44%	72%	–16%
The Pacific	23.9%	15,711,963	25%	–10%	11%	103%	–50%	47%
Australia	29.4%	245,285,101	13%	28%	–10%	47%	95%	–42%
China	83.9%	8,022,798,782	8%	121%	–23%	13%	130%	–43%
India	42.5%	1,317,929,703	17%	58%	–23%	45%	130%	–75%
Indonesia	51.1%	400,869,061	14%	14%	16%	33%	32%	36%
Japan	–14.3%	–238,743,115	2%	10%	–23%	–12%	–62%	174%
Kazakhstan	84.9%	145,065,495	–4%	93%	0%	–7%	107%	0%
Korea, Republic of	–0.1%	–752,387	7%	45%	–35%	–7,917%	–45,031%	53,048%
Lao PDR	146.1%	13,569,611	21%	51%	35%	21%	46%	33%
Papua New Guinea	33.7%	16,907,932	29%	–17%	25%	87%	–64%	77%
Thailand	6.8%	47,933,005	10%	20%	–18%	138%	272%	–310%

I = DMC, ***P*** = Population, ***A*** = GDP*/ Population, ***T*** = DMC/GDP*
* GDP is denominated in exchange rate based, constant year 2000 $US

References

Ehrlich PR and Holdren JP (1971) Impact of population growth. *Science* **171**(3977): 1212–1217.

Grossman GM and Krueger AB (1995) Economic growth and the environment. *Quarterly Journal of Economics* **110**(2): 353–377.

Herendeen RA (1998) *Ecological Numeracy: Quantitative Analysis of Environmental Issues*. John Wiley & Sons Inc: New York.

Krausmann F, Fischer-Kowalski M, Schandl H and Eisenmenger N (2008) The global sociometabolic transition. *Journal of Industrial Ecology* **12**(5–6): 637–656.

Krausmann F, Gingrich S, Eisenmenger N, Erb KH, Haberl H and Fischer-Kowalski M (2009) Growth in global materials use, GDP and population during the 20th century. *Ecological Economics* **68**(10): 2696–2705.

Myers N and Kent J (2004) *The New Consumers: The Influence of Affluence on the Environment*. Island Press: Washington DC.

Schandl H, Fischer-Kowalski M, Grunbuhel C and Krausmann F (2009) Socio-metabolic transitions in developing Asia. *Technological Forecasting and Social Change* **76**(2): 267–281.

Schandl H, Poldy F, Turner GM, Measham TG, Walker DH and Eisenmenger N (2008) Australia's resource use trajectories. *Journal of Industrial Ecology* **12**(5–6): 669–685.

Schandl H and Turner GM (2009) The dematerialization potential of the Australian economy. *Journal of Industrial Ecology* **13**(6): 863–880.

Wirsenius S (2000) Human use of land and organic materials: modeling the turnover of biomass in the global food system. Department of Physical Resource Theory, Chalmers University of Technology: Göteborg.

Wu Y (2004) *China's Economic Growth: A Miracle with Chinese Characteristics*. Routledge: London.

Chapter 3: **Energy**

James West

Main messages

- If the relative growth rates in energy consumption seen over the last 35 years continue, the Asia-Pacific region's total share of global energy demand will increase from 20.5% in 1975 to 50% by 2028.
- There is no example of a country in the Asia-Pacific region actually demonstrating a clear, sustained decrease in energy use per capita, and so little empirical support for the notion that increasing affluence beyond a certain point will lead to a decrease in energy use.
- The region has largely been able to meet radically increased energy demand from domestic energy production. This has been achieved by greatly expanding the share of coal, and decreasing the share of renewable energy in the energy mix.
- The Asia-Pacific region has shown increasing energy intensity (EI) per unit of economic output. This is the opposite of what is required to maintain GDP growth while lowering the environmental impact.
- Some key production processes in a system dominated by building new infrastructure for the first time, rather than modernizing existing infrastructure, tend to be more primary resource intensive. As a consequence, reducing EI in the Asia-Pacific region may prove more difficult than for regions dominated by mature economies.
- Increasing affluence, rather than increasing population, has been the most important factor in driving energy consumption higher in the Asia-Pacific region. Furthermore, changing technology is acting to increase energy consumption rather than to restrain it.
- Between 1970 and 2005, CO_2 emissions in the Asia-Pacific region grew more than fourfold, and rose from 15% to nearly 40% of global emissions. The region now has a major impact on global carbon emission trends.

Energy use patterns and energy efficiency in the Asia and the Pacific region

Energy and socio-metabolic transition

The importance to modern societies of access to abundant energy is hard to overstate. Virtually all major industrial processes are reliant on significant to extremely large inputs of energy. The process of modernizing and increasing labour productivity in the agricultural sector can to a large extent be thought of as the substitution of fossil fuel energy inputs for human and animal labour and, more indirectly, for other inputs such as natural (manure) type fertilizers (in the form of fossil energy intensive chemical fertilizers). The large size of services sectors, so characteristic of the most developed economies, is only made possible by huge increases in labour productivity that have been achieved over the last 200 years in the extraction, transformation, and distribution of natural resources to end consumers. All of this relies on massive inputs of energy from concentrated energy sources, mainly fossil fuels. In recent decades, it has become clear that the Earth's capacity to continue to supply some of the most valuable fossil energy sources, such as petroleum, and to dissipate emissions, such as CO_2, is not only limited, but that those limits are already being tested. It is in this context we present high level trends for the Asia and Pacific region and its subregions, and compare these trends to the global situation.[1]

Growth of energy use in the Asia-Pacific region in the global context

Figure 3.1 shows trends in total primary energy supply (TPES) for the Asia-Pacific region, rest of the world (ROW), and for the world (i.e. Asia-Pacific plus the ROW). Like materials, the rate of growth in TPES for the Asia-Pacific region is faster than for the ROW, although the disparity is less marked. For the three decades from 1975 to 2005, TPES grew at a compounding annual growth rate (CAGR) of 4.0%, compared with 1.3% for the ROW. The Asia-Pacific region's share of World TPES consequently grew from 20.5% to 35.6% over the same period. If these respective growth trends continue, the Asia-Pacific region will require 50% of World TPES by the year 2028.[2]

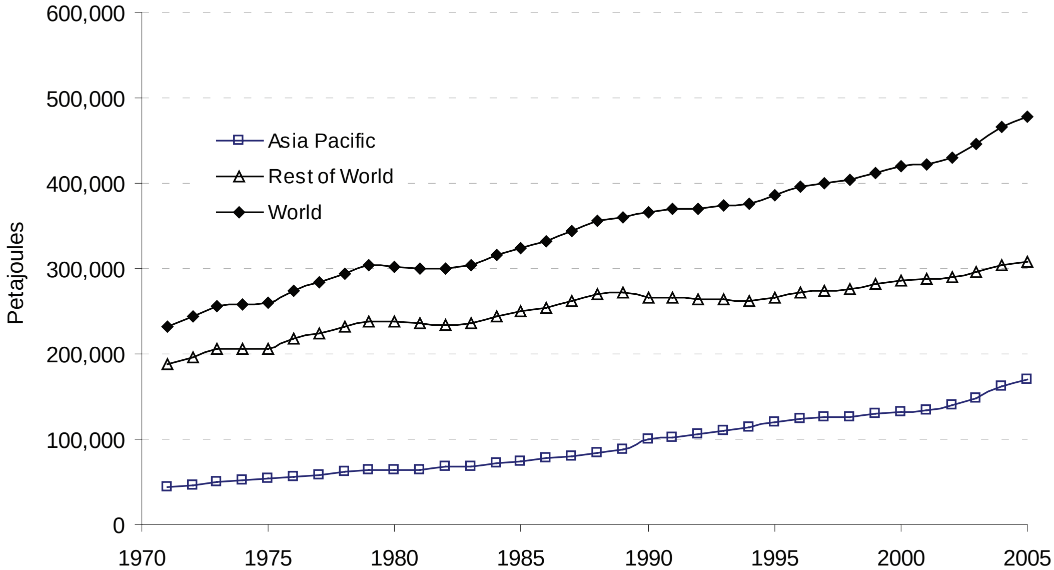


FIGURE 3.1.
Total primary energy supply for the Asia-Pacific region, rest of the world, and world, for the years 1971–2005.

The step change increase in Asia-Pacific TPES between 1989 and 1990 is due to the IEA having data for states of the former Soviet Union available from 1990, after which some were allocated to the Asia-Pacific region. Prior to this time, TPES for the former Soviet Union as a whole is excluded from the Asia-Pacific region.

1 The sources of base data used for this section are much less diverse than those used for materials, with virtually all of the data for energy flows derived from the International Energy Agency (IEA) publications (IEA 2007a, 2007b, 2007c, 2007d) and World Bank data for information on GDP and value added (World Bank 2009).

2 Where a CAGR fits the growth pattern for the full 1971–2005 for the Asia-Pacific region considerably better than a linear trend, this is not the case for the ROW, where a linear trend is slightly better. CAGRs have been applied to both here. At the low level of CAGR used for ROW, this does not significantly change the point at which the Asia-Pacific region's share reaches parity.

Figure 3.2 shows a trend towards convergence in energy use per capita between the Asia-Pacific region and the ROW, although at a much slower rate than that seen previously for materials, in Chapter 2. Annual TPES for the Asia-Pacific region has almost doubled from 23.9 GJ/capita to 46.7 GJ/capita over the full 1971–2005 period, while for ROW it remained almost static. Energy use per capita peaked for the ROW in the early 1970s, with a slight downward trend until the mid 1990s, followed by modest increases in the early 21st century.

Projecting when convergence might occur between Asia-Pacific region and the ROW in energy supply per capita is complicated by the fact that a linear trend fits the growth profile for the Asia-Pacific region, as well as an exponential curve based on a compounding growth rate, but the two alternative trends have a large impact on projected convergence dates. If we use a static ROW energy use per capita (assume 110 GJ/capita), and apply the indicated growth rate for the Asia-Pacific region of 2.3%, convergence would be expected at 110 GJ/capita in 2043. If the linear trend is in fact the better choice, convergence will require more than a century. This is important because there is evidence that the exponential growth that often characterizes the early phases of the industrialization of nations gives way to linear or slower growth in later phases.

The impact of the Asia-Pacific region on total world energy supply is less pronounced than for materials, but it is once again the region of most dynamic growth.

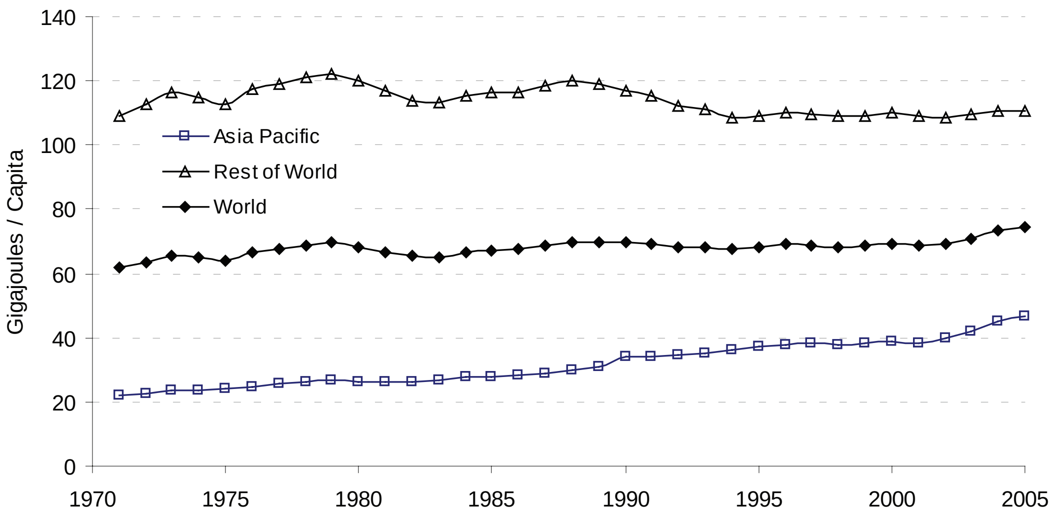


FIGURE 3.2.
Total primary energy supply per capita for the Asia-Pacific region, rest of the world, and world, for the years 1971–2005

Energy use patterns at the subregional level

Figures 3.3 to 3.5 provide a more detailed view of how energy production, trade, and supply per capita are distributed among the subregions of the Asia-Pacific region, and how energy flows changed between1975, 1990 and 2005.

In Figure 3.3, the very high domestic production of primary energy (DPPE) for the Australia and New Zealand subregion, on a per capita basis, is obvious. This is similar to the situation observed for materials. Over half of this production is accounted for by direct exports of energy in the form of coal and natural gas, with a considerable portion of the remainder embodied in exports of energy-intensive products to the rest of the region (refer to text box 2.1 'Who is the consumer?'). With the exception of Central Asia, the other subregions have DPPE/capita levels of 5% to 10% of that for Australia and New Zealand.

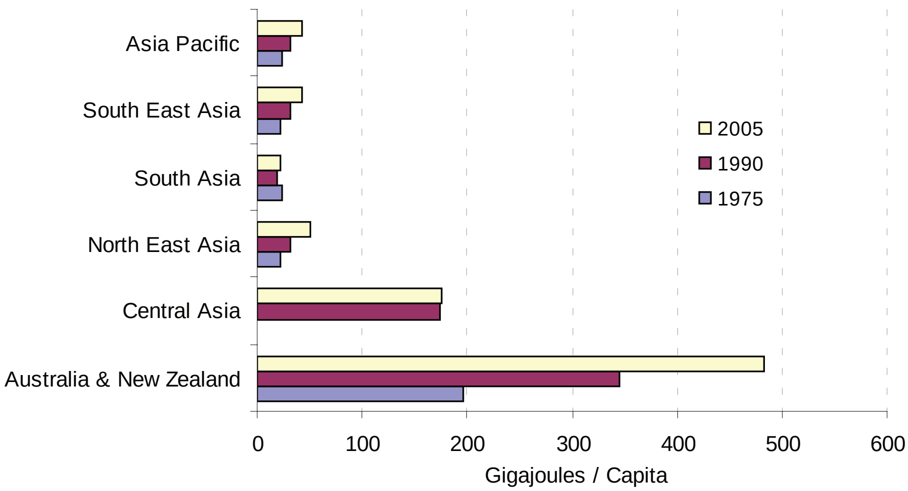


FIGURE 3.3. *Domestic production of primary energy per capita for the Asia-Pacific region and its constituent subregions for the years 1975, 1990 and 2005.*

Domestic energy production grew rapidly in three of the five subregions between 1975 and 2005 – with Australia and NZ, North-East Asia, and South-East Asia showing growth of 146%, 133% and 98%, respectively – while it contracted by around 8% in South Asia. The data series for Central Asia is not complete for the full time period, but between 1990 and 2005 energy output remained almost static.

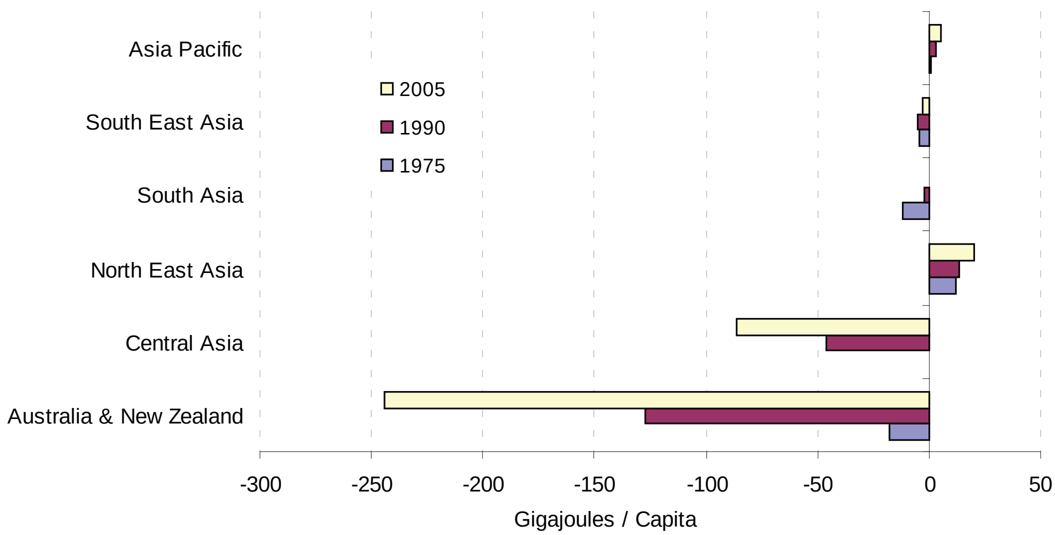


FIGURE 3.4. *Physical trade balance in energy per capita for the Asia-Pacific region and its constituent subregions for the years 1975, 1990 and 2005.*

Figure 3.4 shows the physical trade balance in energy (PTBE). This diagram highlights the role of both the Australia and New Zealand, and Central Asia subregions as important energy sources within the region, and the consistent role of North-East Asia as the major energy sink.

Even though South-East Asia's energy output over the period grew strongly, the increase in PTBE over the period shows that growth in domestic demand outstripped the subregion's capacity to increase production. This trend, if continued, will transform South-East Asia from a net energy exporter to a net importer in the near future. This transition has already taken place in South Asia, between 1990 and 2005.

With the vast bulk of the Asia-Pacific region's population located in countries that are either currently net energy importers, or evolving that way, the region as a whole is going to become increasingly dependent on energy imported from outside the region. Even with the Central Asia and Australia and New Zealand subregions each exporting energy approximately equal to their primary energy supply (both had TPES and net exports of 5,000–6,000 PJ in 2005), their combined net exports are only sufficient to meet around one-third of the net energy import requirements of North-East Asia alone (PTBE of >30,000 PJ in 2005).

While the regional energy trade balance moved further into deficit both in total energy and on a per capita basis over the period 1975–2005, the ratio of the energy trade balance to domestic production for the Asia-Pacific region as a whole has remained fairly static since the early 1980s. The main factor maintaining this stability has been strong growth in domestic energy production in North-East Asia, which more than doubled from 21.5 GJ/capita to 50.0 GJ/capita between 1975 and 2005. This translates to an increase in total primary energy production of over 52,000 PJ in 2005, equal to a compound growth rate of 4.0%. This is more than four times the energy available from those subregions that were net exporters of energy. The region's energy trade balance accounts over the near to medium term will thus be determined much more by the ability of the most populous subregions to increase domestic production, rather than by the capacity of net energy exporters to increase exports.

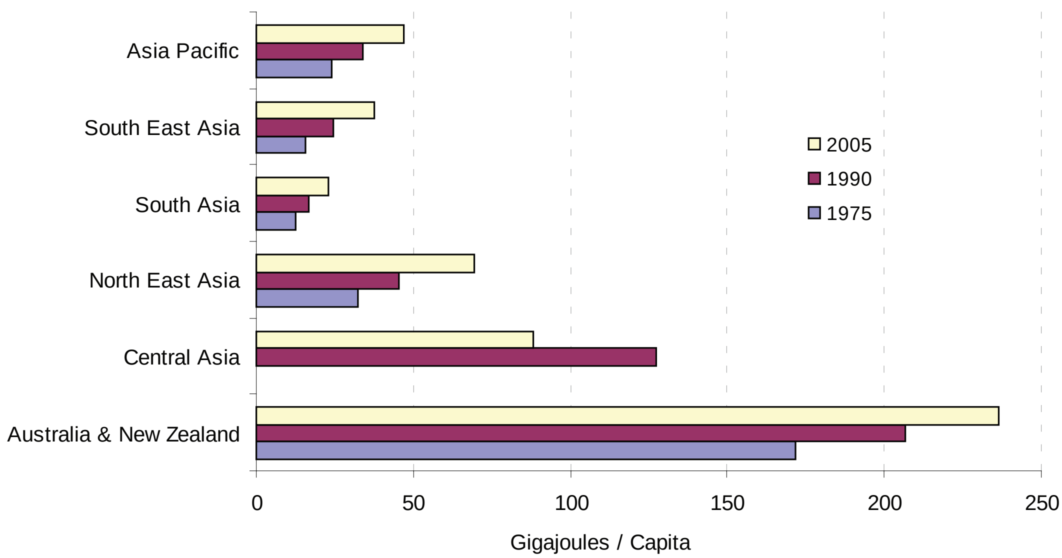


FIGURE 3.5.
Total primary energy supply per capita for the Asia-Pacific region and its constituent subregions for 1975, 1990 and 2005

Figure 3.5 shows how energy supply per capita has evolved for each subregion for the same time intervals as Figures 3.3 and 3.4. The trend for the region as a whole is intermediate between those for the North-East Asia and South Asia subregions, as would be expected from the population weighting effects discussed previously in Chapter 2. The growth in North-East Asia between 1975 and 2005 is consistent with a compound growth rate of 2.5%; for South Asia the corresponding rate is 2.0%.

For South-East Asia, the third most populous subregion, the indicated growth rate is higher at around 2.9%, and for the Asia-Pacific region as a whole the rate is 2.3%. In all four cases, an exponential growth curve fits the full base set of data (1971–2005) better than a linear trend. Of those subregions for which a 30+ year time series is available, only Australia and New Zealand exhibit a better fit to linear rather than exponential growth. This is consistent with the observation above that growth in energy supply per capita tends to become more linear than exponential in later stages of industrialization.

Evolution of the energy mix used in the Asia-Pacific region.

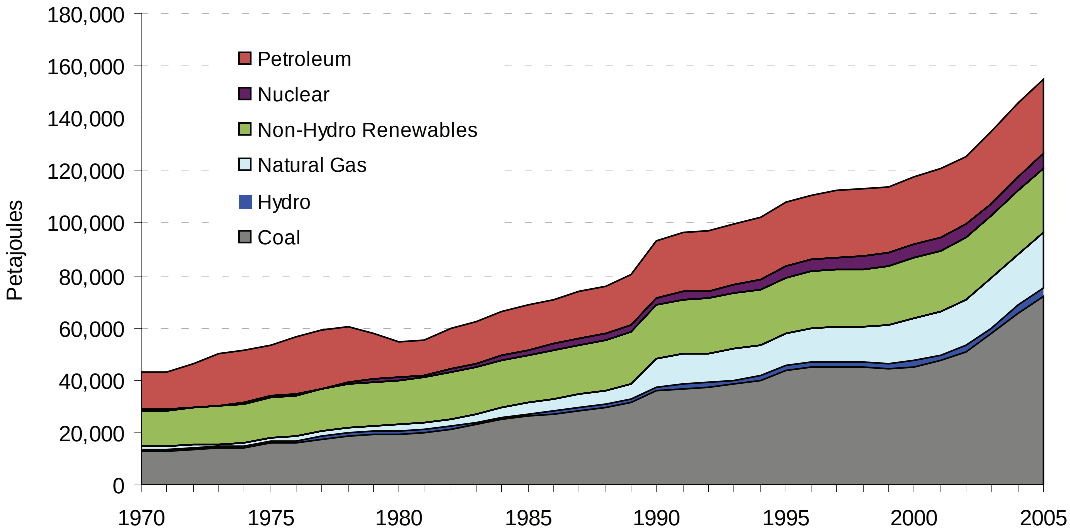


FIGURE 3.6. *Domestic production of primary energy in the Asia-Pacific region, categorized by source, for the years 1971–2005.*

Figure 3.6 illustrates the changing mix of primary energy produced in the Asia-Pacific region for the period 1971–2005. Anomalous features in the graph are a rapid dip in petroleum production from 1978–1980, and a major increase in natural gas production between 1989 and 1990. The first is explained by a major reduction in petroleum production in Iran (which precipitated the Second Oil Shock), and the second relates to the incorporation of some former Soviet states. Another noteworthy element is very the steep rise in regional coal production from 2000.

With respect to longer term trends in domestic energy production, some energy categories have remained relatively static in absolute terms (and declined rapidly as a share of the total), while others have grown strongly. The most important in the first category is petroleum. Like non-hydro renewables, growth in the production of petroleum over the whole period has been small and declined since 2000. Unlike non-hydro renewables, the total requirement for petroleum in the region has increased quite strongly over the period (see Figure 3.8). The result of this divergence between domestic production and total supply can be seen clearly in Figure 3.7, where the trade balance for the region has evolved over time to be totally dominated by large scale petroleum imports.[3] This is of particular importance because petroleum is the major energy source most likely to become relatively scarce in the near to

3 The categories of energy used here are consistent between figures 3.6, 3.8, 3.9, and Table 3.1, but change for Figure 3.7 (PTBE). The major primary categories with significant trade match well – that is, coal, natural gas, and petroleum (with petroleum products added) – but the trade in electricity cannot be classified generally as trade in primary energy. Any electricity traded may be effectively primary, or at least embody the majority of the primary energy used in generation, such as for hydro/wind/solar. It may equally be secondary and embody only a small fraction of the primary energy used, such as from coal fired or nuclear generators (typically <30% of primary energy invested would be reflected in the traded electricity).

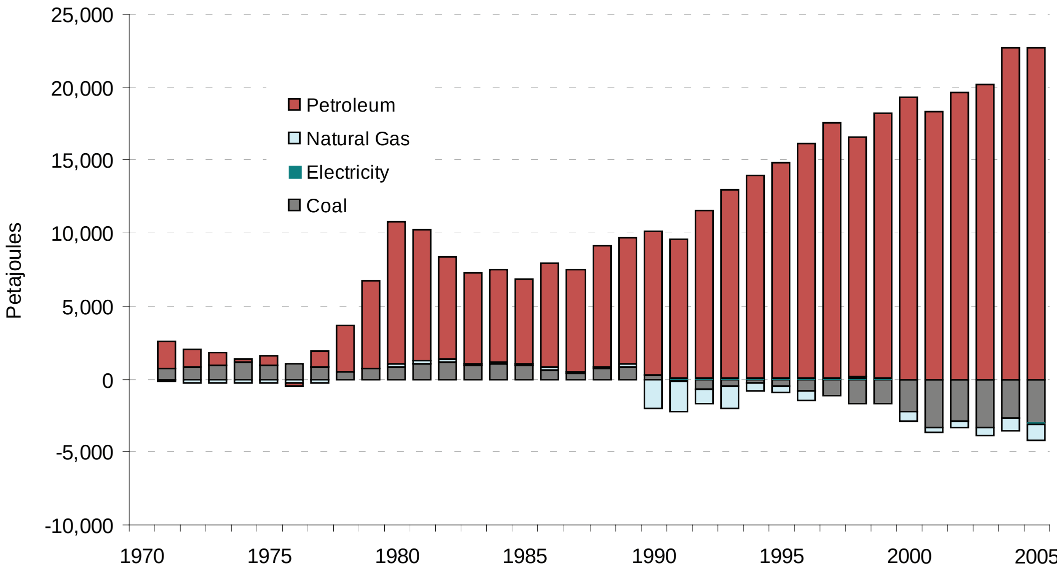


FIGURE 3.7.
Physical trade balance in energy for the Asia-Pacific region, categorized by source, for the years 1971–2005.

medium term. In contrast, despite the massive increase in coal consumption over the same period, coal production has more than kept pace, and the region has gone from being a net importer to a net exporter.

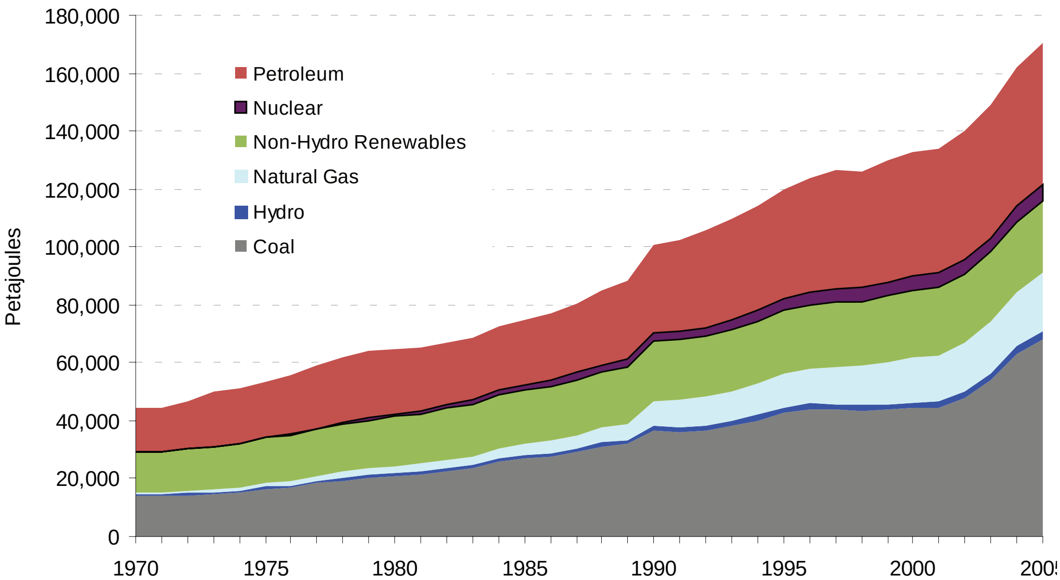


FIGURE 3.8.
Total primary energy supply for the Asia-Pacific region, categorized by source, for the years 1971–2005.

In Figure 3.8, the strong growth of coal and natural gas in both total contribution and share is clear. Coal has come from being slightly less important than either non-hydro renewables or petroleum in DPPE share (30%, 33%, and 34%, respectively in 1971), to being a larger component than both combined (47%, 16%, and 18%, respectively in 2005). The CAGR of best fit for coal DPPE over the period is 5.2%. This does not portend well for containing CO_2 emissions, at least in the near to medium term.

Natural gas, a very minor component in both production and total supply in 1971 (2% and 1%, respectively), grew to contribute 14% and 12%, respectively, by 2005: almost as large a contribution as non-hydro renewables. Due to the discontinuity from 1989–91, which results from the inclusion of some former Soviet states in the Asia-Pacific grouping, a compounding growth rate for the whole period is not calculated here, but from 1990–2005 it was 2.0% for domestic energy production and 2.5% for total energy supply.

Both hydro and nuclear grew quite strongly over the period, but from very low bases, and remain relatively insignificant overall by 2005 (their combined contribution remained under 6% of DPPE and TPES by 2005). The apparent contribution of nuclear in 2005 (3.4%) is double that of hydro (1.7%), but the IEA presents nuclear energy in terms of heat production. The actual energy available for use elsewhere in the economy is the electricity generated, and nuclear will typically lose over 65% of its initial heat energy during conversion, so the actual contribution of hydro to final energy for consumption is probably larger than for nuclear currently. This will probably change. Whereas nuclear power has the potential to continue to expand rapidly, major expansion in hydro is likely to be limited by the availability of physically suitable and socially acceptable sites (see Box 3.1).

Box 3.1. Limitations of hydropower

The potential to expand hydro further is limited by the availability of sites, especially those suitable for large-scale projects. Although individual hydro installations can be of impressive size and generating capacity, cumulatively they are unlikely to contribute a much greater share of overall energy supplies than they currently do, and are instead likely to become of diminishing relative importance.

The example of the recently commissioned Three Gorges Dam project in China illustrates this point. Construction of this project required well over a decade, and it is currently the largest single hydroelectric project in the world, in terms of installed generation capacity (expected to reach 22.5 GW upon completion of additional capacity by 2011). A hydro plant's output is limited by inputs of rainfall to its catchment, so the average output is usually low in comparison to coal fired, natural gas fired, or nuclear generators of similar capacity. Nonetheless, the expected annual output of the Three Gorges Dam remains impressive, with figures in the range of 80 to 100 terawatt hours (360 PJ) generally quoted (Gleick 2008; Yan 2008). Although large, this figure is dwarfed by even a single year's growth in coal production in the Asia-Pacific region, which rose by 6,330 PJ between 2004 and 2005. Even if it is assumed that all of this additional coal energy was used to produce electricity, and incurred conversion losses of 70%, it would still be necessary to create the equivalent of one new Three Gorges project every 2 months to replace the yearly expansion in energy production currently being met by coal.

The large, but decreasing, share of non-hydro renewables over the period merits further examination. This category includes technologies such as wind turbines and solar technologies, but more importantly it includes combustible renewables and waste (largely biomass). A breakdown of the original IEA categories assigned to the non-hydro renewables here is given in Table 3.1.

Table 3.1. Composition of the non-hydro renewables category, showing the dominance of combustible renewables and waste				
	1975	**1985**	**1995**	**2005**
Non-hydro renewables (PJ)	15,454	18,487	21,662	24,543
Combustible renewables and waste	99.7%	98.5%	97.4%	96.5%
Geothermal	0.3%	1.5%	2.4%	3.3%
Solar/wind/other	0.0%	0.0%	0.2%	0.3%

It is clear from Table 3.1 that non-hydro renewables in the Asia-Pacific region consist almost totally of combustible renewables and waste. This is significant because the high proportion of non-hydro renewables in the Asia-Pacific region relative to the rest of the world stems from the region's low levels of development rather than rapid uptake of newer renewable technologies. For poorer agrarian countries, biomass fuels such as wood, crop residues, and agricultural wastes are far more important in the total energy supply than in industrialized countries. As countries industrialize, the share of energy supplied by biomass drops sharply. This phenomenon can be confirmed by reference to pie chart sections of the detailed energy data panels for individual countries in Figures 3.13 to 20, below.

Non-hydro renewable energy sources in the Asia-Pacific region overwhelmingly mean traditional biomass fuels. The share of new, high technology renewable energy is very small, but growing.

The growth rate of the minor non-hydro renewables as a share of total energy supply over the period 1975–2005 was 8.6%, but starts from a very low base. Significantly, this trend decelerated to 3.3% in the final decade (1995–2005), well below the coal growth rate of 4.8% for the same decade. In the Asia-Pacific region, fossil fuels have expanded their share of energy output at the expense of renewables.

Trends in energy efficiency, regionally and by broad industrial sector.

Figure 3.9 shows how energy intensity (EI) has changed over time for the Asia-Pacific, the ROW, and world. EI is the amount of energy used to produce a single unit of GDP; less energy used indicates efficiency is rising whereas more energy indicates lower efficiency. Note that the term energy efficiency as used in this chapter refers only to the economic efficiency with which energy is used; that is, energy intensity TPES/GDP and its inverse, energy productivity. The efficiency with which energy is used to achieve other goals, such as poverty alleviation or broader social development, are not considered or implied.

EI is somewhat more consistent than materials intensity (MI – see Chapter 2), because energy is more restricted in form than materials. Also, conversion losses between primary energy and the forms in which the energy is finally consumed are usually far smaller than those common in important materials processes. When considering energy, there are no important equivalents to the major losses in mass common in many ore-to-metal conversions, for example.

The trends in Figure 3.9 have some major differences to those seen earlier for materials, in Chapter 2. EI starts out better in the Asia-Pacific region than for the ROW, and remains comparable to the ROW

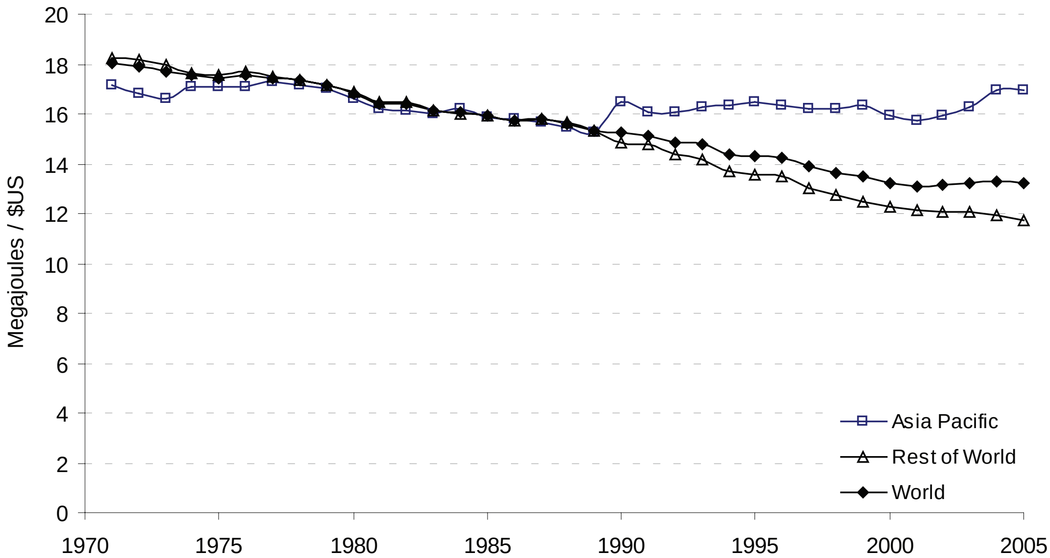


FIGURE 3.9. *Energy intensity per $US GDP for the Asia-Pacific, rest of the world (ROW), and world, for the years 1971–2005. (Energy is TPES, dollars are constant year 2000 $US, exchange rate based).*

and world as a whole until 1990. Also, the Asia-Pacific, the ROW, and world all showed decreasing EI for the period 1971–1989. That is, they became more efficient in the way they use energy.

The step change in EI for Asia-Pacific region between 1989 and 1990 reflects the inclusion of former Soviet states after the dissolution of the Soviet Union. However, the change in trend from declining to static and then increasing EI from that point on reflects the underlying trend for the Asia-Pacific region. In contrast, the ROW continues its approximately linear downward trend until the end of the 1990s, and then levels off in the early 2000s.

The increase in EI for the Asia-Pacific region as a whole is occurring despite a fairly consistent trend towards static or lower EI for individual countries (refer to Figures 3.13 to 3.20). As with materials intensity, this is due to major changes in the relative sizes of the individual economies, with a large shift towards high EI economies. Using the examples of Japan and China between 1971 and 2005, Japan's EI decreased from 6.6 MJ/$ to 4.4 MJ/$, while China's EI decreased from 153 MJ/$ to 38 MJ/$, equivalent to a CAGR of –13%. Despite such dramatic improvements in EI in China, at the end of the period it still required five times more energy per $ of GDP than Japan had required at the start of the period. Over the same period, China's share of the total Asia-Pacific region economy grew from 4% to 19%, whereas Japan's share decreased from 73% to 50%.

Figure 3.10 shows final energy consumption (FEC) for 1971–2005 for four major economic sectors. Services grew fastest, with a growth rate exceeding 10% over the period. Agriculture had the next fastest growth at 4.9%. The growth in services was concentrated in the years before 1995 and contributed to the decrease in EI for that period, because services typically have low energy use. In the early part of the 21st century, growth in services is largely static, growth in industry's energy intensity accelerates, and EI can be seen to increase in Figure 3.9.

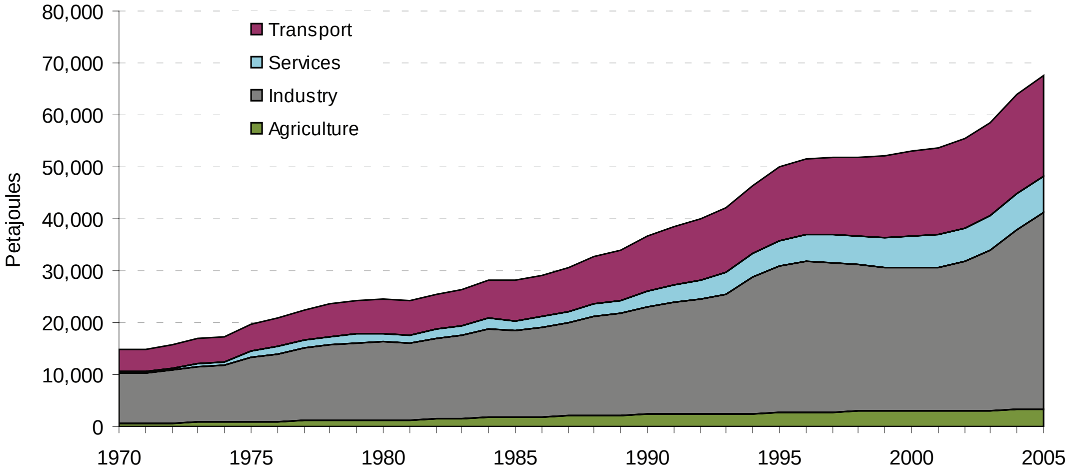


FIGURE 3.10.
Final energy consumption for the Asia-Pacific region for four major economic sectors for the years 1971–2005.

Figure 3.11 shows EI for three major sectors of the economy.[4] An important feature of this graph is the increase in EI for two of the three sectors, with industry nearly static over the full 35 year time interval. For the last 10–15 years the trend has been effectively static for agriculture and services.

The near static performance of industry runs counter to notions that ongoing improvements in industrial energy efficiency are inevitable, and calls into question the likelihood of achieving such goals as 'factor four' improvements in EI or overall resource efficiency. Achieving such improvements is inherently harder in newly industrializing economies than in mature economies (see Box 3.2).

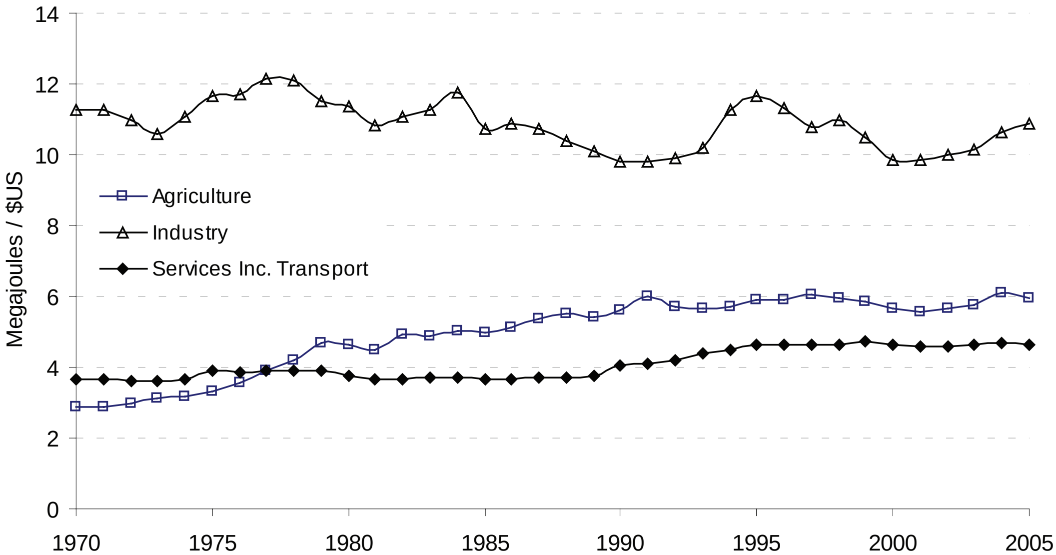


FIGURE 3.11.
Energy intensity per $US value added for three major economic sectors (energy is total final consumption, dollars are constant year 2000 $US, exchange rate based).

4 Transport was aggregated with services when determining EI as the base data on value added by sector did not have separate components for transport and services, unlike the TFEC data.

Box 3.2. Recycling of energy embedded in metals

The structure of inputs to production in newly industrializing nations can be fundamentally different from that of more mature economies. This is especially the case where the scale of new development is large on a world scale, as is currently the case for the Asia-Pacific region. To illustrate, consider the origins of metals used in a mature economy compared with those for an economy engaging in rapid deployment of new physical infrastructure. In a mature economy, a considerable proportion of the metals required are available from recycling of scrapped goods, buildings, industrial plant, and so on. For major metals, such as iron and aluminum, the energy intensity of metal derived from scrap is much lower than for metal produced from raw metal ores (Martchek 2006; Price *et al.* 2002; Ross and Feng 1991).

In contrast, in a rapidly developing economy, where much infrastructure is being built for the first time, there is generally not a large base of scrap on which to draw. A high percentage of its metal requirements must therefore be met by newly mined and extracted metal. As a result of this, even where the processes for producing new metal from primary ore are equally efficient in both economies, the rapidly developing economy will still show higher energy intensity for those metals overall.

For the aggregated Asia-Pacific economy, the previously discussed (Chapter 2) changes in relative shares of industrial output between a rapidly industrializing China and a mature Japan interact with this phenomenon to reduce or even reverse gains in energy intensities, which may occur at the level of individual countries.

In contrast to industry, increasing EI in the agriculture sector is not unexpected. As economies industrialize, agricultural practices generally become more mechanized and so more energy intensive. Furthermore, it is generally the best agricultural land that is used first. If agriculture expands further, that expansion is generally on to less productive land, which requires greater inputs, including energy, to achieve the same level of production. The relatively static EI of agriculture since 1990 implies that other processes have acted to counteract this dynamic recently, but the precise factors have not been investigated here.

Transport accounts for the great majority of energy used in the services category in Figure 3.11 (73% in 2005). The deteriorating EI over the period therefore probably reflects developments in the transport sector, such as private car travel supplanting public transport, increasing air travel and freight, and so on.

Energy use patterns and energy efficiency for selected countries

This section reviews energy use patterns and energy efficiency for a subset of countries of the Asia-Pacific region, selecting representatives from each category of country according to the typology developed in (Krausmann *et al.* 2008) and discussed in Chapter 2.

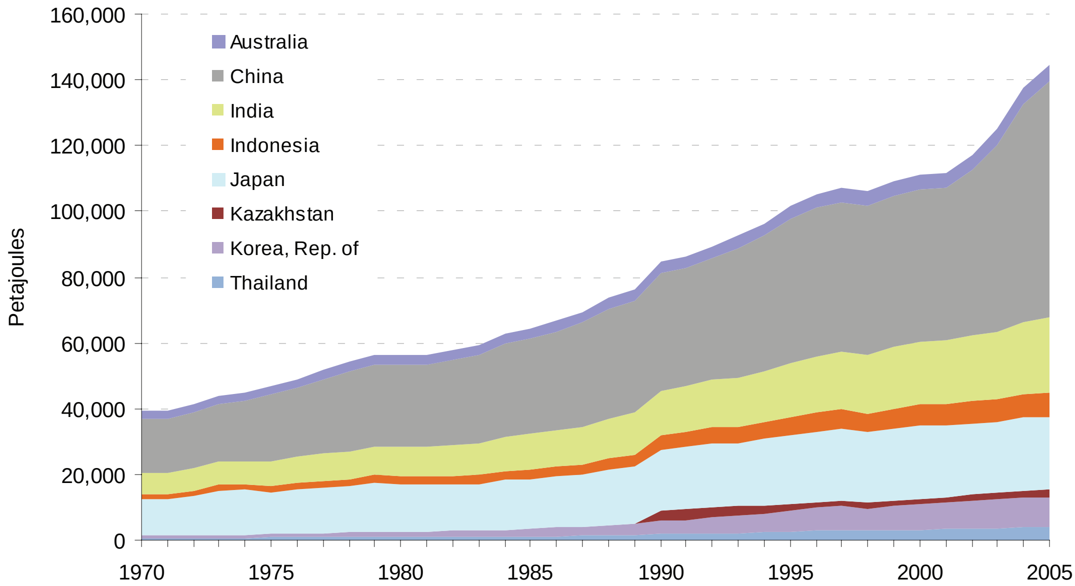


FIGURE 3.12.
Total primary energy supply for each of eight focus countries (the Lao People's Democratic Republic and Papua New Guinea omitted from energy section due to insufficient data)

Figure 3.12 shows total primary energy supply for eight countries from 1971–2005. China was the largest consumer of energy for the whole period, although growth was modest in comparison to that of materials for most of the period. This changed in 2001, where China entered a period of very rapid energy growth.

China's EI remains very high, at 38 MJ/$, but it starts from a much higher base of 153.2 MJ/$ in 1971 (Figure 3.14). This is consistent with a compounding annual improvement in efficiency of 4.0%, by far the fastest improvement among the focus group of countries. This efficiency appears to have started to deteriorate from 2002 on, as shown in Figure 3.14.

India, the other major representative of the high population density developing (HDD) type countries, shows smooth growth in total energy supply from 1971–2005, which is consistent with an annual growth rate of around 3.7% (Figure 3.15). This contrasts with the highly variable trends which characterize China's energy supply over the period. India's EI improved from 56.6 to 34.9 MJ/$ between 1971 and 2005. Encouragingly, the rate of improvement in India's EI was accelerating at the end of the time period. Looking at Figure 3.15, this improvement may have been driven by sustained improvements in Indian industry's EI from 1997 on, on top of the sustained improvements of the country's services sector over the whole period. Note, however, that the EI of individual sectors is calculated on a different basis to the overall national and regional EI, so drawing inferences about national trends from sectoral trends is inadvisable.[5]

5 Detailed energy intensity data on individual economic sectors is done using a different basis, final energy consumed, to the TPES basis used for overall national and regional EI. This is because IEA data for individual sectors is given as FEC, but for the nation as a whole it is more relevant to capture the total energy used, including losses. These losses are captured in the sectoral breakouts given in the detailed national energy panels by the 'TPES–TFEC' series.

The massive increase in energy assigned to 'other final energy consumption' between 1993 and 1994 for India and China results from a change in the underlying IEA accounting. Much energy previously counted under statistical differences' was assigned to the 'residential' category from 1994 onwards.

Indonesia's EI has been relatively static within a band of 33 to 40 since the early 1980s (Figure 3.16), while Thailand's improved marginally from 29.3 MJ/$ in 1971 to 26.7 MJ/$ in 2005 Figure 3.20).

In each of the four HDD countries presented (China, India, Indonesia, and Thailand), there is the same trend towards a generally rapid decline in the share of energy supply being met from non-hydro renewables, and a strong increase in the share met from petroleum and/or coal. This has major, unfavourable implications for the future of both oil supplies (demand increasing even more rapidly than the rapid growth in TPES for these countries), and CO_2 emissions (lower CO_2 sources losing share to high CO_2 sources).

The two high population density industrialized (HDI) countries, Japan and the Republic of Korea, diverged strongly in their trajectories for both energy supply and intensity (Figures 3.17 and 3.19). Japan showed a large decrease in its share of the aggregated TPES for the eight selected countries between 1975 and 2005, while the Republic of Korea showed the largest relative share increase of all the countries analysed, from 2.2% to 6.2%. The Republic of Korea displayed a very high annual growth rate in energy supply of around 8.7% between 1971 and 1997. TPES fell abruptly in 1998, and since then has moved into a much slower growth regime, which appears similar to Japan's trajectory since 1987. With Japan and the Republic of Korea both being examples of HDI type countries, but with the Republic of Korea's industrial development beginning later than Japan's, it is possible the historic trajectory of Japan's energy supply may provide an indication of the future trajectory of the Republic of Korea.

Japan began the 1971–2005 period with exceptionally high energy efficiency, with EI at 6.0 MJ/$, and then continued to improve to 4.4 MJ/$, although nearly all of this improvement was achieved by the mid-1980s. Japan, as at 2005, was able to produce one unit of economic output using only 41% of the energy required by the next most efficient country studied (Australia). Over the same period, the Republic of Korea's EI increased from 10.8 MJ/$ in 1971 to 16.2 MJ/$ in 1997, although it subsequently improved to 14.0 MJ/$ by 2005.

In both countries, there has been a strong trend towards a lower share of energy for petroleum and coal, and greatly increased shares for natural gas and nuclear. There has also been growth in non-hydro renewables, but this began from a near zero base and remains insignificant at less than 2%.

Australia, a low population density industrialized New World (LDI-NW) type country, declined rapidly in its share of the energy supply used by the region as a whole, even as its absolute supply grew from 2,185 PJ in 1971 to 5,106 PJ in 2005 (Figure 3.13). This illustrates how rapidly TPES is growing for the group as a whole. Australia's EI improved marginally, keeping it below the average World EI of 13.2 MJ/$ in 2005: the only focus group country other than Japan to achieve this.

Trends in Australia's energy mix appear intermediate between those for the HDD and HDI countries. The share of petroleum has decreased strongly, while there was a marginal increase in coal. Non-hydro renewables have declined considerably, contributing a larger proportion of TPES than for the HDI countries, but lower than for HDD.

Kazakhstan, a low population density industrialized country of the Old World (LDI-OW), shows highly variable trends over a truncated time series (1992–2005), presumably symptomatic of the process of major political and economic restructuring highlighted in a previous section. Kazakhstan was the only country studied where energy supply per capita at the end of its time series is lower than at the beginning. This situation is not likely to endure, because supply has been growing very rapidly since 1999, at 6.5% a year. Kazakhstan has achieved major improvements in energy efficiency, with EI decreasing at a compounding annual rate of 11.2% between 1992 and 2005. Production increased strongly over the period, which, combined with the decrease in total supply, has enabled Kazakhstan to increase annual net energy exports from 409 PJ to 2868 PJ: a rate of 16.2% per annum.

A final point regarding the full set of summary panels for individual countries is that despite covering a very wide range of incomes per capita, from some of the poorest to some of the wealthiest nations, there is no example of a country actually demonstrating a clear decrease in energy use per capita. Wealthier nations such as Australia do show slower rates of growth than poorer nations – and in the case of Japan it becomes effectively static – but none of them so far display the downward trajectory in TPES/capita we would expect if some form of Environmental Kuznets curve does exist for energy consumption. The observed data give little support to the notion that increasing affluence beyond a certain point will lead to a decrease in energy use. This is also consistent with the situation observed for materials.

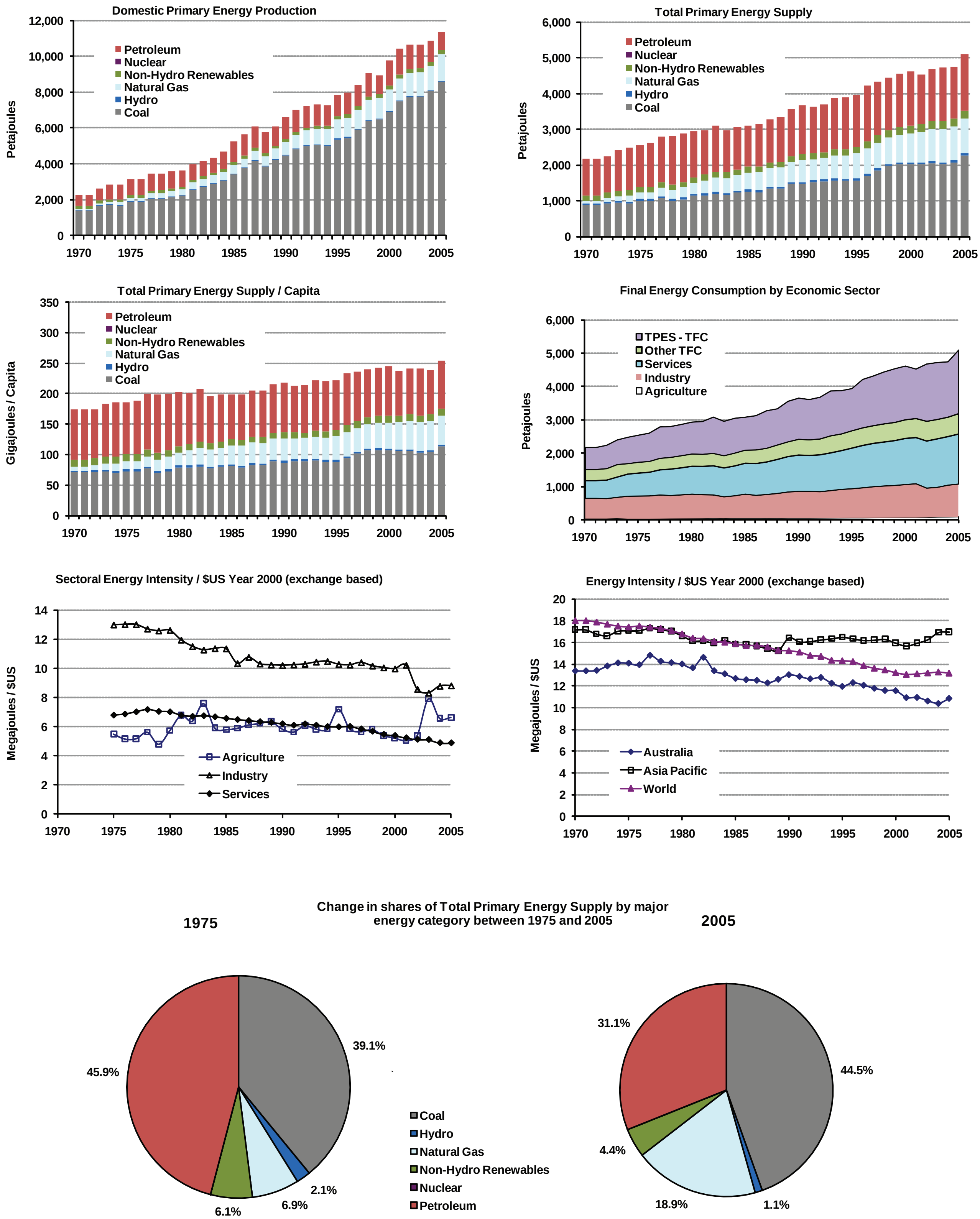


FIGURE 3.13. Summary panel of energy flows and energy intensity for Australia

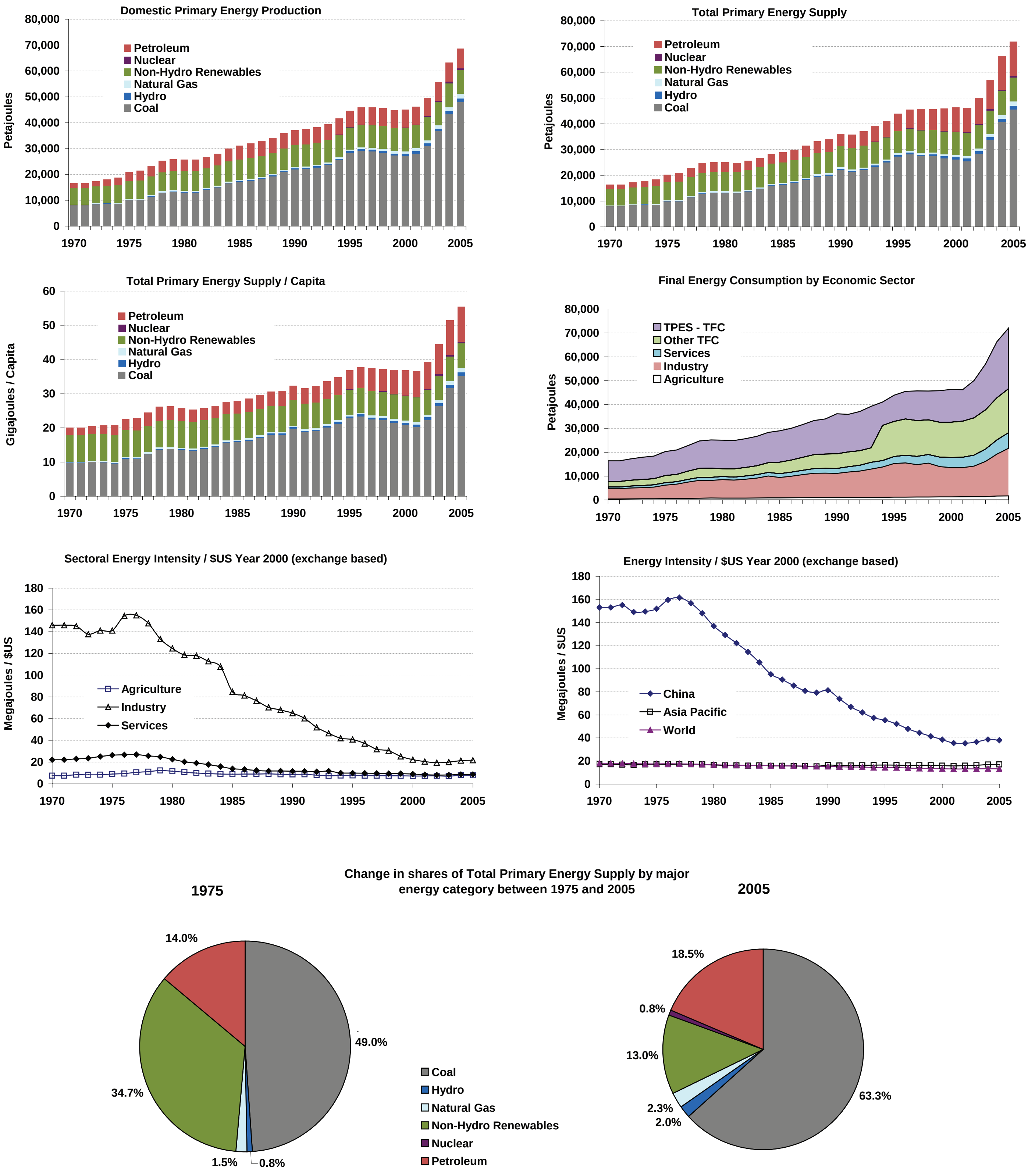


FIGURE 3.14. *Summary panel of energy flows and energy intensity for China*

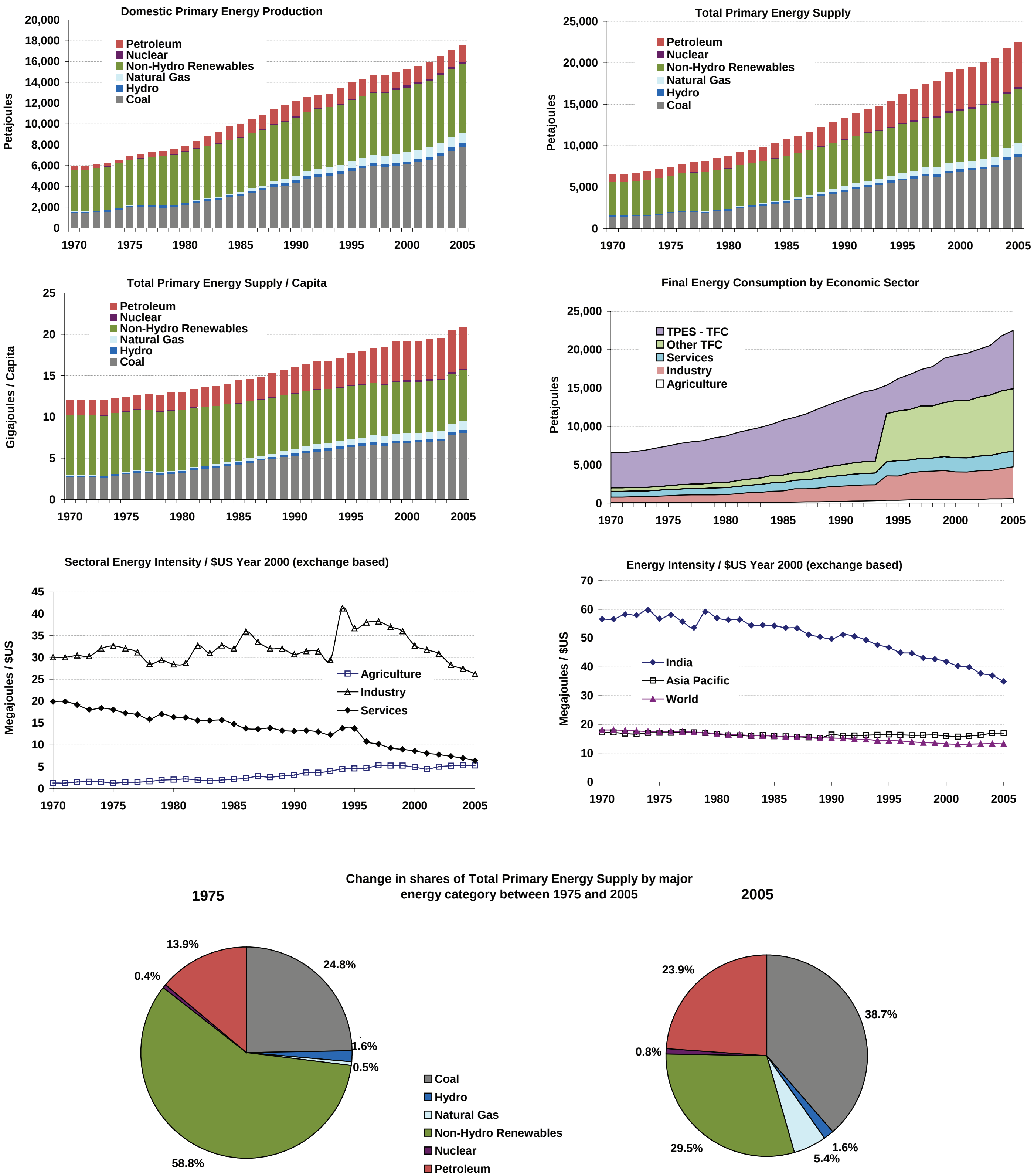


FIGURE 3.15. Summary panel of energy flows and energy intensity for India

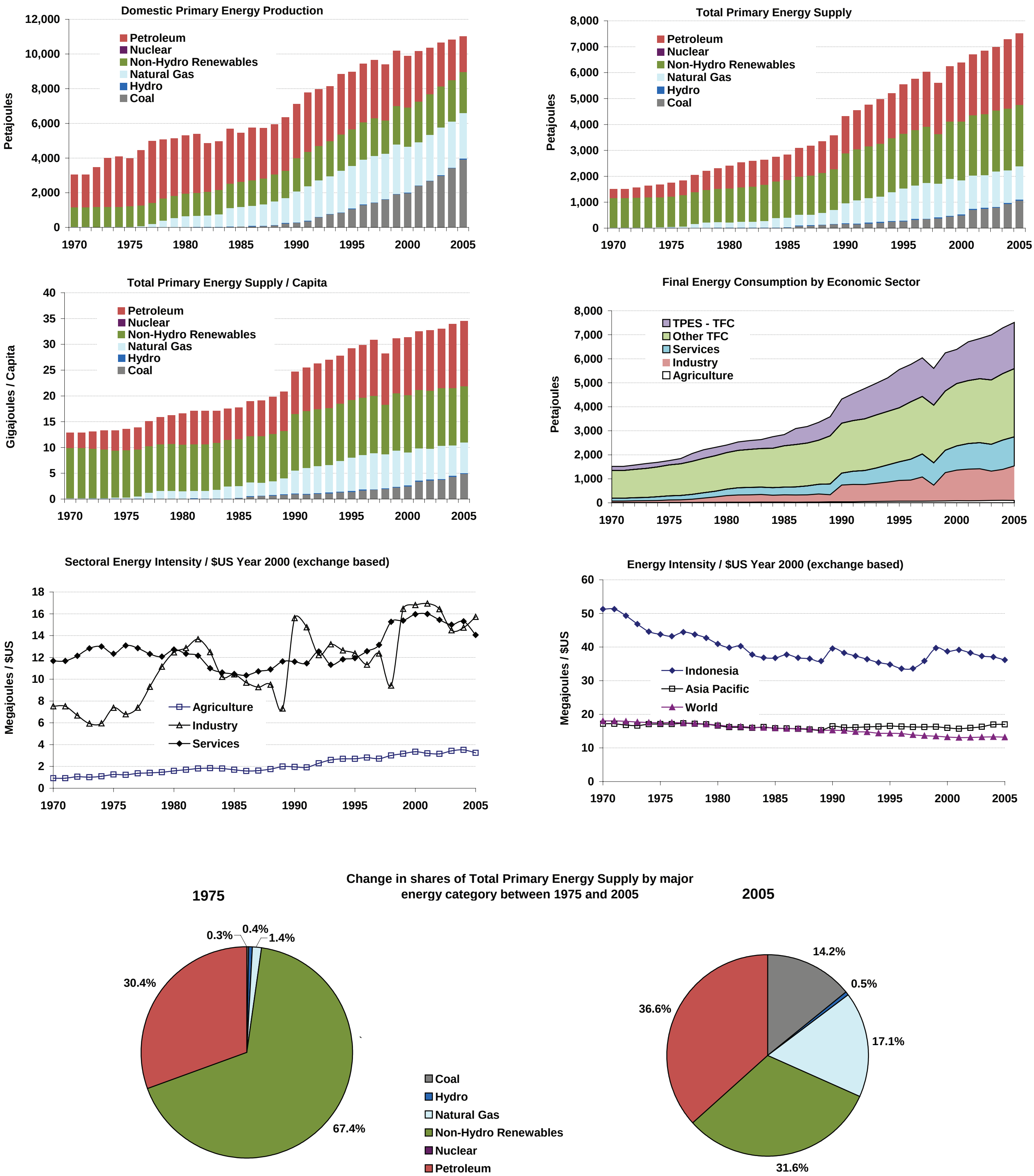


FIGURE 3.16. Summary panel of energy flows and energy intensity for Indonesia

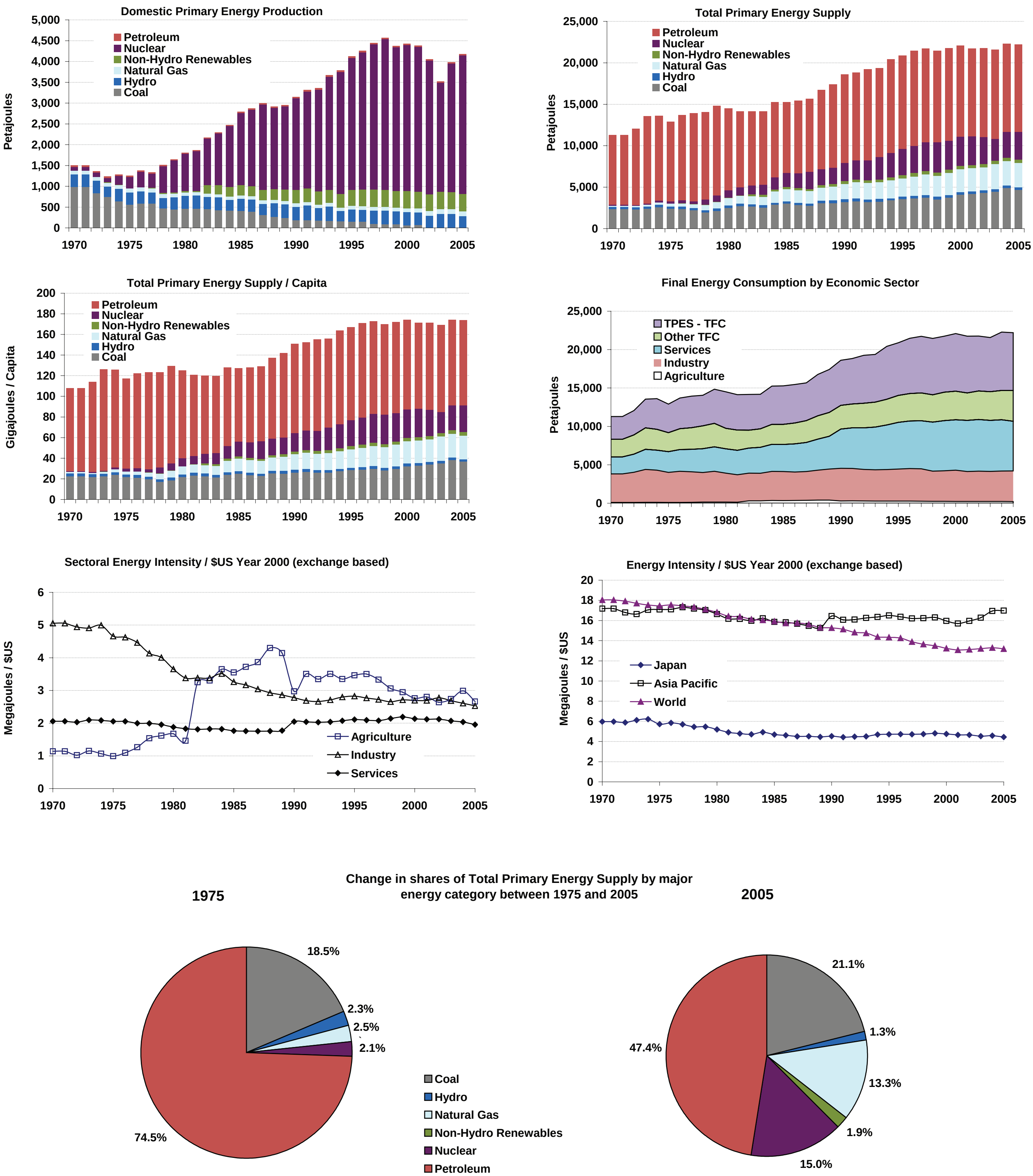


FIGURE 3.17. *Summary panel of energy flows and energy intensity for Japan*

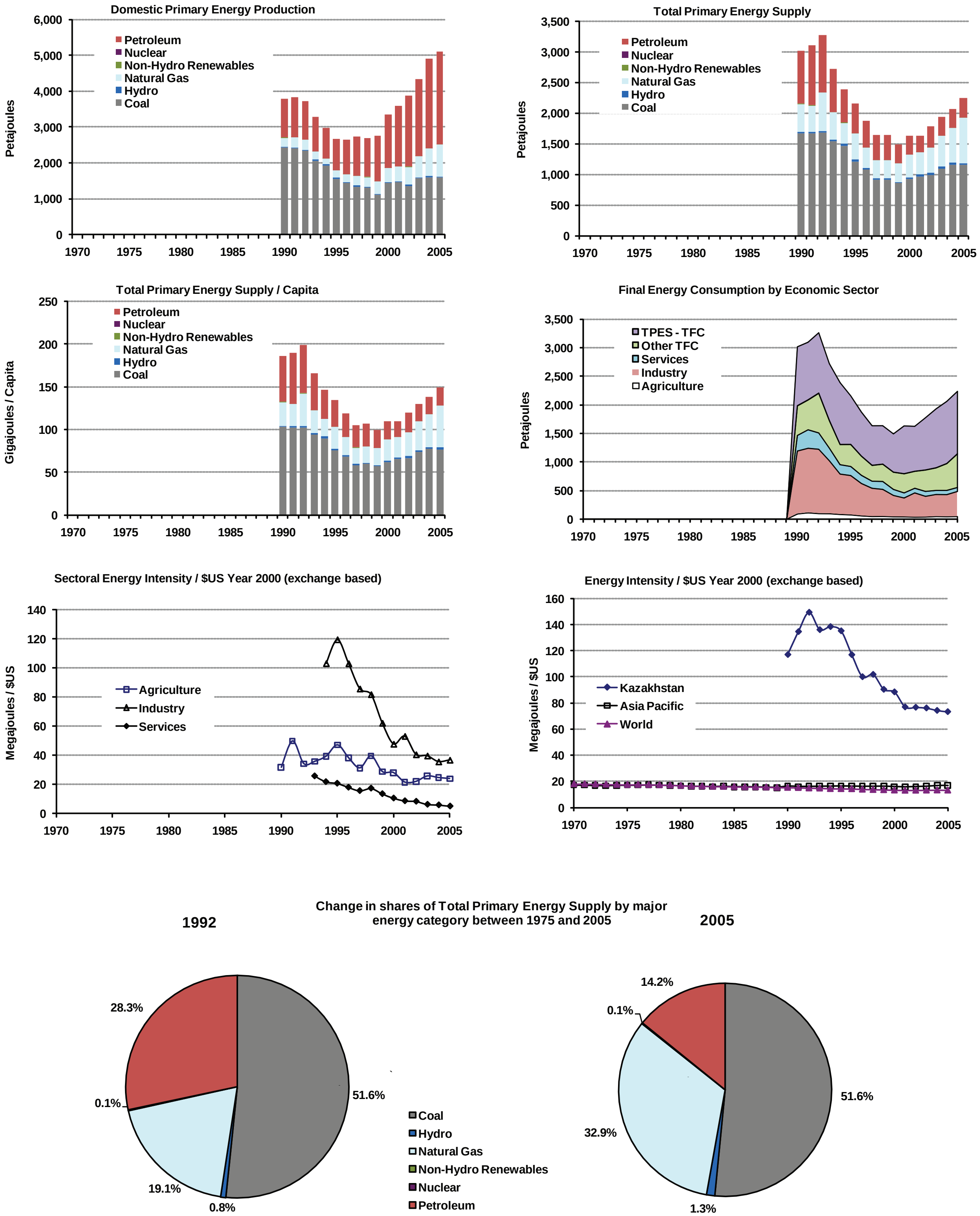


FIGURE 3.18. Summary panel of energy flows and energy intensity for Kazakhstan

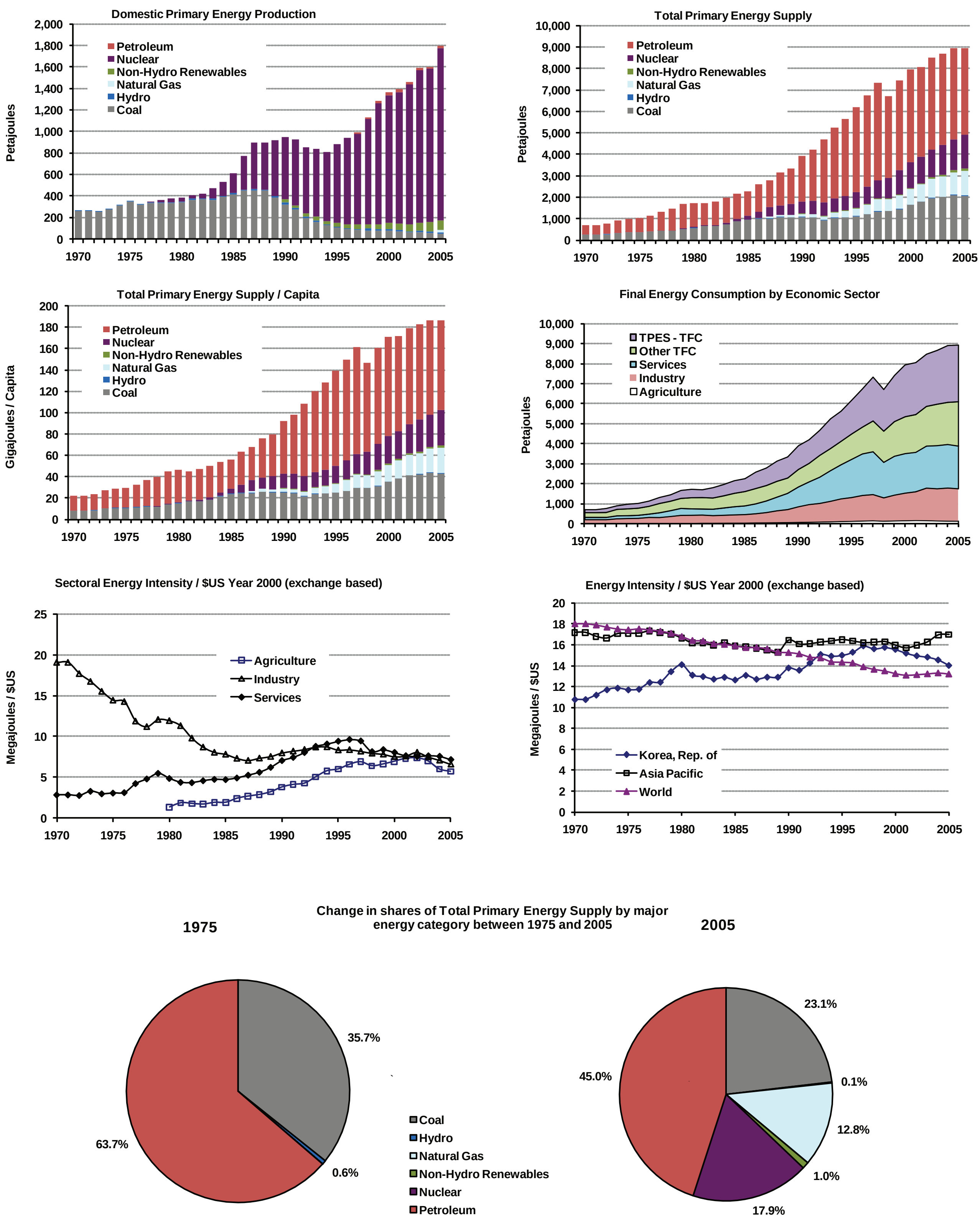


FIGURE 3.19. Summary panel of energy flows and energy intensity for Republic of Korea

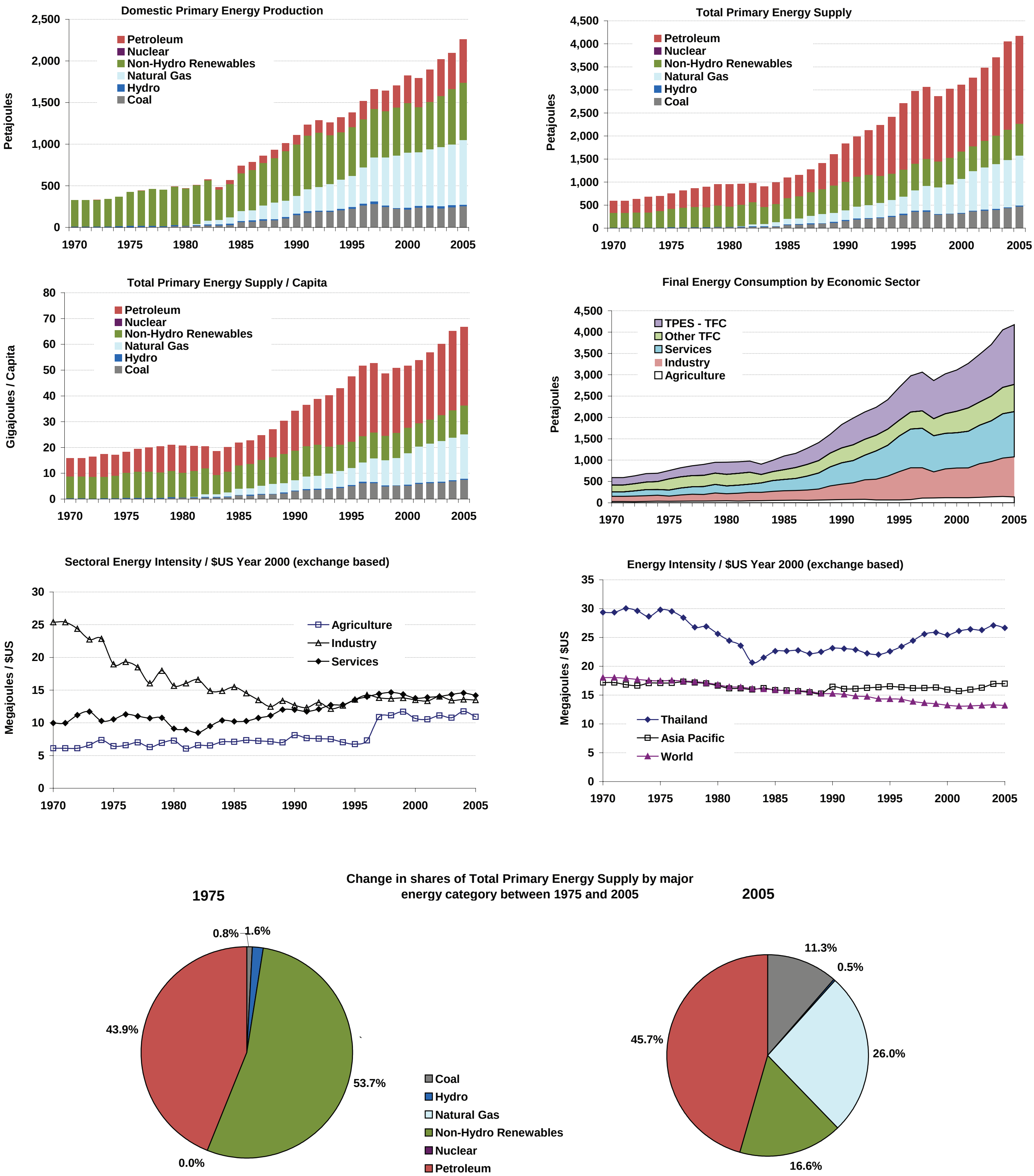


FIGURE 3.20. Summary panel of energy flows and energy intensity for Thailand

Drivers of energy use patterns and energy efficiency

In this section, the major drivers of change in energy use are analysed over a series of time intervals, using the same IPAT-based methodology employed previously on materials in Chapter 2. The main change here is that TPES has been substituted for DMC, thus:

I = TPES, P = Population, A = GDP/Population, and T = TPES/GDP.

It is important to emphasise that the term 'Technology' (T) used in relationship to this IPAT analysis has the very specific definition of TPES/GDP, *and is not simply connected to the more common concepts of (small t) technology*. This means that an 'advance' in technology, such as replacing water buffalo with tractors, may well lead to an increase in T, but if those tractors are subsequently replaced with more fuel efficient tractors (which we probably think of as an improvement in technology), T should actually decrease (as reduced fuel requirements result in reduced TPES). Thus an improvement in T means only that T has decreased, *and does not necessarily imply that more 'advanced' technology is being used*. Indeed, fluctuations in exchange rates can have profound impacts on T even where technologies employed remain constant.

Table 3.2. Analysis and attribution to major drivers of the change in total primary energy supply in the Asia-Pacific Region over the period 1975–1985, using IPAT framework

	Attribution of change in TPES for the period 1975–1985 to main drivers					Share contributions using log transforms		
	Δ*I*%	**Δ*I* (Petajoules)**	**Δ*P***	**Δ*A***	**Δ*T***	**Δ*P***	**Δ*A***	**Δ*T***
Asia-Pacific	40%	21,368	20%	26%	–7%	54%	68%	–22%
Australia and NZ	22%	645	12%	17%	–7%	59%	78%	–36%
Central Asia	NA	0	NA	NA	NA	NA	NA	NA
North-East Asia	37%	13,163	14%	33%	–10%	42%	91%	–33%
South Asia	51%	5,186	26%	12%	7%	56%	28%	16%
South-East Asia	48%	2,373	24%	40%	–14%	54%	85%	–40%
Australia	21%	540	14%	18%	–10%	68%	87%	–55%
China	43%	8,710	15%	99%	–37%	38%	193%	–131%
India	45%	3,348	25%	21%	–4%	60%	52%	–12%
Indonesia	62%	1,083	23%	57%	–16%	43%	93%	–37%
Japan	18%	2,372	8%	33%	–18%	48%	170%	–117%
Kazakhstan	NA	0	NA	NA	NA	NA	NA	NA
The Republic of Korea	120%	1,236	16%	76%	8%	18%	72%	10%
Thailand	45%	343	23%	56%	–24%	54%	119%	–74%

I = TPES, ***P*** = Population, ***A*** = GDP*/ Population, ***T*** = TPES/GDP*

* GDP is denominated in exchange rate based, constant year 2000 $US

Table 3.2 shows that, between 1975 and 1985, the main driver of energy supply growth for the region as a whole was increasing affluence, then growth in population. Improvements in T contributed to maintaining TPES at a lower level than it would have been had this parameter remained unchanged over the time interval.

At the level of individual subregions, South Asia experienced the largest growth in TPES in percentage terms, although in absolute terms this growth contributed less than 40% of that attributable to North-East Asia. South Asia was also the only subregion where population was a more important driver than affluence, and where *T* acted to increase energy consumption.

Factor changes in North-East Asia accounted for both the largest absolute increase and the largest restraint on energy consumption growth in the region. Increased affluence in North-East Asia can have an increase of 11,978 PJ in TPES attributed to it (91% of 13,163 PJ), while improvements in *T* reduced TPES by 4,343 PJ (–33% of 13,163 PJ).

Table 3.3. Analysis and attribution to major drivers of the change in domestic material consumption in the Asia-Pacific Region over the period 1985–1995, using IPAT framework

Attribution of change in TPES for the period 1985-1995 to main drivers						Share contributions using log transforms		
	Δ*I*%	**Δ*I* (Petajoules)**	**Δ*P***	**Δ*A***	**Δ*T***	**Δ*P***	**Δ*A***	**Δ*T***
Asia-Pacific	61%	45,222	21%	28%	4%	39%	52%	8%
Australia and NZ	29%	1,041	14%	17%	–3%	51%	61%	–13%
Central Asia	NA	4,792	NA	NA	NA	NA	NA	NA
North-East Asia	50%	24,102	13%	33%	–1%	31%	71%	–3%
South Asia	54%	8,336	23%	30%	–3%	48%	60%	–8%
South-East Asia	95%	6,951	23%	65%	–4%	31%	75%	–6%
Australia	28%	857	14%	18%	–6%	55%	69%	–24%
China	51%	14,889	15%	127%	–42%	33%	198%	–131%
India	50%	5,406	22%	43%	–14%	49%	88%	–37%
Indonesia	95%	2,707	18%	74%	–5%	25%	83%	–8%
Japan	37%	5,619	4%	31%	0%	12%	87%	1%
Kazakhstan	NA	2,187	NA	NA	NA	NA	NA	NA
The Republic of Korea	174%	3,930	11%	109%	19%	10%	73%	17%
Thailand	146%	1,609	15%	114%	0%	16%	85%	0%

I = TPES, ***P*** = Population, ***A*** = GDP*/ Population, ***T*** = TPES/GDP*
* GDP is denominated in exchange rate based, constant year 2000 $US

Table 3.3 shows that, from 1985 to 1995, all three factors acted to drive TPES for the region as a whole higher. Increasing affluence was again the most important contributor, followed by growth in population, but even technology drove TPES 4% higher than it would have been had it remained unchanged over the period. Changing *T* contributed 8% of the overall increase of 45,222 PJ.

For every subregion, increasing affluence over the period was the main contributor to increased TPES, followed by growth in population. Although improvements in *T* contributed to restraining growth in TPES for every individual subregion, the deterioration in *T* for the region as a whole shows that subregional improvements were insufficient to offset the effect of structural shifts towards less energy-efficient subregions.

The dominant role of North-East Asia in TPES growth for the region continued, but decreased in percentage terms from 61.6% to 53.3%. China alone accounted for nearly 33%. South-East Asia's share increased the most, from 11.1% to 15.4%.

China showed by far the largest improvement in *T*, while simultaneously posting the greatest deterioration attributable to increasing affluence. These changes must in part reflect underlying 'real' factors such as improved process efficiencies and increases in real incomes, but the role of changes in exchange rates must be kept in mind. An appreciation in the value of a local currency against the reference year 2000 $US would, all other things being equal, have the effect of simultaneously increasing the impact of affluence and decreasing that of *T*.

The Republic of Korea showed the fastest percentage growth in TPES for both the 1975–1985, and 1985–1995 periods. Throughout this period, all of the contributing factors for the Republic of Korea acted to drive TPES higher, with increasing affluence made by far the largest contribution for both periods.

Table 3.4. Analysis and attribution to major drivers of the change in domestic material consumption in the Asia-Pacific Region over the period 1995–2005, using IPAT framework

Attribution of change in TPES for the period 1995–2005 to main drivers						Allocations using log transforms		
	∆I%	**∆I (Petajoules)**	**∆P**	**∆A**	**∆T**	**∆P**	**∆A**	**∆T**
Asia-Pacific	42%	50,638	13%	22%	3%	35%	57%	8%
Australia and NZ	26%	1,200	12%	26%	–11%	50%	100%	–50%
Central Asia	7%	319	9%	63%	–40%	130%	759%	–789%
North-East Asia	44%	32,245	8%	24%	8%	20%	59%	21%
South Asia	45%	10,627	19%	48%	–17%	46%	105%	–51%
South-East Asia	44%	6,247	15%	26%	–1%	39%	64%	–4%
Australia	29%	1,154	13%	26%	–9%	46%	92%	–38%
China	64%	28,029	8%	120%	–31%	16%	160%	–76%
India	39%	6,275	17%	58%	–25%	49%	140%	–89%
Indonesia	35%	1,966	14%	14%	4%	44%	43%	13%
Japan	6%	1,313	2%	11%	–6%	30%	167%	–96%
Kazakhstan	0%	8	–4%	93%	–46%	-1,186%	18,070%	–16,784%
The Republic of Korea	45%	2,756	7%	44%	–6%	19%	99%	–18%
Thailand	55%	1,479	10%	19%	18%	22%	40%	38%

I = TPES, ***P*** = Population, ***A*** = GDP*/ Population, ***T*** = TPES/GDP*
* GDP is denominated in exchange rate based, constant year 2000 $US

Table 3.4 shows a very similar pattern from 1995–2005 to 1985–1995 for the region as a whole, with a scaling down of the factors leading to a smaller percentage increase in TPES overall, although the absolute increase was greater at 50,638 PJ compared with the preceding period's 45,222 PJ.

North-East Asia's share of the total increase in TPES for the region rebounded to become even more dominant, increasing to 63.7%, with China alone accounting for 55.3%. South Asia's share expanded modestly over the period, from 18.4 to 21.0%. South-East Asia's share contracted, and its increase in TPES was less in absolute terms than for the preceding period. A strong improvement in *T* made a major contribution to moderating TPES growth in South-East Asia.

In all three time periods, the TPES for the Australia and New Zealand subregion grew by between 22 and 29%, and always constituted less than 3.1% of the regions total growth in TPES. Central Asia only has sufficient data for the last time period, and over that time contributed even less than Australia and New Zealand to TPES growth in the region.

Perhaps the most significant development in Table 3.4 is that *T*, which had been acting to moderate growth TPES in North-East Asia, changed to being an exacerbating factor of similar importance to population growth. This means that over the most recent period, for this key subregion of the Asia-Pacific region (and thus of the world more generally) all three drivers (population, affluence, and *T*), acted to increase energy use.

References

Gleick PH (2008) 'Three Gorges Dam Project, Yangtze River, China'. *Water Briefs: The World's Water 2008–2009*. Pacific Institute: Oakland, CA.

IEA (2007a) *Energy Balances of Non-OECD Countries*. International Energy Agency: Paris.

IEA (2007b) *Energy Balances of OECD Countries*. International Energy Agency: Paris.

IEA (2007c) *Energy Statistics of Non-OECD Countries*. International Energy Agency: Paris.

IEA (2007d) *Energy Statistics of OECD Countries*. International Energy Agency: Paris.

Krausmann F, Fischer-Kowalski M, Schandl H and Eisenmenger N (2008) The global sociometabolic transition. *Journal of Industrial Ecology* **12**(5–6): 637–656.

Martchek K (2006) Modelling more sustainable aluminium. *The International Journal of Life Cycle Assessment* **11**(1): 34–37.

Price L, Sinton J, Worrell E, Phylipsen D, Xiulian H and Ji L (2002) Energy use and carbon dioxide emissions from steel production in China. *Energy* **27**(5): 429–446.

Ross M and Feng L (1991) The energy efficiency of the steel industry of China. *Energy* **16**(5): 833–848.

World Bank (2009) *World Development Indicators 2009*. World Bank: Washington DC.

Yan (Ed.) (2008) Three Gorges reservoir raises water to target level. In *China View*. Xinhua News Agency: Beijing.

Chapter 4: **Water**

Kim Alexander and James West

Main messages

- The Asia-Pacific region has increased total water withdrawals over the 15 year period (1985–2000) by 329,160 GL, representing an approximate 25% increase. All other subregions have increased withdrawals, except Central Asia, which has maintained a constant withdrawal.

- Many countries have been extracting water in an unsustainable manner by withdrawing more water per year than is available from renewable sources. The situation is serious in Central Asia, particularly in Uzbekistan, Turkmenistan, and Tajikistan. These countries are already withdrawing more water per year than is available from renewable sources. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia large volumes of withdrawals indicate that China has also been extracting water rapidly.

- Central Asia withdraws significantly more water per capita, and as a whole, than other subregions (1998–2002). Australia and New Zealand have the second highest water withdrawal per capita, though significantly less than Central Asia.

- Over 81% of annual water withdrawals in the Asia-Pacific region in the recent past (1998–2002) have been used for agriculture. Although the percentage of water withdrawn for agriculture may be high, the actual volume used varies widely between countries.

- Water intensity increased, indicating that water productivity decreased, in the Asia-Pacific region in 1985–2000. In Central Asia, water use intensity increased significantly, indicating less GDP has been generated while using the same amount of water.

- Central Asia had the largest water intensity value for agricultural use at 18,315 L/$US, and has the lowest productivity. The subregion was using 63% of total renewable water resources, more than double the extraction of the other subregions (1998–2002).

- The predictions of future water withdrawals will be a decline in developed nations and rising withdrawals in developing nations, thereby further increasing pressure on water resources. Accordingly, many river basins will be under severe stress, complicated by strong competition for scarce water resources between households, industry, and agriculture.

- By 2025, agriculture is expected to increase requirements for water withdrawal by 1.3 times, industry by 1.5 times, and the domestic supply by 1.8 times. Future scenarios suggest that many of the region's transboundary river basins will be stressed or highly stressed, and the competition for these resources will cause ongoing tension between nations.

Water resources – general world overview

Water is essential to life, supplying human needs and maintaining ecosystems for all living species. Water resources are important to socio-economic development, providing material input into production and consumption activities and acting as sinks for waste material. Consequently, water resource systems are closely linked to the economic use of resources. This section of the report investigates water resource and water use patterns, trends in water use, and resultant stress on water systems across the Asia-Pacific region.

Changing climatic conditions, rapidly increasing populations, and persistent over-use of available resources have generated concerns of a pending 'global water crisis'. In many regions of the world, socio-economic activities are rapidly changing water use patterns, which have implications for future water resources, water policy, and water planning. The challenge of managing and developing water resources to sustain communities continues to grow in the face of the pressures of economic growth, major population increases, and climate change (UN-WATER/WWAP 2006).

While the distribution of global water resources is highly variable, water issues are inherently localized and interdependent, and almost fully reliant on the interaction between social systems and their socio-technical environments. Global water resources are increasingly in demand for purposes such as drinking, hygiene, and the production of food, energy, and industrial goods, as well as for the maintenance of natural ecosystems. The construction of dams and diversions are influencing river regimes in many regions. The impact on communities can be highly significant, as in several cases in North-East Asia and South-East Asia, or more localized, as with small dams in hillside terrace systems. The removal, destruction, or impairment of natural ecosystems, has the greatest critical impact on the sustainability of natural water resources (UN-WATER/WWAP 2006)

Groundwater is by far the most abundant and readily available source of fresh water, followed by lakes, reservoirs, rivers, and wetlands. Currently, there are high levels of exploitation of groundwater, with extraction rates often more than 50% of the rate of recharge in many countries in the Middle East, Africa, Asia, and Europe (UN-WATER/WWAP 2006). In many developing countries, groundwater assessment and monitoring activities are minimal or ineffective. Consequently, there is a limited knowledge of groundwater resources and aquifer systems.

Water is often used in the production of commodities, particularly food, and there are flows of virtual water through international trade. In some instances, water-scarce countries import virtual water (through import of water-intensive products), thus relieving the pressure on the domestic water resources (Water Footprint Network 2010). However, continued economic development will lead to decreased water availability and water quality. Poor water quality, low water availability per person, high dependence on water use for agriculture, and the impacts of climate change mean that many countries will be vulnerable to long-term water scarcity (UNESCAP 2005).

More than half of the world's major rivers are seriously depleted and polluted, leading to the degradation and poisoning of surrounding ecosystems, health consequences, and reduced livelihoods (World Commission on Water 1999). Most water bodies are now heavily polluted with domestic sewage, industrial effluents, chemicals, and solid wastes (UNEP 2002; UNESCAP 2005). Globally, eutrophication is the most prevalent water quality problem resulting from high-nutrient loads (mainly phosphorus and nitrogen), which substantially impairs beneficial uses of water (UN-WATER/WWAP 2009). Consequently, water availability is also linked to the quality of available water. Box 4.1 provides an example of the complex issues facing water courses in the Asia-Pacific region.

Box 4.1. Serious water issues in Panay Island, Philippines

The port city of Iloilo, Panay Island, Western Visaya, Philippines, has a population of 300,000, and is the commercial, cultural, and intellectual hub of the island. The city sources water from the Tigum Aganan Watershed and residents have been subject to poor water quality, lack of sanitation, increasing siltation, decreasing water availability, groundwater contamination, the threat of saltwater intrusion into the aquifer, and catastrophic floods and droughts. The productivity of the river has been compromised by headwater surges, pollution from mining activities, riverbank erosion, reduced fish habitat, and the relentless impacts of urban migration. A severe typhoon in 2008 damaged regional infrastructure and ecosystems. Natural hazards such as landslides and erosion are exacerbated by heavy rains in the uplands, threatening the lives and livelihoods of village communities. Over-exploitation of resources, social injustices, indigenous welfare, problematic governance, and rural poverty are embedded issues in the management of the watershed.

FIGURE 4.1.
Headwaters of the Tigum Aganan Watershed, Panay Island, Philippines. (Source: Alexander et al. *2010)*

Water resources – Asia and the Pacific region

The Asia-Pacific region is characterized by a range of climates, and therefore experiences a variety of hydrological regimes. The hydrology of the region is dominated by the typical monsoon climate, which induces large inter-seasonal variations of river flows (FAO 2009). In the humid areas, water management concerns have been largely related to flood control because flooding is a common problem in the Mekong, Brahmaputra, and Ganges basins. In the arid areas, such as in central China, where water is scarce, hydrological studies have been oriented much more towards water resources assessment (FAO 2009). Withdrawals in upstream countries (e.g. India), are known to significantly affect the volumes of water available to downstream countries (e.g. Bangladesh). Where there are shared river basins, as in South and South-East Asia, the computation of water resources becomes relatively complex and transboundary issues often occur. The futures of rivers dependent on glacier melt are expected to be affected by the rate of glacial retreat and precipitation (WWF 2010).

The Asia-Pacific region contains 60% of the world's population and agricultural land and is the largest consumer of water, with withdrawal rates of 2,268,726 GL/year (Table 4.1), which is far more than the consumption of the rest of the world according to UNESCAP (2009). The average annual total withdrawal for agriculture was approximately 81.5% of total water use (1995–2002) in the region. Total withdrawal for industrial purposes was 11.4%, with 7.1% used for domestic purposes during this period (UNESCAP 2009).

While the Asian and Pacific region experiences further economic growth, the region faces some major development challenges in the coming decades. Population growth, changing water regimes and climate, and rising demand for energy, water, and other basic needs are likely to intensify over the next few decades. The important factors that have an impact on water resources in the Asia-Pacific region include (UNESCAP 2006):

- **Natural resource endowment:** Water is a vital component of the natural resource endowment of a region. The natural resource endowment per capita is much lower in Asia and the Pacific than global averages, because the region has a population density of 1.5 times the global average with the lowest freshwater availability per capita of all global regions.
- **Pollution:** Several highly polluting industries are growing more rapidly in regional developing countries than in developed countries, with consequences for the quality of available water.
- **Increased use of water:** Increasingly more water is used for agricultural and industrial processes. The majority of water is used for agricultural production, which tends to be highly chemically, energy, and water intensive.
- **Changing consumption patterns:** As incomes increase, consumption patterns are changing. Growing supply of consumer goods is increasing the amount of water needed for industrial processes.
- **Water extraction rates:** Extraction rates are already unsustainably high in the majority of countries in the Asia-Pacific region. Irrigation systems, the largest user of water, are highly inefficient and poorly maintained in most countries, resulting in wastage. Some countries with the least available water also have the poorest water quality, and experience disruption to industrial production from water shortages.
- **Ecological efficiency of water use:** The ecological efficiency of water use is highly variable in the industrial sector, and does not necessarily reflect the availability of water. Some water-

stressed countries have highly developed industrial sectors that use much more water to produce one dollar of GDP than do water-rich countries.

- **Long-term sustainability of the water supply:** The water supply is further threatened by climate change, which may increase the severity and incidence of drought and cause long-term reductions in water flows in freshwater systems, particularly those dependent on glacier melt.

Water use patterns

Continued economic growth that increasingly demands more energy, water and other basic inputs, population increases, changing water regimes and climate change are challenging abilities to manage global water resources. Many countries of the Asia-Pacific region are highly vulnerable to long-term water scarcity and experience poor water quality, low water availability and have a high dependence on water used for agriculture. In the Asia-Pacific region, water withdrawal per capita has been increasing and shows an ongoing upward trend. Many countries have been extracting water in an unsustainable manner. The situation is serious in Central Asia, where several countries are already withdrawing more water per year than is available from renewable sources. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia, high withdrawals indicate that China has also been extracting water rapidly. Countries in the Asia-Pacific region have increasingly used their water resources and, by 2025, assuming current consumption patterns continue, a significant proportion of the population in the region will live in water-stressed river basins. By 2025, many transboundary river basins will be stressed or highly stressed, and the competition for these resources may cause ongoing tension between nations.

Regional water withdrawals

Table 4.1 shows the annual water withdrawals for the Asia-Pacific region by subregion (Australia and New Zealand; Central Asia; North-East Asia; South Asia; South-East Asia and the Pacific) for the period 1998–2002. Water withdrawal data has been compiled to allow comparisons between agricultural use (irrigation and livestock), community use (municipal or domestic water), and industrial use.[1]

---

1 Although national data on water withdrawal is often available for some years, large uncertainties remain about the computation methods used to develop the statistics. In this report, water data has been derived from FAO Aquastat data, which deals with a series of 5-year time intervals, where the value given for any interval may come from any single year within it. Here, either the full interval is quoted, such as 1998–2002, or the midpoint of the time interval is given. For example, where the year 2000 is quoted, the value may actually have been recorded for any year within the period 1998–2002. This latter convention is important mainly where an intensity such as water withdrawals per $US GDP is given, as the GDP data is for the exact year nominated.

Because many countries do not have recorded data for many years in the FAO Aquastat database, for this review of water resources it was not possible to simultaneously retain a large sample of the countries within each subregion, and also make comparisons between years. As a result, variable bases have been used here. For single interval (1998–2002) graphs, the largest and most representative sample of countries within a subregion was retained by including all countries for simple totals, such as total withdrawals, or by excluding only those countries that do not have a value for either the numerator or denominator, such as when calculating withdrawals per capita. Where a comparison was to be made between two different years (e.g. 1985 and 2000), to achieve meaningful results, it was necessary to also exclude countries where a record for either year was missing. Unfortunately, this reduces the size of the sample, in the case of Central Asia and the Pacific sometimes to zero. As a result, values for quantities that might be expected to be identical will sometimes not be. This is why, for example, sectoral water intensities for 1998–2002 (Figure 4.3) do not match the water intensities given for 2000 in the comparison between 1985 and 2000 (Figure 4.8).

Trends in water withdrawal for Asia and the Pacific between 1985 and 2000

Figure 4.2 shows the change in total water withdrawals for subregions during the 15-year time period between 1985 and 2000.[2]

The Asia-Pacific region increased total water withdrawals over the 15 years, by 329,160 GL, representing an approximate 25% increase in water withdrawal. Central Asia maintained roughly constant withdrawals, while all other subregions increased withdrawals. In 1985, the total for those countries included in this sample for South Asia and North-East Asia had similar withdrawals of approximately 500,000 GL, and similar levels of increase over the period to 646,000 GL and 630,000 GL, respectively, or approximately 30% over the 15 year period.

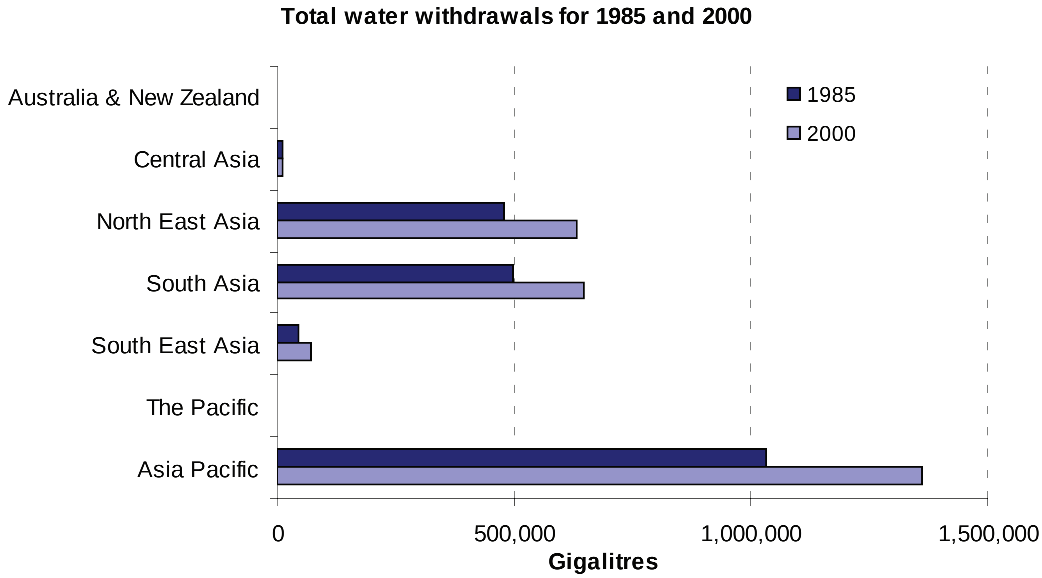


FIGURE 4.2.
Total water withdrawals for 1985 and 2000

Figure 4.3 shows that per capita water withdrawals for the Asia-Pacific region increased by some 0.04 ML per capita, or around 6%, during the 1985–2000 period. Values for Central Asia were not calculated due to insufficient data, while the figure for Australia and New Zealand is in reality only for New Zealand, where water use per capita decreased. Of far greater significance is the 5% decrease in water withdrawals per capita in South Asia. However, this improvement was not sufficient to offset the increases in North-East Asia and South-East Asia, where usage per capita increased by some 12% in both subregions.

The volume of water withdrawn per unit of land area in the Asia-Pacific region was 64 ML/km^2 while in South Asia it was 150 ML/km^2, as shown in Figure 4.4. This is indicative of widespread, high-intensity agricultural activities, with a high reliance on irrigation. At the other end of the spectrum, on a per unit area basis, withdrawals in Australia and New Zealand are over an order of magnitude lower, at less

2 Data are available for Australia and New Zealand and the Pacific, but values are not of sufficient size to be visible at the scale required here. Also note that data for 2000 here may not match that displayed in single time interval graphs and tables, as discussed earlier.

than 4 ML/km². This low rate reflects both the limited availability of water within much of Australia (which dominates the subregion in terms of land area), and the low intensity of agricultural activities and restricted extent of irrigation over the majority of the area.

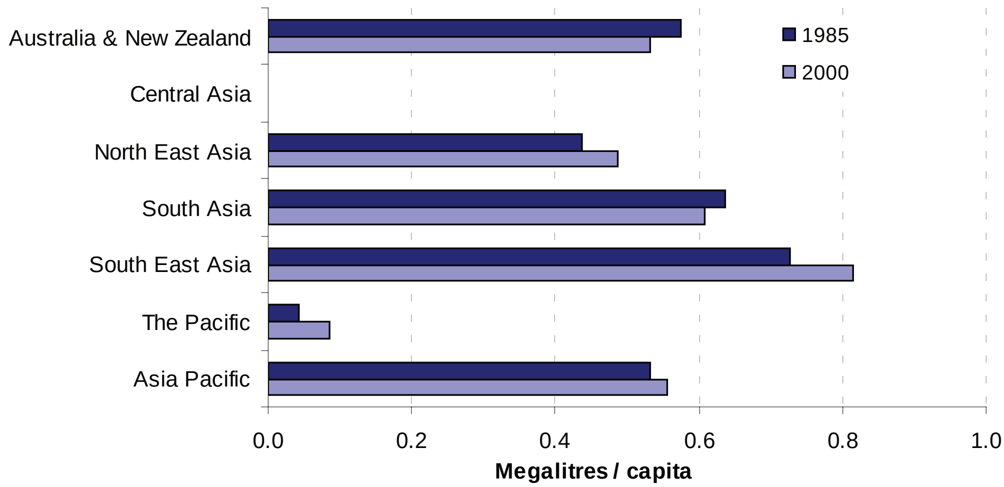


FIGURE 4.3.
Per capita withdrawals for 1985 and 2000 (note that data shown for 'Australia and NZ' in this case only includes New Zealand)

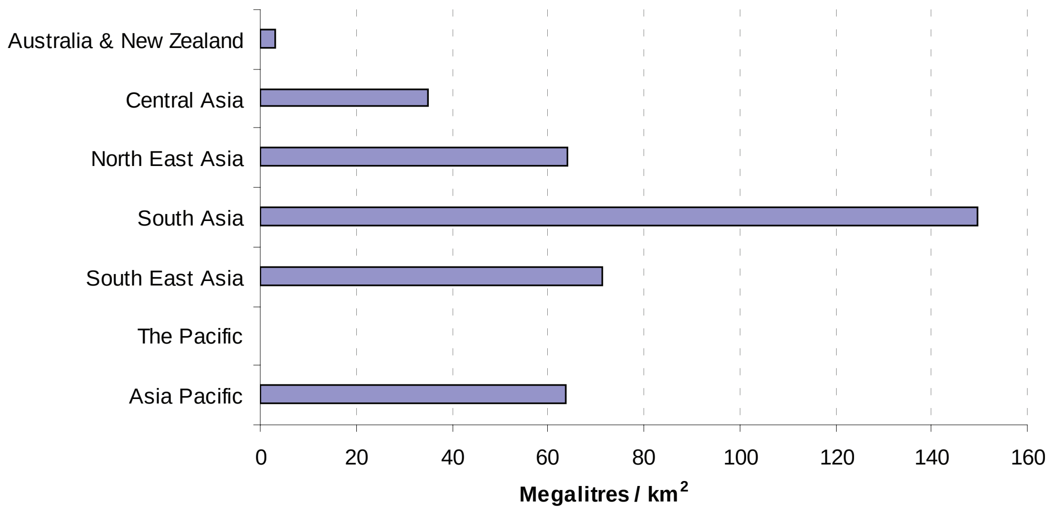


FIGURE 4.4.
Water withdrawals per km² land area for 1998–2002

Figure 4.5 indicates that water intensity decreased, and hence water productivity increased, in the Asia-Pacific region between 1985 and 2000, but these trends mask important subregional differences. In Central Asia an already high water use intensity more than doubled, indicating much less GDP was generated using the same amount of water. However, in this sample Central Asia is represented only by Tajikistan, so the overall subregional performance may be much better than this. Water intensity also increased in the Pacific (not visible at this scale), while all other subregions decreased their water intensities. These improvements included major decreases in the all important subregions of North-East Asia and South Asia, of over 66% and 52%, respectively, with similar levels of improvement in South-East Asia. The net result for the region as a whole (or at least the sample available for cross time interval comparisons) is that water intensity decreased by over 57% between 1985 and 2000. This is an encouraging development, and shows that water efficiency trends are generally heading in the right direction in the most important subregions. However, due to the ongoing increase in total water withdrawals shown in Figure 4.2, it has clearly not been enough to prevent increasing pressure on water resources.

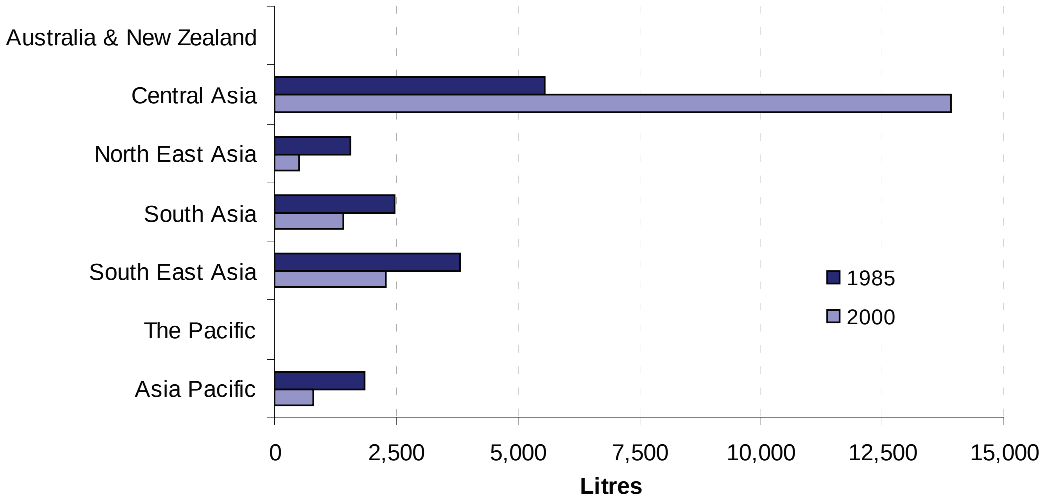


FIGURE 4.5.
Water intensity, litres per $US for 1985 and 2000

Sectoral water withdrawals

Over 80% of annual water withdrawals in the Asia-Pacific region in the recent past (1998–2002) have been used for agricultural purposes, representing 1,848,041 GL (Table .1). During that time, 11.4% of water or 259,385 GL/year was withdrawn for industry, slightly more than for municipal use. Although heavily populated, the Asia- Pacific region withdrew only a small fraction of water (7.1%) for municipal/ domestic use, with an overall volume of water withdrawn of 161,260 GL. Although withdrawals for domestic use were lower in the poorest countries, many countries have seen a rapid trend of increasing domestic water use over the last decade (UNESCAP 2009).

Table 4.1. Annual water withdrawals by sector for 1998–2002

Subregion	Agriculture (GL)	Percentage of total withdrawals	Industry (GL)	Percentage of total withdrawals	Municipal (GL)	Percentage of total withdrawals	Total withdrawals (GL)
Australia and NZ	18,900	72.6%	2,600	10.0%	4,540	17.4%	26,040
Central Asia	127,450	91.0%	8,040	5.7%	4,540	3.2%	140,030
North-East Asia	503,120	66.7%	183,240	24.3%	67,370	8.9%	753,760
South Asia	925,510	89.9%	40,575	3.9%	63,580	6.2%	1,029,675
South-East Asia	273,010	85.6%	24,890	7.8%	21,180	6.6%	319,080
The Pacific	51	36.2%	40	28.4%	50	35.5%	141
Asia-Pacific	**1,848,041**	**81.5%**	**259,385**	**11.4%**	**161,260**	**7.1%**	**2,268,726**

Source: FAO Aquastat (2009)

According to Table 4.1, during 1998–2002, the highest percentage withdrawal per sector was in Central Asia for agricultural use, at 91%, the least in the Pacific at 36.2%. The Asian subregions had larger water withdrawals for agriculture than did the Pacific. Australia and New Zealand's' withdrawals for agricultural at 18,900 GL are just over 2% of those for South Asia alone, and 1% of regional withdrawals. In terms of actual volumes of water withdrawn, agriculture in South Asia consumed the most at 925,510 GL, while in the Pacific only 51 GL were withdrawn. This indicates that, while the percentage of water withdrawn for agriculture may be high, the actual volume used varies widely between countries and subregions, in keeping with the large disparities in population. Furthermore, water withdrawal figures fail to account for the water used in rain-fed agricultural practices.

Withdrawals for industry was greatest as a proportion of total subregional withdrawals for the Pacific (28.4%), followed by North-East Asia (24.3%), while for all other subregions it constituted less than 10% of water used. The greatest total volume of water used for industry was by North-East Asia, with 183,240 GL, which is over four times greater than the next largest user, South Asia. Across the Asia-Pacific region, many economies were using more water for industry. China and Viet Nam have significantly increased their industrial water withdrawal over the last decade (UNESCAP (2009). Figure 4.6 depicts the water withdrawals by sector for 1998–2002. Note that in some of the following graphs the disparities between some subregions are so large that values for the smaller subregions are not actually discernable, such as any of the Pacific's water withdrawals, or Australia and New Zealand's municipal or industry withdrawals.

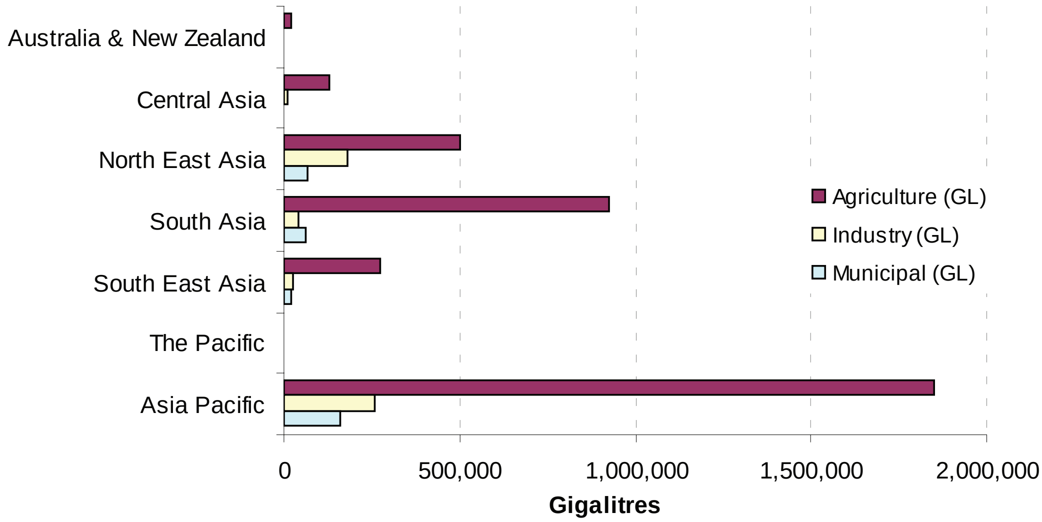


FIGURE 4.6.
Water withdrawals by sector for 1998–2002

Water withdrawals in megalitres (ML) per capita for each subregion during 1998–2002, are represented in Figure 4.7. Central Asia withdrew almost 2.5 ML/capita, which is significantly more than other subregions. Australia and New Zealand had the second highest water withdrawals per capita, though less than 50% those of Central Asia. The Pacific used very little water per head of population. As could be anticipated, the effects of these sparsely populated subregions on consumption in the region as a whole is insignificant, with overall consumption per capita at 0.63 ML/capita being intermediate between the region's most populous subregions South Asia (0.68 ML/capita) and North-East Asia (0.5 ML/capita).

It should be noted that some countries of the Pacific are highly water stressed because of limited access to water resources: in particular, Tuvalu, Nauru, Kiribati, and the Marshall Islands. Consequently, water intensity rates fail to account for under-developed water management systems, reliance on rain-fed agriculture, and threatened freshwater resources (Burns 2000).

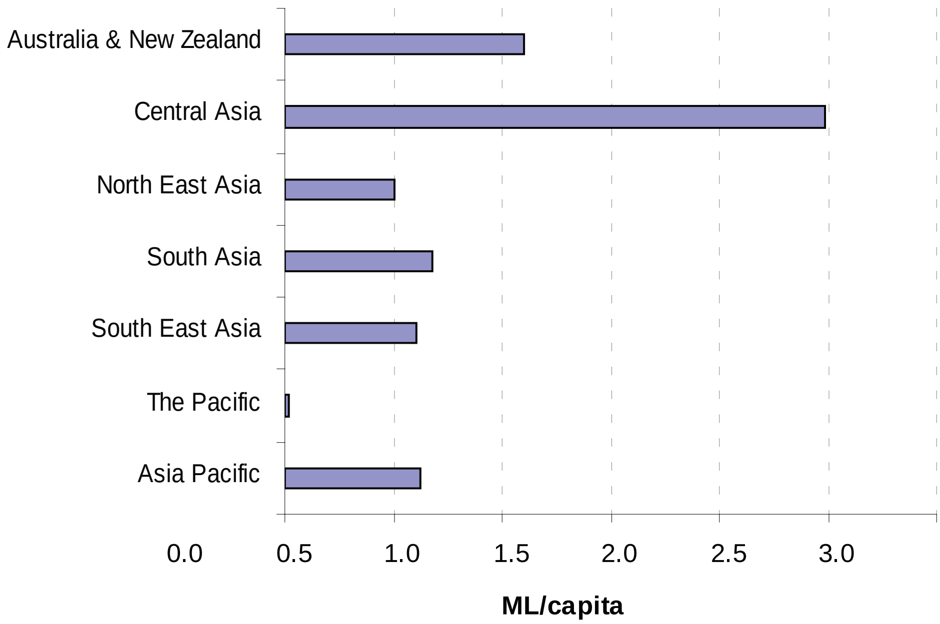


FIGURE 4.7.
Water withdrawals in Asia-Pacific in ML/capita

Water productivity and water intensity

Water productivity is the quantity of produce (crops and other goods) that can be obtained per unit of water used (Molden and Sakthivadivel 1999). Consequently, water productivity can be increased through improved agronomic practices, such as crop varieties, and improved supply and demand management, regionally and at farm scale. In other words, increasing water productivity is achieved by increasing the technical efficiency of production (Billi *et al.* 2004). According to FAO (2003), increases in crop yields between 1961 and 2001 improved the productivity of water used in agriculture by 100%. At the same time, irrigated rice yields doubled and rain-fed wheat yields rose by 160%, with little variation in water consumption per kilogram of output. Globally, FAO (2003) estimates that water needs for food per capita halved between 1961 and 2001; a significant saving and a significant gain for other water users. However, it must be noted that there are many other uses of water; for the production of timber, firewood, and fiber, aquaculture and animal husbandry, domestic consumption and environmental servicing, which should also be considered when assessing and valuing water resources (FAO 2003).

In practice, estimating comprehensive measures of water productivity across an economy from physical outputs of crops, materials, and so on, is generally not practical because of the lack of sufficiently disaggregated data on water use and the individual product categories. More generally achievable measures of water efficiency can be obtained by using measures of value added or expenditures within a broad sector, such as agriculture or industry, which can be matched to correspondingly broad categories in water use accounts, to calculate water intensities. The overall water intensity of an economy refers to the total water consumed in that economy, divided by economic output per dollar (US) of GDP. Sectoral water intensities refer to the water used by that sector per dollar of value added by that sector, such as water withdrawals for agriculture/ value added from agriculture. Water intensity is simply the inverse of water productivity, so lesser values for water intensity reflect higher water productivity.

Figure 4.8 shows the Asia-Pacific region to have had an overall water intensity for agriculture of 3,454 L/$US. Central Asia had the highest water intensity for agriculture at 18,315 L/$US, which was the lowest water productivity for any subregion and sector. The all sectors average depicted in Figure 4.8 for Central Asia was 3,766 L/$US after the high water intensity for agriculture was combined with 694 L/$US for industry and 104 L/$US for municipal/domestic use. Australia and New Zealand had a value of 1,093 L/$US for agriculture, a relatively low intensity for this sector and less than a third of the regional average. For the region as a whole, the average all sector water intensity of 273 L/$US is again intermediate between that of North-East Asia and South Asia. The third most populous subregion, South-East Asia, is also intermediate in its water intensity (579 L/$US) between North-East Asia and South Asia, as it was for per capita withdrawals.

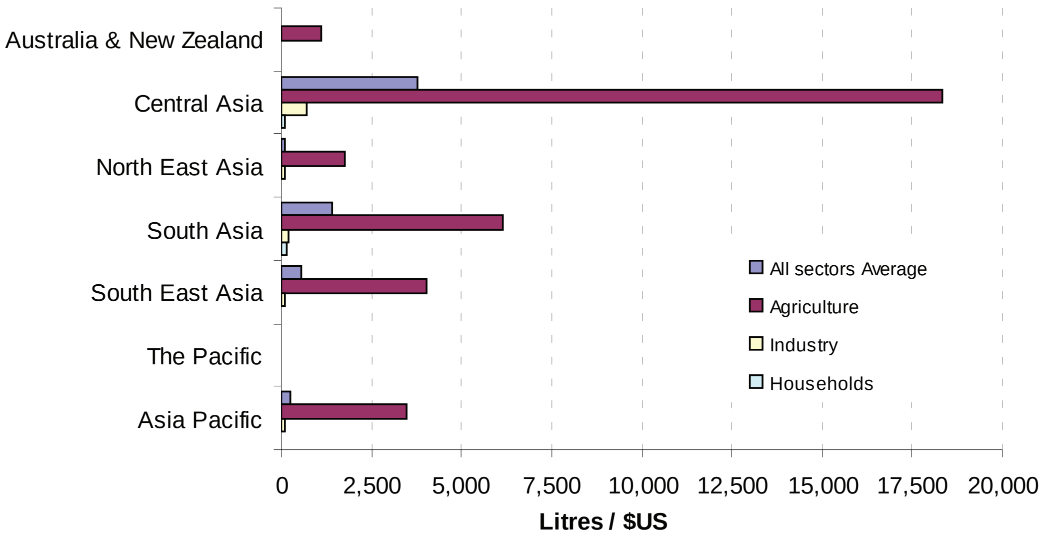


FIGURE 4.8.
Water intensity per $US, by sector, for 1998–2002

Figure 4.9 maps the water intensity per $US, for countries in the Asia-Pacific Region, for 1998–2002. Central Asia shows the highest water intensity values, with countries around the Himalayas, particularly Pakistan, also yielding high water intensity values. The Mekong river area in South-East Asia also displays high water intensities. These subregions and river basins support major food production through intensive agricultural activity. The associated countries are characterized by large populations, many of which are expected to grow rapidly over the next few decades, so reducing water intensity will be important to improve food security in the future.

Water abstraction rates and water stress

The difficulties in meeting water resource needs from available freshwater resources are often exacerbated by limited water availability and poor-quality water supplies. Further challenges are experienced by countries highly dependent on external water resources. This is particularly apparent for countries dependent on river flows sustained by glacier melt, especially the Ganges, Indus, Brahmaputra, Mekong, Thanlwin, Yangtze, and Yellow Rivers, as well as the Amu Darya and Syr Darya rivers. India, the Islamic Republic of Iran, Uzbekistan, and Pakistan are among the most vulnerable countries in this regard (UNESCAP 2005).

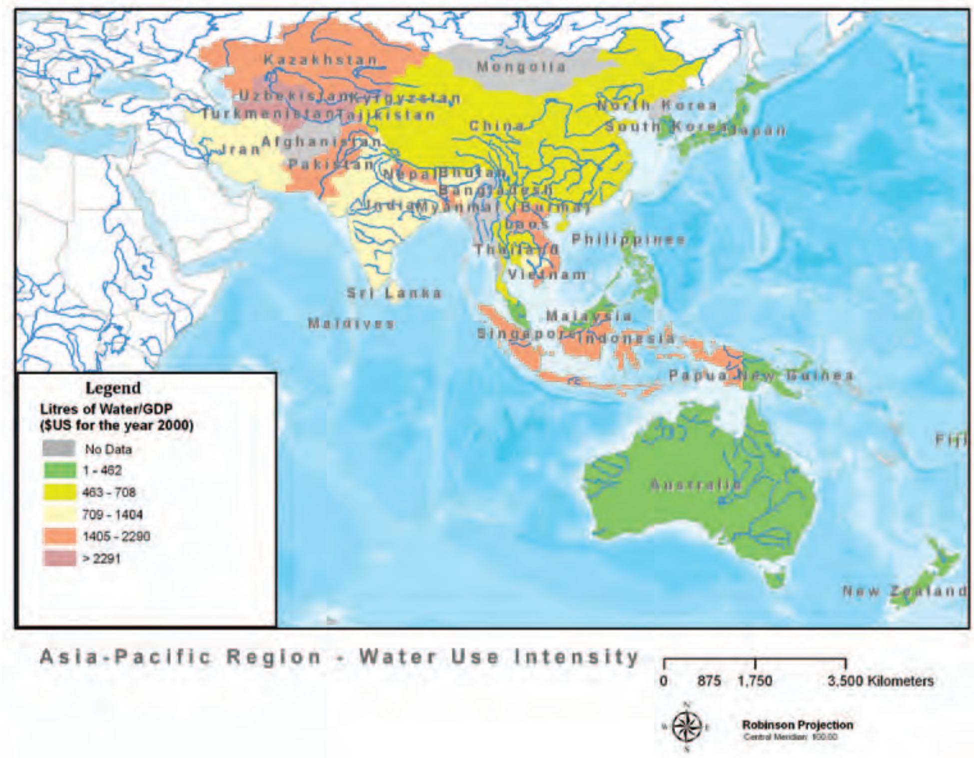


FIGURE 4.9.
Water intensity per $US, in Asia and the Pacific, for 1998–2002

Water abstraction is the portion of available freshwater resource used and is an indication of pressures on water resources. Countries with high abstraction rates in relation to renewable resources are prone to water stress. Water abstraction rates are unsustainably high in many countries in the Asia-Pacific region (UN-WATER/WWAP 2006). The situation is serious in Central Asia, particularly in Uzbekistan, Turkmenistan, and Tajikistan. These countries are already withdrawing more water per year than is available from renewable sources. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia, high withdrawals indicate that China has also been extracting water rapidly.

Total water withdrawal as a percentage of total renewable resources during 1998–2002 is shown in Figure 4.10. The Asia-Pacific region used 14% of total renewable resources, while Central Asia accessed 63% of total renewable water resources, more than double the extraction of the next subregion. South Asia and North-East Asia, with values of 27% and 22%, respectively, had higher extraction rates than South-East Asia (4.5%) and Australia and New Zealand (3.2%), while there was insufficient data to calculate values for the Pacific.

Water stress is considered to occur when per capita water supply drops below 1,700 m³/year and then frequently disruptive water shortages occur (World Resources Institute 2003). When annual water supplies drop below 1,000 m³ per person per year, severe consequences can include disruption to food production and economic development unless the region is wealthy enough to apply new technologies for water use, conservation, or reuse. Globally, a quarter of the terrestrial surface (excluding Greenland and Antarctica) is under severe water stress. In Asia and Pacific countries, the highly and severely water stressed areas are in the large basins in China (including the Yellow River), the Krishma in India, and much of Central Asia (Alcamo *et al.* 2000).

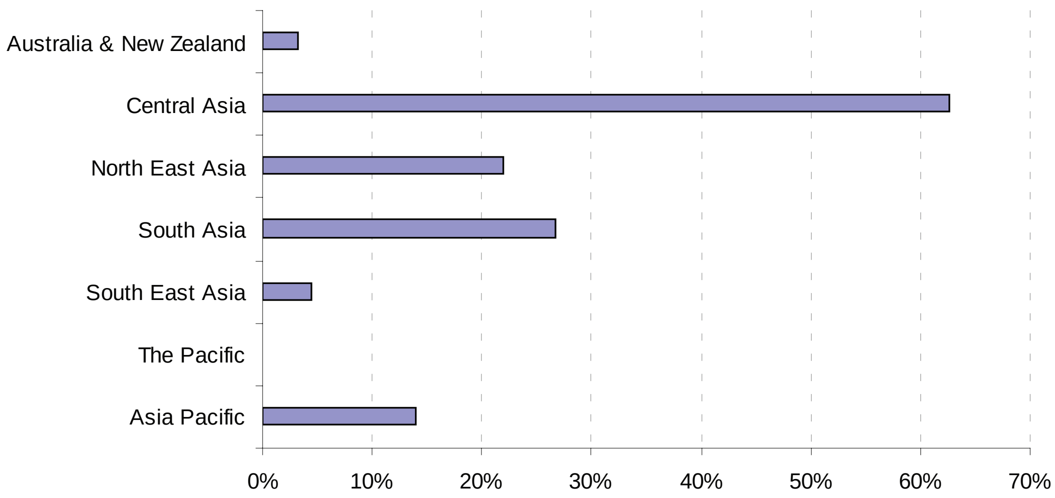


FIGURE 4.10.
Total water withdrawal as a percentage of total renewable water resource for 1998–2002

Figure 4.11 compares water stress for various countries in the Asia-Pacific region using the Water Exploitation Index, calculated by dividing the national mean annual total abstraction of fresh water with the mean annual total renewable freshwater resource, expressed in percentage terms. The index shows available water resources in a country compared with the amount of water used. An index of over 20% usually indicates water scarcity, relative to the amount required. Accordingly, countries between 20 and 40% are considered stressed, while those with a Water Exploitation Index above 40% are considered to be under severe stress.

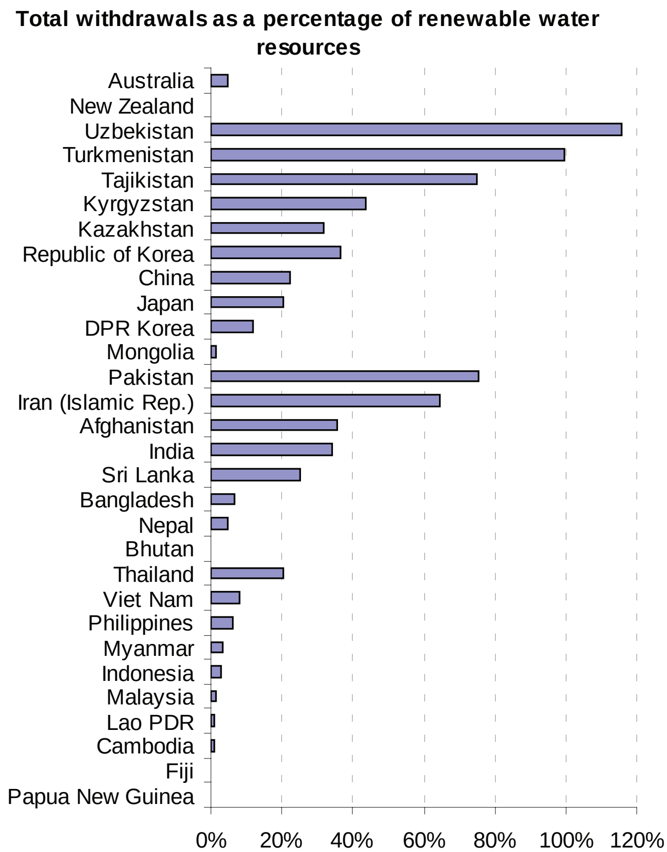


FIGURE 4.11.
Water Exploitation Index – indicator of the sustainability of withdrawals and resultant water stress.

Box 4.2 details how climate change is projected to affect one of Australia's major river basins.

Box 4.2: Key findings of the CSIRO Sustainable Yields Project for the Murray-Darling Basin, Australia

The CSIRO Murray–Darling Basin Sustainable Yields Project assessed 18 regions of the Murray–Darling Basin, which collectively are considered to make up Australia's 'food bowl'. The key findings are summarized as:

- Water resource development has caused major changes in the flooding regimes that support nationally and internationally important floodplain wetland systems in the Murray–Darling Basin (MDB). Integrating the flow impacts down through the connected rivers of the Basin shows that total flow at the Murray mouth has been reduced by 61%; the river now ceases to flow through the mouth 40% of the time compared with 1% of the time in the absence of water resource development.

- The south of the MDB was in severe drought from 1997 to 2006 and the catchment runoff in the southernmost parts of the MDB was the lowest on record. This event would occur once in more than 300 years without climate change. Such conditions will become increasingly common. The drought conditions in the south of the MDB further worsened in 2007 and 2008.

- The impacts of climate change by 2030 are uncertain; however, surface water availability across the entire MDB is more likely to decline than to increase. A decline in the south of the MDB is more likely than in the north. In the south of the MDB, a very substantial decline is possible. In the north of the MDB, significant increases are possible. The median decline for the entire MDB is 11%: 9% in the north of the MDB and 13% in the south of the MDB.

- The median water availability decline would reduce total surface water use by 4% under current water sharing arrangements, but would further reduce flow at the Murray mouth by 24% to be 30% of the total without-development outflow. In volumetric terms, the majority of the impact of climate change would be borne by the environment rather than by consumptive water users.

- The relative impact of climate change on surface water use would be much greater in dry years. Under the median 2030 climate, diversions in driest years would fall by more than 10% in most New South Wales regions, around 20% in the Murrumbidgee and Murray regions and from around 35 to over 50% in the Victorian regions. Under the dry extreme 2030 climate, diversions in driest years would fall by over 20% in the Condamine-Balonne, around 40 to 50% in New South Wales regions (except the Lachlan), over 70% in the Murray and 80 to 90% in the major Victorian regions.

- Groundwater currently represents 16% of total water use in the MDB, but under current water sharing arrangements groundwater use could increase by 2030 to be over one-quarter of total water use. One-quarter of current groundwater use will eventually be sourced directly from surface water diversions. Current groundwater use is unsustainable in seven of the twenty high-use groundwater areas in the MDB and will lead to major drawdowns in groundwater levels in the absence of management intervention.

- Expansion of commercial forestry plantations and increases in the total capacity of farm dams could occur by 2030. 'Best estimate' projections of these developments indicate only very minor impacts on the total runoff reaching rivers across the MDB. However, the volumes of surface water used by these developments, and the within-subcatchment streamflow impacts, may be significant.

(Source: CSIRO 2008)

Future trends in water use, withdrawal and consumption

Between 2000 and 2050, the world's population is projected to grow from 6 billion to 9 billion, and demand for food and other goods will increase significantly (UN-WATER/WWAP 2009). Alcamo *et al.* (2000) explore future water usage under several scenarios based on assumptions designated as (1) Business as usual (BAU), (2) Technology, Economics and the Private sector (TEC – in which the free market system and new technologies are assumed to reduce water demand) and (3) Values and Lifestyle (VAL – in which commitment and human values avert a water crisis). These were used to explore the consequences to water use of continuing current trends in populations, economy, technology, and human behaviour up to 2025. The findings indicate that water withdrawals will decline in developed nations and rise in developing nations, thereby further increasing pressure on water resources. Accordingly, many river basins will be under severe stress, complicated by strong competition for scarce water resources between households, industry, and agriculture. Many of the world's transboundary river basins will be stressed or highly stressed, and the competition for these resources may cause ongoing tension between nations.

Under the three future scenarios (BAU, TEC, and VAL), Alcamo *et al.* (2000, p. 39) suggest outcomes for the Asia-Pacific region which indicate rapid population growth. In addition, urban populations are likely to increase by 60% before 2025, significantly increasing pressures on available water supplies (UN-WATER/WWAP 2006).

Structural change in the domestic sector will increase water use per capita while technical change will decrease water use slightly, with a net overall increase. Strong economic growth will lead to more material wealth and greater water use in households, increasing overall domestic water withdrawals. Meanwhile, industrial water intensity will decrease through efforts to improve water efficiency, but larger quantities of water will be used and water withdrawals will increase.

In the agricultural sector, irrigated areas in the region will remain at current levels, with some expansion in India, while irrigation efficiency is expected to improve. Investment in irrigation will reduce and there will be losses of irrigated areas to salt intrusion and waterlogging. Future predictions indicate the role of agriculture will slightly decrease with intensive growth of other water uses, primarily industrial and public water withdrawal. By 2025, agriculture is expected to increase requirements for water withdrawal by 1.3 times, industry by 1.5 times, and the public supply by 1.8 times (Shiklomanov 2000, p.23).

The overall predicted trend for water use to 2025 for the BAU scenario is an increase in total water withdrawals and increasing pressure on water resources, causing water stress (Alcamo *et al.* 2000). In the TEC scenario, withdrawals will not grow as rapidly because of structural changes, though a net increase is predicted. In the VAL scenario, total water withdrawals are predicted to decrease because of a decline in water intensity in the industrial sector and as irrigated efficiency improvements override the small expansion in irrigated land.

Conclusion

Water withdrawal per capita in the Asia-Pacific region is increasing, with an ongoing upward trend, and many countries are extracting water in an unsustainable manner. In Central Asia, the situation requires immediate attention and appropriate policies and international agreements to dampen cross-boundary tensions. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia, high withdrawals indicate that China has also been extracting water rapidly. In the Pacific, coral islands are threatened by reduced precipitation, increasingly variable rainfall patterns and rising sea levels, storms, and tsunamis that can have an impact on the shallow freshwater lenses that form to provide and protect groundwater (Moglia *et al.* 2008). Saline intrusion may infiltrate the aquifers. This would be a significant threat to islands reliant on freshwater aquifers and decrease their ability to maintain water quality fit for drinking and agricultural purposes. IWRM techniques are essential to protect vital water resources in the Pacific region (SOPAC 2009).

Data limitations on water resources have been overcome by exploring trends in water withdrawals in various sectors in the past and predicting future trends. An unsustainable trend is emerging in the Asia-Pacific region, with increasing water withdrawals leading to over-extraction. The situation is serious in Central Asia, South Asia and increasingly so for North-East Asia. Notably, Central Asia is experiencing serious water extraction issues, with the highest extraction for agriculture in the region and the highest per capita extraction, and the lowest water productivity for the region.

Scenarios of future water withdrawals indicated a decline in developed nations and rising withdrawals in developing nations, and that many river basins will be under severe stress, complicated by strong competition for scant water resources between households, industry, and agriculture. Under the *Business as usual* future, a significant proportion of the population in Asia-Pacific region will live in water-stressed river basins, which will heighten the need for policies supporting water use efficiencies and water demand strategies to provide a basis for future economic growth and to provide water resources for burgeoning populations. Improved water productivity of regions more dependent on irrigated agriculture and an increase in water efficiency is needed. Additionally, technologies and infrastructure supporting alternative water sources, recycled water, eco-city development, and dampened water demands while tackling industrial and urban pollution at point of source, may allow for water savings and protect the quality and quantity of water available for consumptive use. All sectors are expected to increase requirements for water withdrawal in the future and consequently many of the world's transboundary river basins will be stressed or highly stressed, and the competition for these resources may threaten harmony between nations.

International assistance in developing effective IWRM policies and transboundary agreements for riparian areas will be needed to ensure access to a sustainable water supply. Monitoring of groundwater levels and managing of surface to groundwater connectivity and provision of environmental flows will be necessary to ensure biodiversity and ecosystem services outcomes and sustainable water supplies into the future.

References

Alcamo J, Henrichs T *et al.* (2000) 'World Water in 2025: global modelling and scenario analysis for the World Commission on water for the 21st Century'. Center for Environmental Systems Research, University of Kassel: Kassel, Germany.

Alexander KS, Moglia M *et al.* (2010) Water needs assessment: learning to deal with scale, subjectivity and high stakes. *Journal of Hydrology* **388**(3–4): 251–257.

Billi A, Cannitano G *et al.* (2004) The Economics of water efficiency: a review of theories, measurement issues and integrated models. *OPTIONS mediterraneennes* **Series B No 57**: 227–262.

Burns WCG (2000) The impact of climate change on Pacific island developing countries in the 21st century. In *Climate Change in the South Pacific: Impacts and Responses in Australia, New Zealand, and Small Island States*. (Eds A Gillespie and WCG Burns) pp. 233–251. Kluwer Academic: Dordrecht.

CSIRO (2008) 'Water availability in the Murray-Darling Basin'. Summary of a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. Canberra.

FAO (Food and Agriculture Organization) (2003) 'Agriculture and Consumer Protection Department. Raising water productivity.' Retrieved 23 March 2010, from www.fao.org/AG/magazine/0303sp2.htm.

FAO (2009) 'Aquastat: general summary on Southern and Eastern Asia.' Retrieved from www.fao.org/nr/water/aquastat/regions/asia/index.stm.

Moglia M, Alexander KS *et al.* (2008) Regional and country scale water resource assessment; Informing investments in future water supply in the Asia Pacific Region – a decision support tool. Water for a Healthy Country National Research Flagship: CSIRO.

Molden D and Sakthivadivel R (1999) Water accounting and access to use and productivity of water. *Water Resources Development* **15**(1–2): 55–71.

Mount Gambier Tourism (2010) 'Mount Gambier: city of craters, lakes, caves and sinkholes.' Retrieved 9 December 2010, from www.mountgambiertourism.com.au/.

Shiklomanov IA (2000) Appraisal and assessment of world water resources. *Water International* **25**: 11–32.

SOPAC (2009) ‘Pacific Islands Applied Geoscience Commission: water sanitation and hygiene.’ Retrieved 23 March 2010, from www.pacificwater.org/pages.cfm/resource-center/water-tools/iwrm-toolboxes-1/water-resources-policy-legislation.html.

UN-WATER/WWAP (2006) ‘Water: a shared responsibility. Section 2: Changing natural systems: The state of the resource’. United Nations World Water Development Report 2. United Nations: Paris and New York. Retrieved 20 April 2010, from http://unesdoc.unesco.org/images/0014/001444/144409e.pdf

UN-WATER/WWAP (2009) ‘Water in a changing world (WWDR-3)’. United Nations World Water Development Report 3. United Nations: Paris and New York. Retrieved 3 March 2010, from http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/WWDR3_Water_in_a_Changing_World.pdf

UNEP (2002) Global Environment Outlook 3. United Nations Environment Programme: Nairobi, Kenya.

UNESCAP (2005) ‘State of the environment in Asia and the Pacific 2005 synthesis: economic growth and sustainability’. UNESCAP: Bangkok. Retrieved 22 April 2010, from http://www.unescap.org/esd/environment/soe/2005/

UNESCAP (2006) ‘UNESCAP report: Asia-Pacific environment at boiling point.’ Retrieved 23 March 2010, from www.unescap.org/unis/press/2006/dec/g61.asp.

UNESCAP (2009) ‘Statistical yearbook for Asia and the Pacific 2008.’ Retrieved 23 March 2010, from www.unescap.org/stat/data/syb2008/27-Water-use.asp.

Water Footprint Network (2010) ‘International virtual water flows.’ Retrieved 23 March 2010, from www.waterfootprint.org/?page=files/VirtualWaterFlows.

World Commission on Water (1999) ‘World’s rivers in crisis – some are dying; others could die’. Press release. World Water Council: Paris.

World Resources Institute (2003) Watersheds of the world: Global Maps 15. Annual renewable water supply per person by basin for 1995 and projections for 2025. *Water Resources eAtlas*.

WWF (2010) ‘Going, going, gone! Climate change and global glacier decline’. World Wide Fund for Nature: Berlin. Retrieved 20 April 2010, from http://assets.panda.org/downloads/glacierspaper.pdf

Chapter 5: **Land use**

Kerry Collins

Main findings

- Regionally, the Asia-Pacific's transition from an agrarian socio-ecological regime into an industrialized one is still in the early phases and its effects on land use, while already substantial, will continue to evolve into the future.

- Agricultural land expansion in the Asia-Pacific region has occurred at much higher rates than any other region in the world, increasing some 6% from 1970 to 2007, compared with a growth of only 1% for the rest of the world.

- Regionally, the rate of decline in forest area eased between 2000 and 2005, primarily because of large-scale afforestation activities reported by China. However, deforestation rates in South-East Asia and the Pacific have continued, fuelling concerns of unsustainable logging practices in these subregions.

- Urban land area in the Asia-Pacific region is estimated to be around 2–3%, but it is hard to achieve a reliable estimate because of a lack of credible information. Given the increasing growth and impact of urban areas in the region, both environmentally and economically, there is an urgent need to improve the datasets of urban land use at both the national and regional scale.

- Land use intensity in the Asia-Pacific region has increased over time, with less land now being used per unit of economic output, implying that the region as a whole has made improvements in land use efficiency. Central Asia reported one of the least intensive use of managed land (11.8 m^2 per US$ GDP in 2005) and also the greatest rate of intensification over time, reflecting the subregion's rapid industrialization and land use efficiency improvements.

- Improved land use efficiency does not necessarily translate into sustainable land use. Improved reporting and data collection on the various land use types, their GDP contribution, and associated environmental costs is required to better understand land use efficiency at both the national and regional scale. This will also assist further policy development that is needed to ensure that national and regional land use efficiency is improved, and that future land use needs can be met.

- The Asia-Pacific region's use of ecosystem management economics to guide land use activities has been wide and varied, with payments for ecosystem services receiving considerable attention as a way of obtaining desired ecosystem management outcomes. Careful consideration in the design and implementation of such schemes is necessary to ensure that any instrument applied stimulates the desired outcomes and limits negative externalities.

- The development of carbon trading markets in the Asia-Pacific region has the potential to bring about major changes in land use and land use efficiency. This is already happening to some degree. There is growing interest in 'deforestation avoidance' carbon credits (i.e. REDD) that provide incentives to make sustaining a forest more attractive and profitable than timber production or conversion to other land uses such as agriculture.

Land use patterns in Asia and the Pacific region

The Asia-Pacific region is currently experiencing production and consumption demands that are outstripping the renewal capacity of the region's natural resources (ADB 2008). These demands have resulted in dramatic changes in forest area and composition, the expansion and intensification of agriculture, and rapid urbanization. This has been largely driven by the extraordinary economic growth experienced in parts of the Asia-Pacific region across the last decade (ADB 2008) combined with continued population growth.

Agricultural land use patterns

Agriculture has caused the greatest land transformations seen across the globe (Ramankutty *et al.* 2006). Today it occupies roughly one-third of the planet's land area (FAO 2009), with much of this being created at the expense of natural forests, grasslands, and wetlands. The global expansion of agriculture has changed spatially over time, following shifts in human settlements and economic development. Since the late 20th century, the rate of global agricultural land expansion has slowed because of a general trend towards intensification and more efficient use of existing land (Ramankutty *et al.* 2006).

Today the Asia-Pacific region accounts for around 37% of the global agricultural land area. In the past 20 years, the region has experienced the highest rate of growth in agricultural land in the world, growing at an average of 0.8% per year. In comparison, the global agricultural growth rate was only 0.1% during the same time period. This has seen agricultural land expand in the Asia-Pacific from 47% of the region's total land area in 1970 to 53% in 2007, now covering approximately 1.8 billion ha at around 0.5 ha per capita (Figure 5.1) (FAO 2009). These changes in agricultural land use have been driven to a large extent by the rapid economic development, technological advances, infrastructure programmes, and population growth and mobility in the Asia-Pacific region (Schandl *et al.* 2009).

Figure 5.1 shows the trend in overall agricultural land area for the Asia-Pacific region, ROW, and the world (i.e. Asia-Pacific plus ROW) for the period 1970 to 2007 in greater detail. It should be noted that the marked difference between land areas in 1991 to 1992 is associated with the breakup of the Soviet Union and the subsequent inclusion of some of the successor states in the Asia-Pacific region as Central Asia.

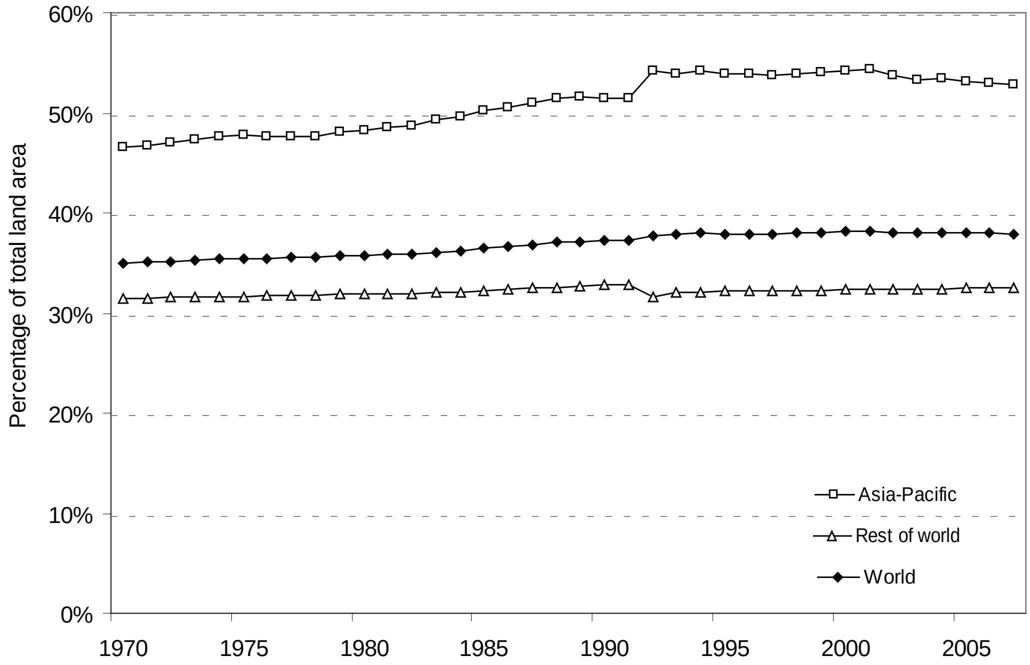


FIGURE 5.1.
Agricultural land use for the Asia-Pacific region, the rest of the world, and the world as a percentage of each region's total land area, for the years 1970–2007 (FAO 2009).

Agricultural land expansion in the Asia-Pacific region resulted from the increase in all three agricultural land use types, arable land,[1] cropland,[2] and pastures.[3] The region's pastures grew at the fastest rate, but, unlike the other two land use types, which have continued to increase, pasture area began to decline in the early 2000s.

Growth in agricultural land area has largely occurred in the North-East Asia and South-East Asia sub-regions, with minor gains also observed in the Pacific (Figure 5.2). Changes in North-East Asia were principally the result of arable land and pasture expansion in China. However, for the last decade, pasture growth has stopped in China, no longer offsetting the decline of this land use type in other countries in the subregion. Agricultural land expansion in South-East Asia has largely occurred through the growth of cropland, especially in Indonesia, Thailand, and Viet Nam, accompanied by a smaller increase in the area of arable land. This subregion has the largest area of cropland in the Asia-Pacific region, at 34.4 million ha, and also the greatest proportion of total land area devoted to this type of land use. International market demands for tree crop products, including palm oil, coffee, and cocoa, have help drive these observed changes in this subregion and also in other areas of the Asia-Pacific.

1 The definition of arable land used here is taken from the FAO. It includes land that is under temporary agricultural crops, temporary meadows or pastures, land under market and kitchen gardens, and land that is temporarily fallow (less than 5 years). It does not indicate the amount of land that can potentially be cultivated.

2 The definition of cropland used here is taken from the FAO. It includes land cultivated with long-term crops that are not replanted for several years (such as cocoa and coffee), land under trees and shrubs producing flowers (such as roses), and nurseries (other than those used for forest trees).

3 The definition of pastures used here is taken from the FAO. It includes meadows and pastures that are used permanently (5 years or more) to grow herbaceous forage crops, both cultivated and wild.

The steady increase in agricultural land area in the Pacific subregion has occurred across all three land use type, with the largest changes occurring in Fiji and Papua New Guinea.

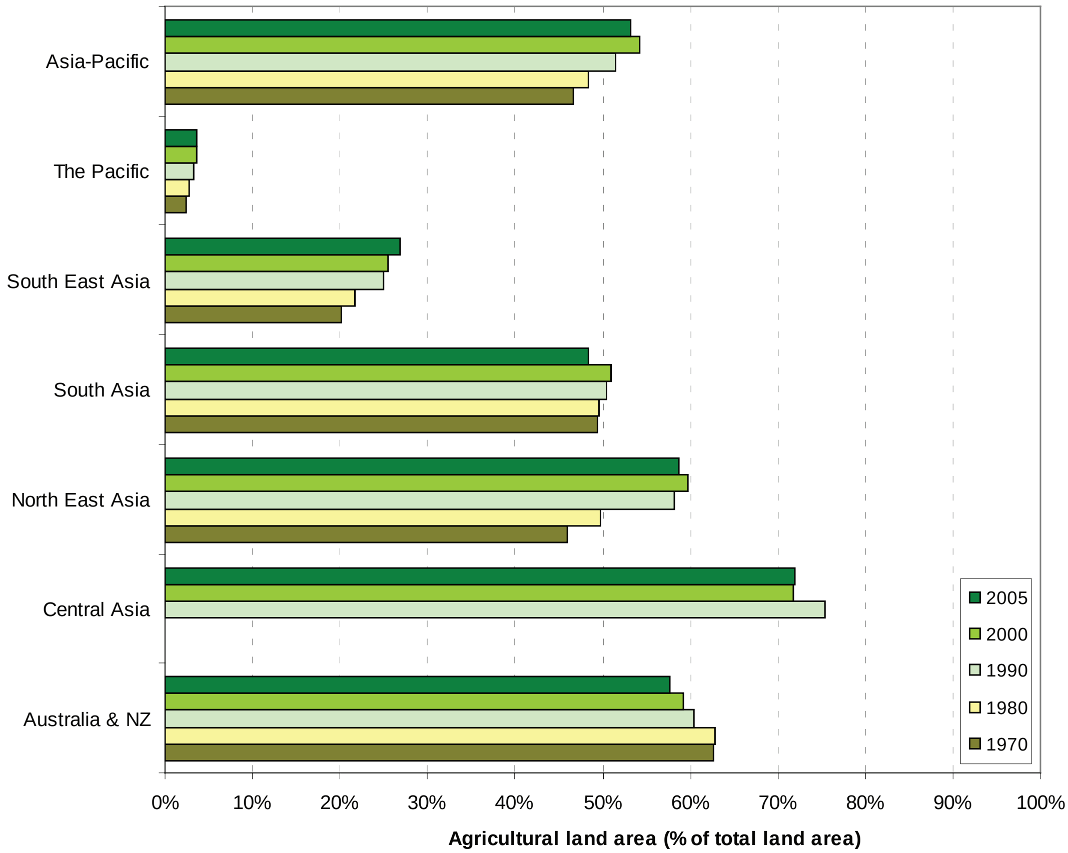


FIGURE 5.2.
Agricultural land area (as a percentage of a region's total land area) for the Asia-Pacific and its subregions for the years 1970, 1980, 1990, 2000 and 2005 (FAO 2009). Note: for Central Asia 1992 data is presented instead of 1990.

Reductions in agricultural land area were observed in the Australia and New Zealand, South Asia and Central Asia subregions (Figure 5.2). The decline noted for the Australia and New Zealand subregion largely resulted from the loss of pastures in Australia and of arable land in New Zealand. The Central Asia subregion recorded the largest loss of arable land for the entire Asia-Pacific region. This is attributable to losses in Kazakhstan, likely resulting from the abandonment of land associated with failed agricultural expansion projects such as the Aral Sea Basin. Agricultural expansion in South Asia reached a peak of approximately 51% of the subregion's total land area in around 2000, and since then has slowly retracted to a little under its 1970 area. The pre-2000 agricultural gains resulted from arable and cropland expansion in most countries in this subregion, while the retraction was largely driven by a reduction in pastures in the Islamic Republic of Iran and India, as well as the loss of arable land in Bangladesh and India.

Forest land use patterns

In 2007, the world's forest cover was reportedly just under 4 billion ha, with the Asia-Pacific region accounting for around 20% of this, at approximately 758 million ha (FAO 2009), an average of 0.2 ha per capita. China, Australia, Indonesia, and India are among the 10 most forest-rich countries in the world; and together account for around 69% of the forest land in the Asia-Pacific region.

While global forest area continues to decline, albeit at a reduced rate, the Asia-Pacific region defied this trend, recording a very slight increase in forest area since the year 2000 (Figure 5.3). The region reported a net annual gain in forest area in the period 2000 to 2007 of approximately 0.5 million ha per year (FAO 2006, 2009). This compares with a net loss of around 0.1 million ha per year in the previous 10 years (FAO 2006). The regional forest gains were primarily due to forest expansion in North-East Asia, specifically China. China began a large scale afforestation and reforestation effort in the 1980s, and reported a forest expansion of around 4 million ha per year from 2000 to 2007 (see Box 5.1) (FAO 2006, 2009).

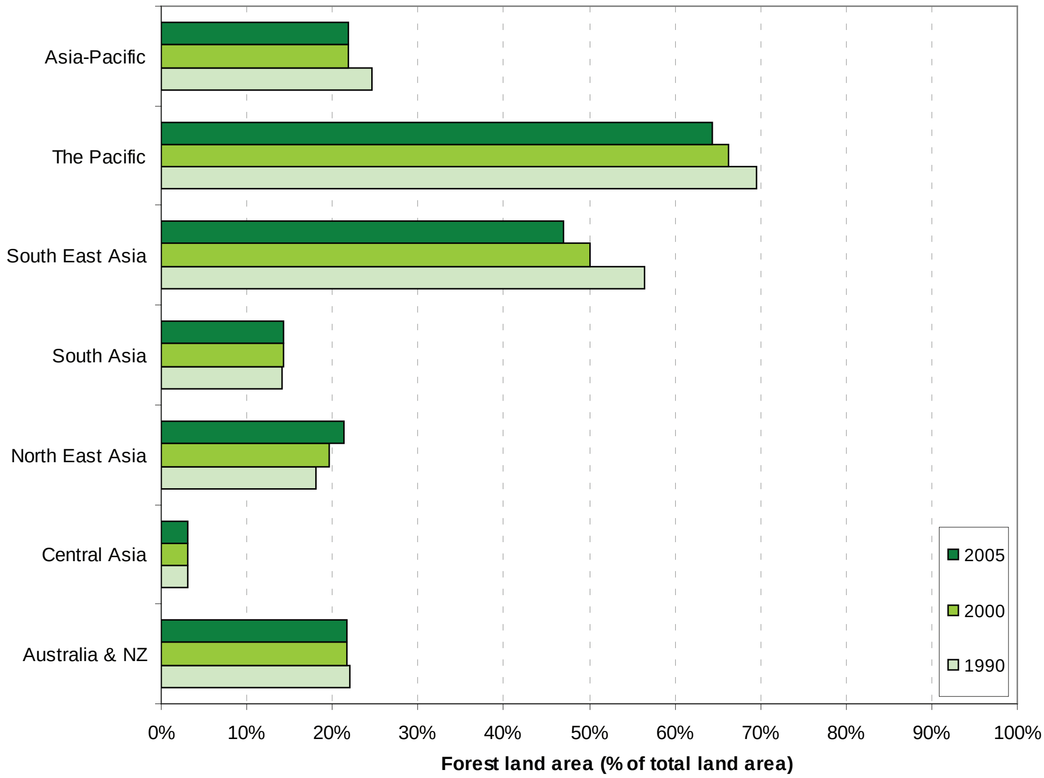


FIGURE 5.3.
Forest land area (as a percentage of a region's total land area) for Asia and the Pacific and its subregions for the years 1990, 2000 and 2005 (FAO 2009). Note: for Central Asia 1992 data is presented as 1990.

South Asia reported a swing from annual net forest gains prior to 2000 to annual net forest losses after 2000 (Figure 5.3). The drivers behind this change were a decline in forest growth in India, and increased forest losses in Bangladesh and, to a lesser extent, in Pakistan and Sri Lanka. The Pacific subregion also reported an increase in net annual forest losses after 2000, fuelling concern regarding unsustainable logging practices in a number of Pacific Island countries. Specifically, Papua New Guinea and the Solomon Islands, where logging rates continue to occur at two to three times the sustainable yield (Commonwealth of Australia 2006).

Globally, plantation forests are increasing but still only account for around 3% of total forest area (FAO 2006). This growth trend has also been reported in the Asia-Pacific region, where plantations were estimated to be around 63 million ha, or 8.4% of the region's forest, in 2005. The annual net gain in plantations across the region increased from 50,000 ha per year in 1990–2000 to around 1.4 million ha per year in the period 2000–2005. In comparison, the global rate of plantation growth was 2.4 million ha per year in 2000–2005. China has the greatest area of plantation forests in the

Asia-Pacific region, with approximately 31 million ha, followed by Japan with approximately 10 million ha. Other countries with significant proportions of their forest area as plantation include Bangladesh, Kazakhstan, New Zealand, Republic of Korea, Thailand, and Viet Nam (FAO 2006). The majority of Asia-Pacific region's plantations are designated for production which, while relieving the pressure placed on natural forests, provides limited value from a biodiversity point of view and reduced options in payments for ecosystem services schemes.

Box 5.1: 'Grains for Green' afforestation/reforestation of wasteland in China

Government-sponsored reforestation programmes have expanded rapidly in China since the early 1980s and there are now widespread subsidies for the conversion of farmland and 'wasteland' to forest (Ediger and Chen 2006). One example is the Sloping Land Conversion Program (SLCP) or 'Grain for Green', which is a nationwide project to encourage afforestation. Farmers are supplied with grain and cash subsidies in return for planting trees on designated areas. This policy aims to convert large areas of steeply sloping (greater than 25^{o}) agricultural land to forest or grassland to prevent water and soil erosion. Between 1999 and 2002, the programme reported the successful conversion of over 3 million ha of cropland to forest, with over 15 million farming households participating. The reported impacts have been mixed, with some areas reporting reductions in food production, rural self-sufficiency, and agricultural land per capita, as well as positive impacts on hydrology and erosion, habitat and biodiversity benefits (Ediger and Chen 2006).

Urban land use patterns

The worldwide trend for urbanization has been dramatic in the Asia-Pacific region, particularly in Asia where urban population growth has occurred at unprecedented rates for the last two and a half decades (Fragkias and Seto 2008). Projections have this trend continuing, estimating that 70% of the world's population will live in urban areas by 2050, one-third of which will be concentrated in Asia (Seto and Shepherd 2009).

The area of urban settlement, or impervious land surfaces, is estimated to occupy between 2 and 3% of the Earth's land surface (Grübler 1994; Young 1999; UN Population Division 2007; Millennium Ecosystem Assessment 2005). A similar percentage is reported for the Asia-Pacific region (UN Population Division 2007).

Although current and future population time series datasets are available, parallel information on the rates, magnitudes, and shapes of urban land use and its change over time is missing. The majority of current knowledge of global urban land use is based on studies of individual cities or regions, with limited long-term studies. Although there is coarse scale monitoring, which provides global and national estimates of urban areas, this can vary widely and should be used with caution (Seto and Shepherd 2009). Yet time series information has been identified as a key data need in order to better understand the interactions between humans and the environmental systems (Seto and Shepherd 2009). Given this, there is an urgent need to expand the datasets of urban land use at national, regional, and global scales, and only then can questions of rural verse urban land use efficiency can truly be considered.

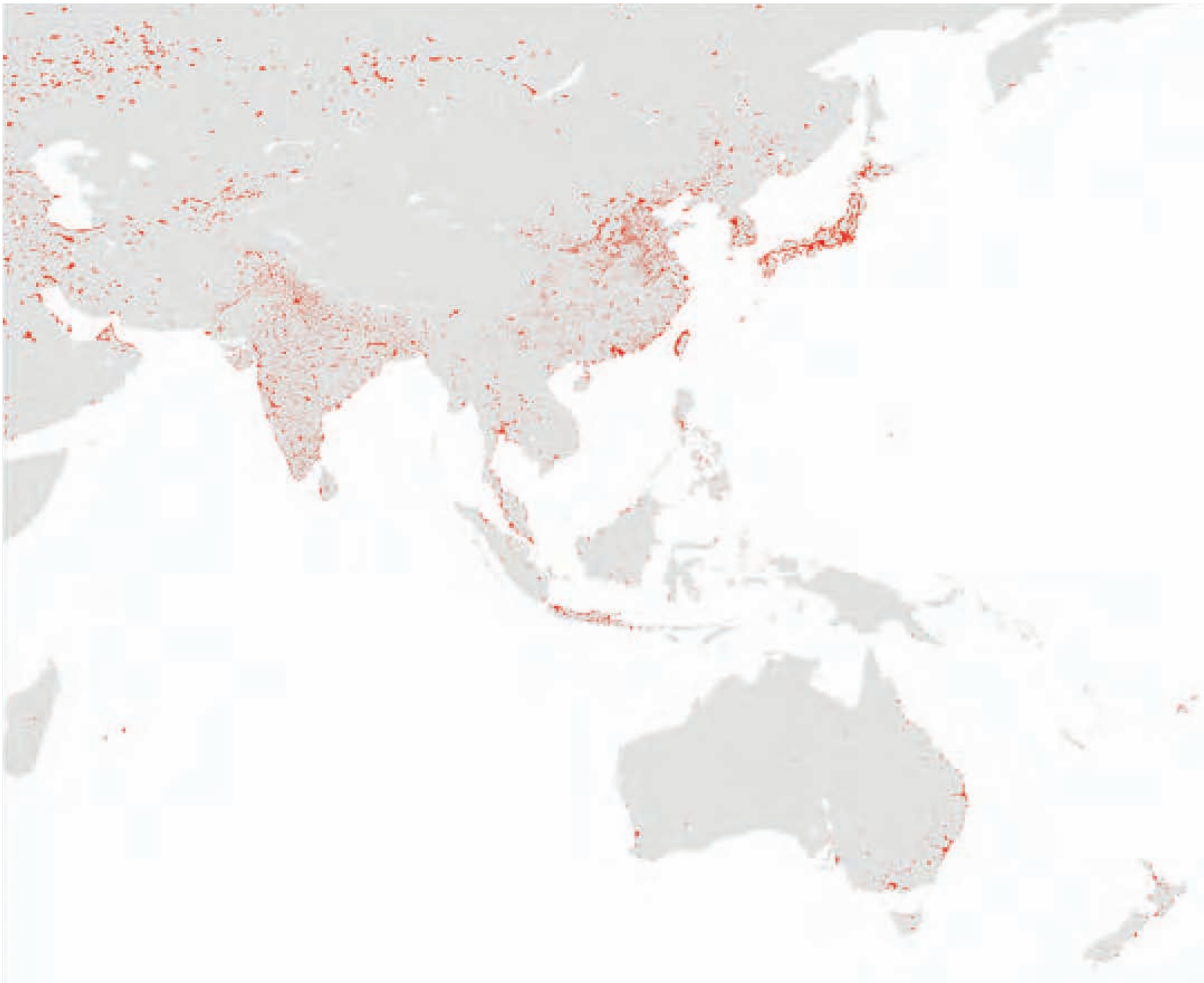


FIGURE 5.4.
Map of Asia and the Pacific region showing urban settlement locations (red) from the GRUMP dataset (CIESIN Columbia University et al. *2004).*

One example of a global scale monitoring attempt of land area occupied by urban settlements is the Global Rural-Urban Mapping Project (GRUMP) undertaken by Columbia University's Earth Institute's Centre for International Earth Science Information Network (CIESIN) and others (Figure 5.4). Data from this research, presented by the UN Population Division (2007), provides an estimate of the urban settlement extent in the Asia-Pacific region, being approximately 89 million ha, the majority of which is in North-East Asia and South Asia (Table 5.1). A second example of a global land use dataset is provided by Erb *et al.* (2008). Based on this research, the urban and infrastructure land use estimation for the Asia-Pacific region was a little less than 36 million ha (Table 5.1). These two datasets demonstrate the range of estimations of urban settlement extent and why they should be used with caution.

Table 5.1. Urban land use statistics for Asia and the Pacific subregions		
Region	**Urban land (1000 ha) 2005 (UN Population Division 2007)**	**Urban land (1000 ha) 2000 (Erb *et al.* 2008)**
North-East Asia	39,778	14,020*
South-East Asia	9,712	3,885#
South Asia	31,004	11,321^
Central Asia	3,950	4,420*
Australia and New Zealand	4,644	2,243*
The Pacific	373	71+
Total Asia-Pacific	**89,460**	**35,960***
Total Global	**35,054,310**	

* No data for Democratic Republic of Korea or Mongolia
# No data for Singapore
^ No data for the Maldives
+ Only Papua New Guinea

‘Other land’ use

The FAO Statistics Division ‘other land’ dataset provides the most consisted time series information for land used for purposes other than agriculture and forestry, and includes that used for urban settlement and related infrastructure, barren land, and other wooded land not considered to be forest.

Across the Asia-Pacific region, the area of ‘other land’ has been steadily increasing. Since 1990, the start of FAO records, this land use category has expanded substantially at an annual net rate of some 7.8 million ha per year. In 2007, ‘other land’ covered around 873 million ha, or 25% of the Asia-Pacific region’ total land area (FAO 2009). Much of this land use change has been at the expense of agricultural land, and is thought that a significant proportion has been converted to human settlements and associated infrastructure.

North-East Asia is the only subregion of the Asia-Pacific region that reported a reduction in the area of ‘other land’ since 1990 (Figure 5.5). This can be solely attributed to land use changes in China. From 1990 to 2007, China’s ‘other land’ area declined by some 69.7 million ha, at an annual rate of around 3.9 million ha per year (FAO 2009): the result of a combination of changes in agricultural land use, urbanization, and China’s reforestation policies providing incentives for the conversion of wasteland to forests (see Box 5.1) .

Land use efficiency in Asia and the Pacific region

Efficiency of land use in agriculture is usually expressed as land productivity; that is, agricultural yield measured in tonnes per hectare, but can also be measured as monetary output per hectare. Land use efficiency is defined as the amount of land required to produce a unit of product or service. Using land more efficiently involves using smaller areas of land to produce the same product or service. Although this encourages the consideration of the economic value of land it, unfortunately, does not

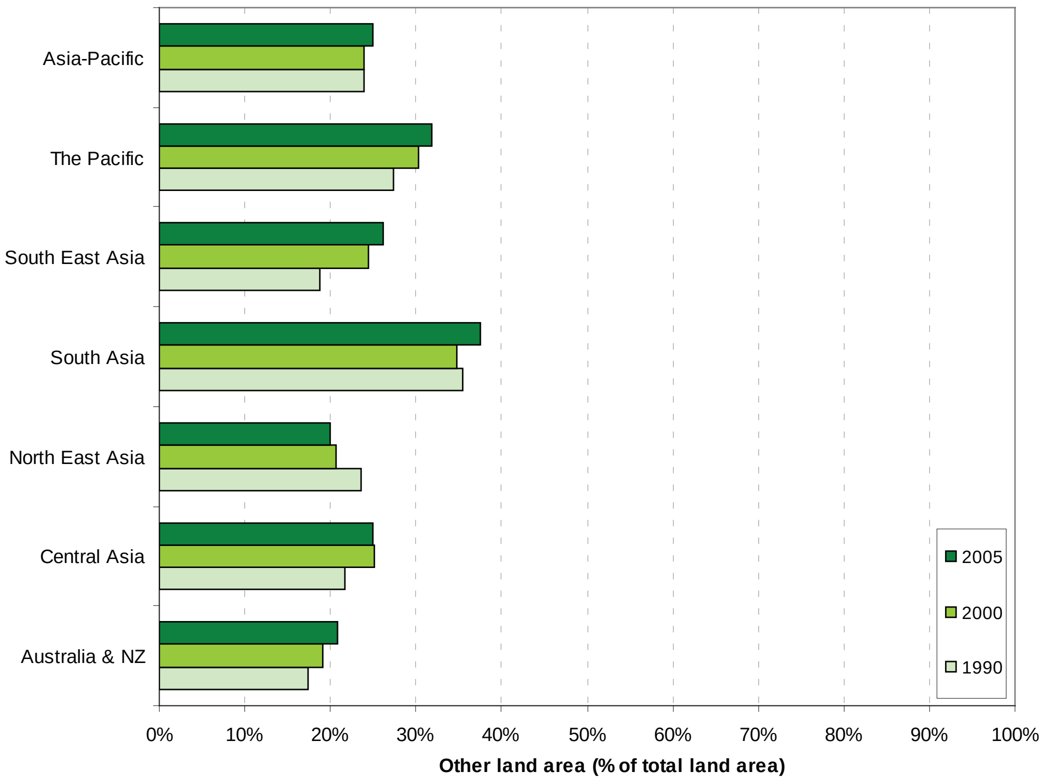


FIGURE 5.5.
Other land area (as a percentage of a region's total land area) for Asia and the Pacific and its subregions for the years 1990, 2000 and 2005 (FAO 2009). Note – for Central Asia 1992 data is presented as 1990.

automatically transfer to sustainable land use because productivity increases are often the result of increases in inputs

As a rule, most GDP is generated from the most intensively managed land. This is the land most altered to provide goods and services for human needs; it has the highest level of use, as well as the highest associated risks. Thus, by considering the area of intensively managed land per unit of economic output, an overview of land intensity was developed and, in turn, of land use efficiency. The total area of intensively used land is the sum of managed agricultural land (including managed forests) and the built-up area. Once again, dataset shortfalls mean that some broad assumptions needed to be made for this report.

The area of intensively managed agricultural land as defined by this report is the sum of arable land, cropland, cultivated pastures, and managed forests. Because not all countries provide information on the area of intensively managed pastures, and because pasture areas reported in the dataset used by this report consist of both cultivated and wild, they were not included in the intensively managed agricultural area calculations. This is likely to increase the error for countries whose extensive grazing industries provide an important proportion to their national agricultural GDP. Additionally, information on the area of forests used for production was only available for the year 2005. An assumption was made that the proportion of forests used for production did not vary greatly, thus managed forest areas were back-calculated until 1990 when forest area records began.

As mentioned previously, the area of land used for urban settlements and the associated infrastructure is poorly reported at the national and regional scale. Using the single year estimates of population size and density made available through the GRUMP study by CIESIN *et al.* (2004), an inference of the extent of the built-up area was achieved. By assuming that the urban densities varied little within this study's time frame, built-up areas were back-calculated.

Land use intensity in the Asia-Pacific region has increased over time; that is, less land is now used per unit of economic output (Figure 5.6a). This implies that the region as a whole has made improvements in its land use efficiency. The Asia-Pacific region's managed land use intensity increased from around 2.3 m^2 per US$ GDP in 1990 to 1.3 m^2 per US$ GDP in 2005. The subregions of Central Asia and the Pacific used the largest amount of land per unit of economic output, returning figures of 11.8 and 20.1 m^2 per US$ GDP, respectively, in 2005. Central Asia also reported the greatest rate of intensification of managed land over time, reflecting the subregion's rapid industrialization and improvements in land use efficiency. North-East Asia returned the highest land use intensity across the Asia-Pacific region at 0.6 m^2 per US$ GDP in 2005, with Japan reporting one of the most intensive land use systems in the region (0.1 m^2 per US$ GDP in 2005). The North-East Asia subregion also reported a land use intensity that changed the least with time, despite significant improvements in the managed land use intensity for both China and Mongolia.

Rural land use intensity in the Asia-Pacific region has also improved over time (Figure 5.6b), intensifying from around 21.7 m^2 per US$ GDP in 1990 to 16.8 m^2 per US$ GDP in 2005. Again the subregions of Central Asia and the Pacific used the largest amount of land per unit of economic output at 46.0 and 57.1 m^2 per US$ GDP, respectively, in 2005, while North-East Asia returned the highest rural land use intensity of 12.0 m^2 per US$ GDP. These results reflect the different stages of industrialization of the economically dominant countries in each region, with the Pacific generally still heavily reliant on subsistence agriculture, compared with North-East Asian countries such as Japan, which is already heavily industrialized, and China, which is presently undergoing rapid industrialization.

FIGURE 5.6.

Land use intensity of (a) total managed land, (b) rural land, and (c) urban land for the Asia-Pacific region and its six subregions (FAO 2009; World Bank 2009; CIESIN et al. 2004).

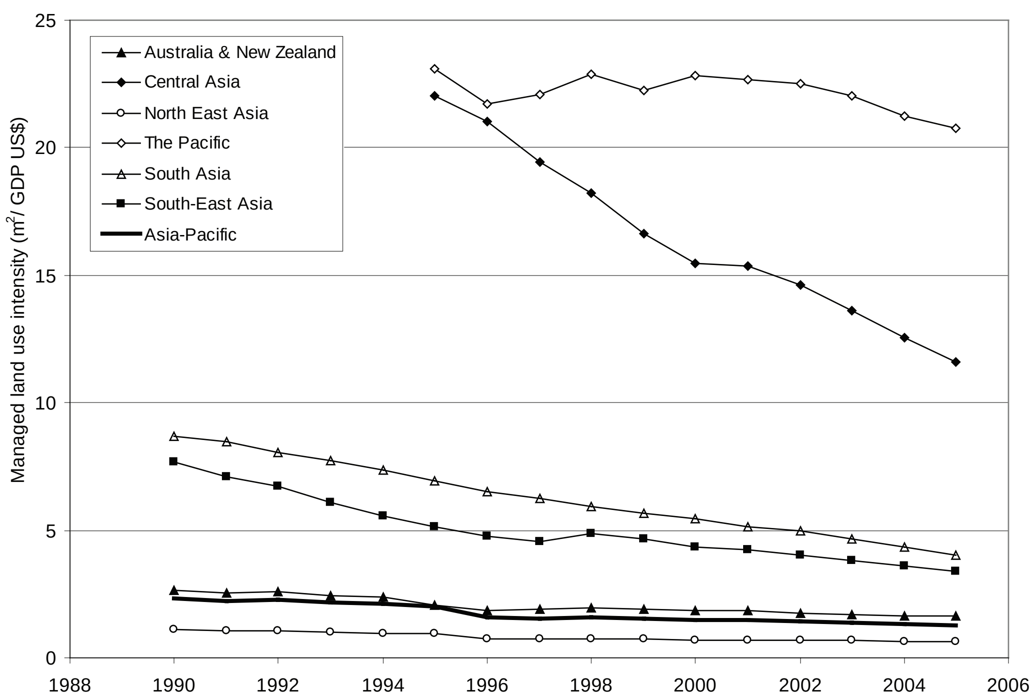


Figure 5.6.(a)

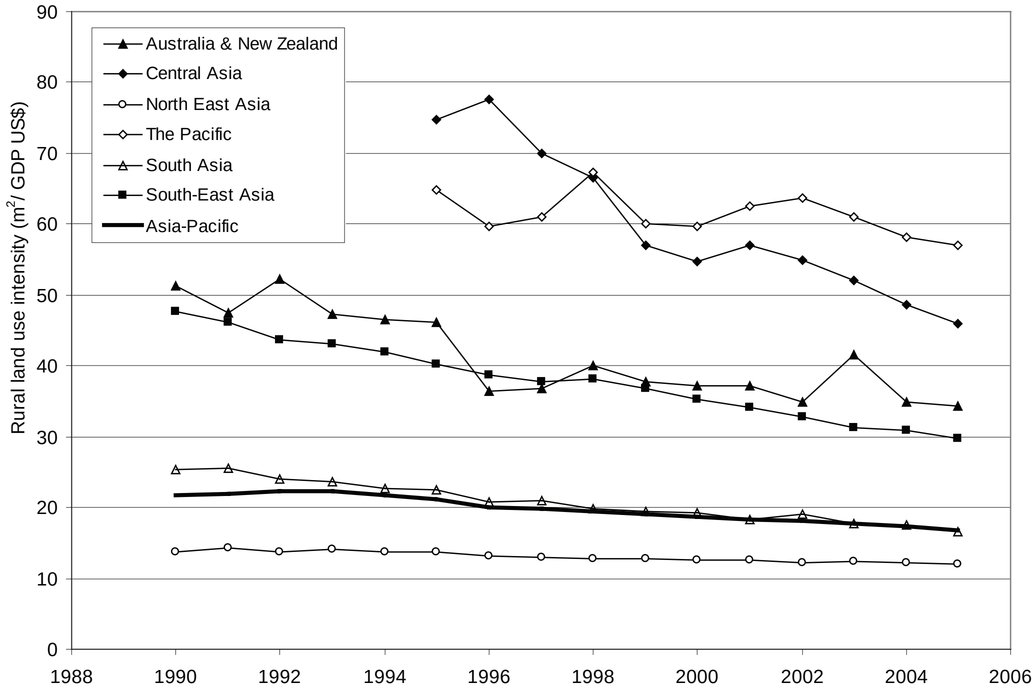


Figure 5.6.(b)

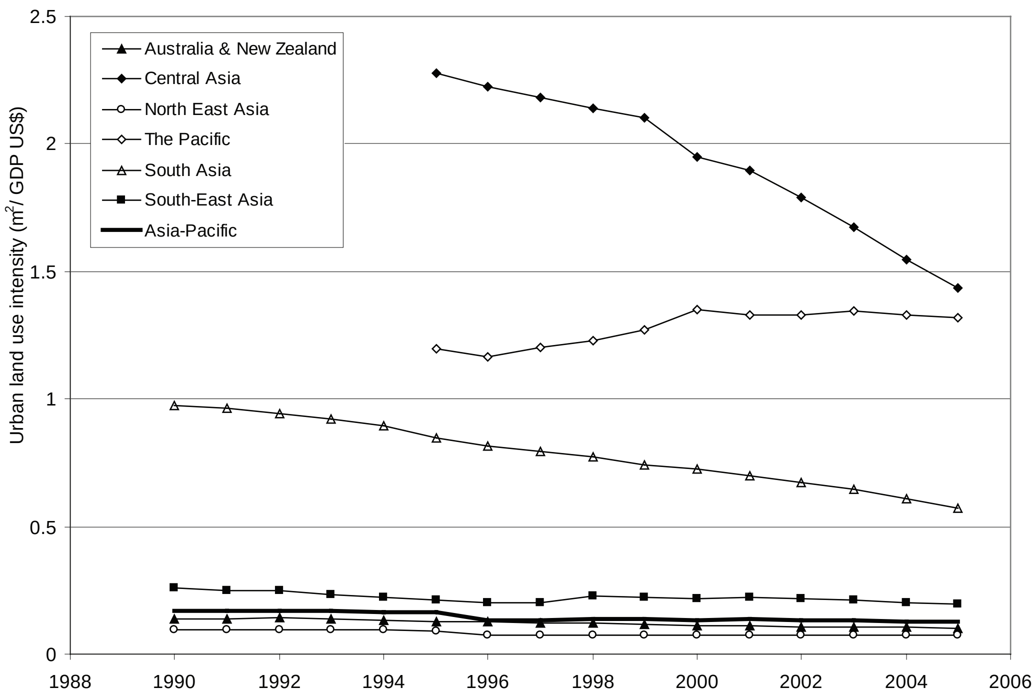


Figure 5.6.(c)

The Asia-Pacific region's urban land use intensity increased from around 0.17 m^2 per US$ GDP in 1990 to 0.13 m^2 per US$ GDP in 2005 (Figure 5.6c). However, it must be stressed that urban area data was only available for the year 2005, and not for all countries, and some broad assumptions were made to estimate urban land use in the previous years. All subregions in the Asia-Pacific region followed this trend except for the Pacific, which decreased. This decrease in urban land use intensity may reflect a greater rate of urbanization in the Pacific relative to its economic growth in the manufacturing and services sectors. However, it is important to note that this result must be treated with care because only six of the 14 countries in this subregion had the required information.

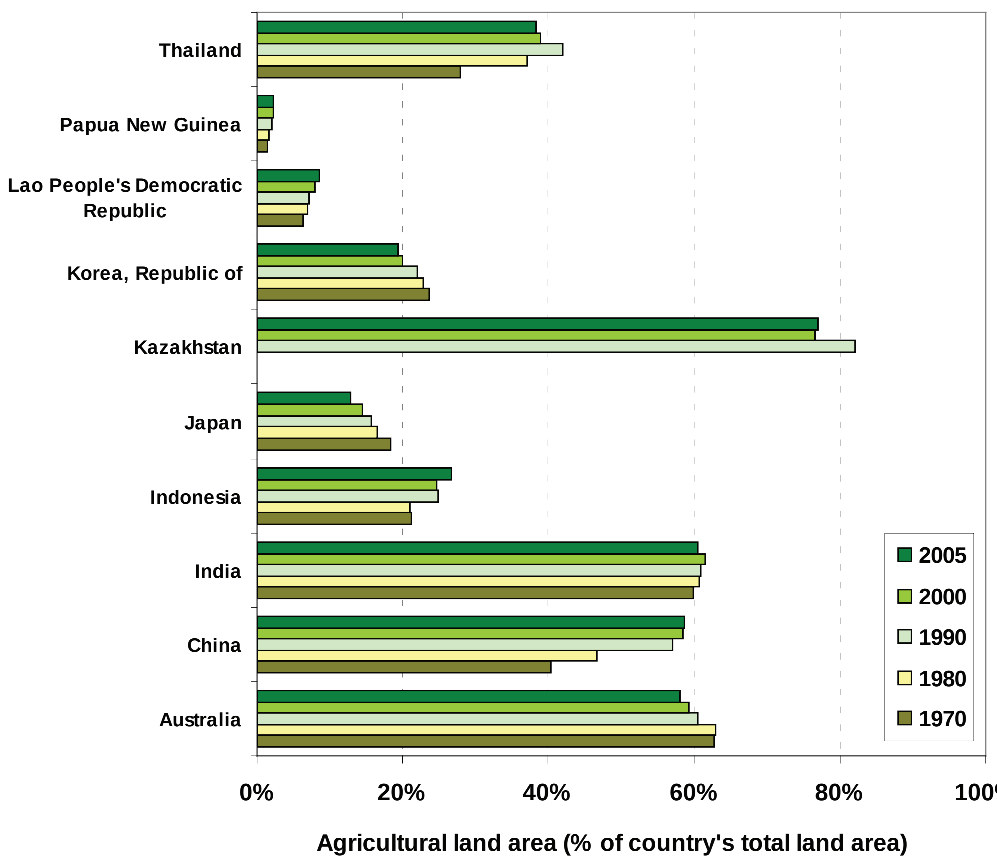
Land use patterns and land use efficiency for selected countries

This section provides a review of land use patterns and land use efficiency for a selection of countries for the Asia-Pacific region. Each is representative of the typology categories developed in Krausmann *et al.* (2008), as discussed in Chapter 2 of this report.

Figure 5.7 shows the land use patterns in (a) agriculture, (b) forestry, and (c) 'other land' of the 10 subset countries. Those countries that are already industrialized – that is, Japan, the Republic of Korea, Australia, and Kazakhstan – display evidence of features typically associated with this metabolic state, such as a contraction of agricultural land area, relative stability of forest resources, and growth in the 'other land' use category, which includes urban, commercial, and industrial land uses, all of which increase with industrialization.

FIGURE 5.7.
Land use patterns in (a) agriculture, (b) forestry, and (c) other land for the 10 selected countries (FAO 2009).

Figure 5.7.(a)



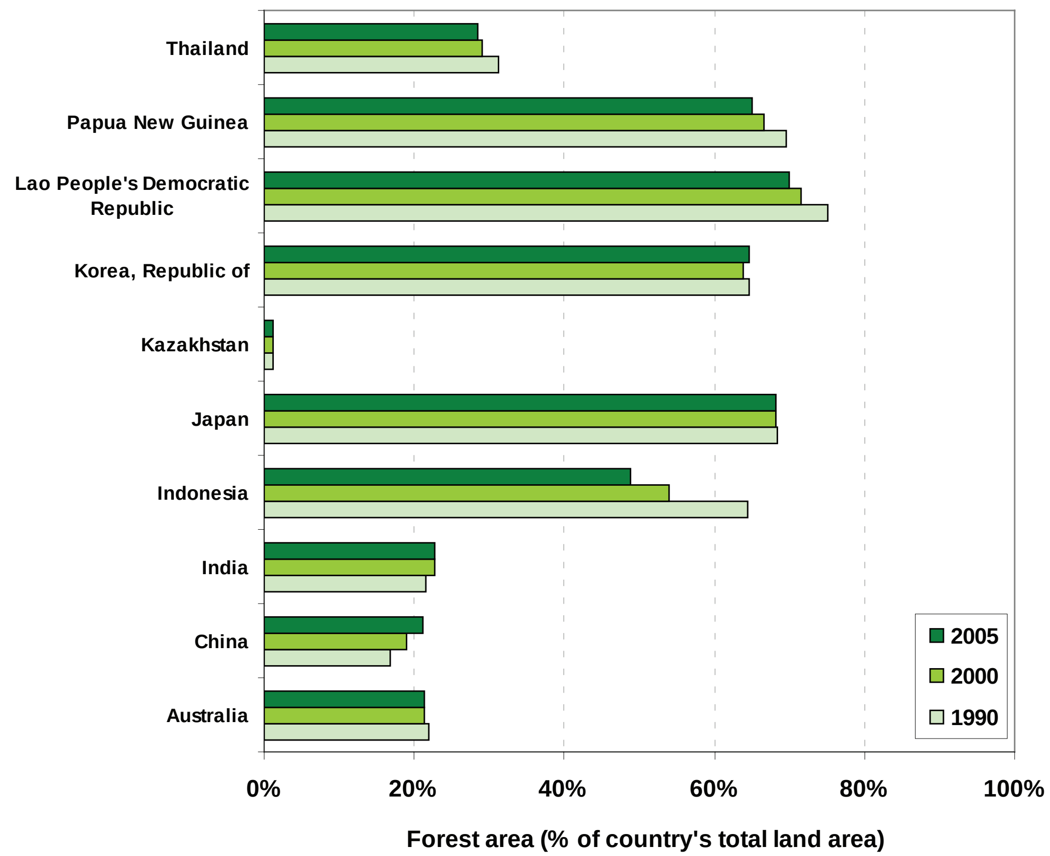


Figure 5.7.(b)

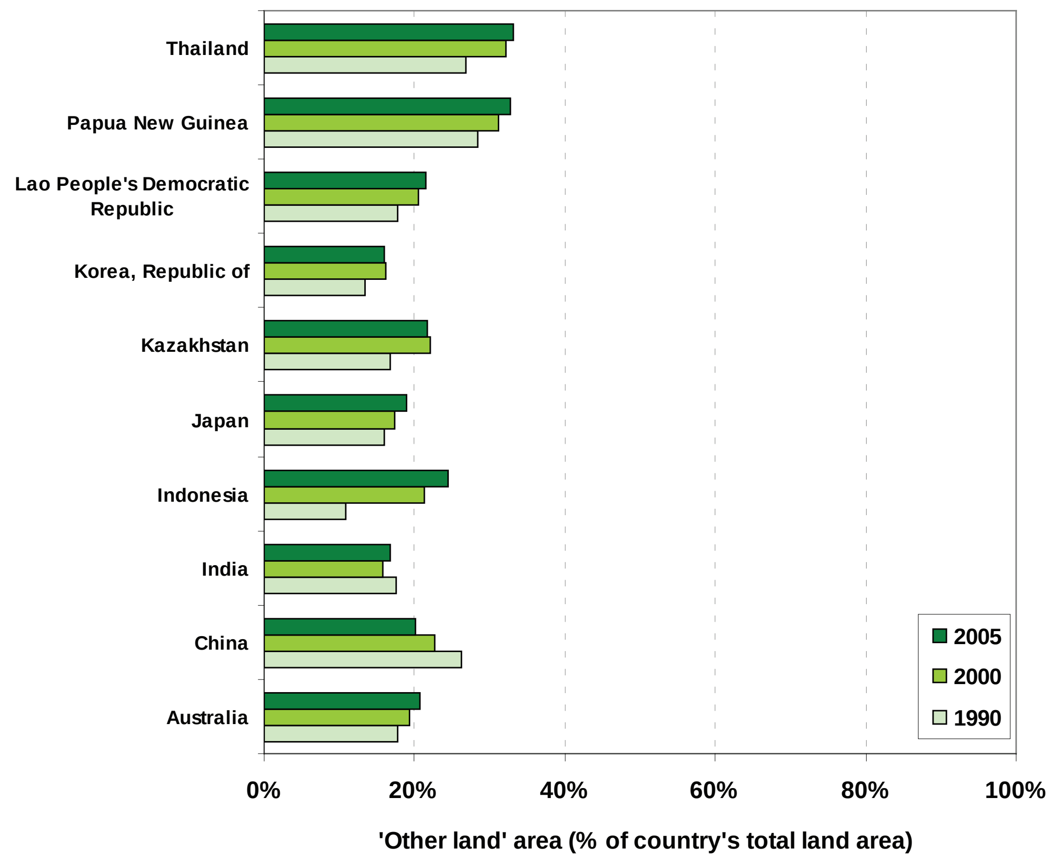


Figure 5.7.(c)

Japan and the Republic of Korea are representatives of the group of high population density industrialized countries (HDI). As discussed previously, these countries have a long history of agricultural production and industrialization, with high population densities and limited natural resources and undisturbed ecosystems.

Japan is one of the most densely populated countries in the world. Scarcity of land suitable for agriculture and human settlement has meant Japan has long considered its effective use of land. Overall, Japan reported one of the most intense land use systems in the Asia-Pacific region, with a total managed land use intensity of 0.09 m^2 per US$ GDP in 2005: around two-thirds of its 1990 level (0.13 m^2 per US$ GDP) (Figure 5.8a). For a long time, the country's forest land area has been relatively stable, protected largely by its topography, climate, and susceptibility to natural hazards (Figure 5.7b). On the other hand, industrialization has led to many changes to Japanese agriculture and its use of land for the industry, manufacturing, and service sectors. The relative importance of Japan's agricultural sector has declined. In the 1970s, agriculture contributed around 5% to the country's total GDP; this had reduced to a little more than 1% by the late-1990s (World Bank 2009). Japan has also experienced a slow decline in agricultural land area (Figure 5.7a), agricultural land per capita, and in people employed in the sector. Substantially more people have left the sector than the decline in land area or GDP, resulting in more land being available per agricultural employee (6.3 ha per person in 1990 to 13.9 ha per person in 2005) and in a greater GDP contribution from each employee (US$20,839 per worker in 1990 to US$37,842 per worker in 2005). Despite these efficiency gains, the amount of rural land used per unit of economic output grew from around 3.0 m^2 per US$ GDP in 1990 to 3.7 m^2 per US$ GDP in 2005, implying a reduction in rural land use efficiency. It can therefore be assumed that Japan's overall managed land use efficiency improvements can be attributed to efficiency gains in the manufacturing and service sectors, with urban land use efficiency making small improvements from around 0.04 m^2 per US$ GDP in 1990 to 0.02 m^2 per US$ GDP in 2005. Land use efficiency gains in Japan during the past 15 years have been among the lowest in the Asia-Pacific region, and may largely be due to land scarcity and because the levels of resource use efficiencies are already some of the highest in the region.

The Republic of Korea, in comparison, has been able to make larger improvements in land use efficiency than Japan. Like Japan, forest land area has largely remained stable (Figure 5.7b), while experiencing declines in agricultural land area, agricultural land per capita, in employee participation in the sector and in the overall importance of the agricultural sector to the country's economy. However, unlike Japan, the Republic of Korea recorded an increase in the amount of GDP generated by the sector, demonstrating the presence of a greater ability for efficiency improvements with the continuing industrialization of its agricultural sector. This is further reflected in the increasing rural land use intensity that the Republic of Korea achieved, intensifying from 3.8 m^2 per US$ GDP in 1990 to 3.0 m^2 per US$ GDP in 2005. Efficiency gains also occurred in urban land use, intensifying from 0.08 m^2 per US$ GDP in 1990 to 0.04 m^2 per US$ GDP in 2005. Overall, land use changes resulted in a halving of the land use intensity for managed land, intensifying from 0.4 m^2 per US$ GDP in 1990 to 0.17 m^2 per US$ GDP in 2005 (Figure 5.8a).

Australia represents the group of low population density industrialized countries of the New World (LDI-NW). These countries have vast available land areas with abundant natural resources. Australia differs from other countries in the group in that, despite industrialization, its agricultural sector remains an important export market. Land use changes have resulted in a decrease in agricultural and forest land areas, while 'other land' areas increased (Figure 5.7c). From 1970 to 2005, Australia experienced the largest annual net loss of agricultural land in the Asia-Pacific region, declining by around 1 million ha per year. It also saw a decline in agricultural land availability per capita, in percentage of the population employed in the sector, and in its economic contribution to the country's GDP. Despite these decreases, GDP generated by the agricultural sector and by each agricultural employee increased, implying improvements in land use efficiencies. Supporting this, rural land use intensified from 65.0 m^2 per US$ GDP in 1990 to 43.8 m^2 per US$ GDP in 2005. Urban land use also intensified during this period, moving from 0.15 m^2 per US$ GDP to 0.11 m^2 per US$ GDP. Overall, Australia's managed land intensified by around two-thirds on its 1990 level, rising from 2.8 m^2 per US$ GDP to 1.8 m^2 per US$ GDP, implying improvements in land use efficiency (Figure 5.8b).

Kazakhstan is an example of the group of low population density industrialized countries of the Old World (LDI-OW). As discussed in earlier chapters, due to their turbulent political and economic pasts, the countries in this group have a mix of both industrial and developing attributes. As a result, Kazakhstan has a highly industrialized agricultural sector but with one of the lowest levels of rural land use intensity in the Asia-Pacific region. Land use change in Kazakhstan has seen agricultural land areas decline by approximately 5%, while 'other land' correspondingly increased and forest land area remained stable (Figure 5.7). A reduction in the country's population has meant that agricultural land area per capita has been largely stable despite its reduction in extent, while falls in the percentage of employees in the sector led to increases in the agricultural land availability per employee, rising from 134 ha per person to 175 ha per person. Agricultural GDP and that generated per employee has been quite variable since 1992, but both have shown an increasing trend since the year 2000. Changes in the agricultural sector have led to an intensification of rural land use, rising from 127.4 m^2 per US$ GDP in 1993 to 116.0 m^2 per US$ GDP in 2005, but again there was much variation across the 13-year period. An intensification of urban land use was also noted in the same time period, changing from 1.3 m^2 per US$ GDP to 0.6 m^2 per US$ GDP. Overall, the managed land use intensity in Kazakhstan increased, intensifying to 11.3 m^2 per US$ GDP in 2005, two-thirds of that recorded in 1993 (31.5 m^2 per US$ GDP) (Figure 5.8c).

China, India, Indonesia, and Thailand are all examples of high population density developing countries (HDD). The group includes a diverse array of countries, ranging from some of the least developed in the Asia-Pacific region to those that are rapidly industrializing. Generally, they have a substantial agricultural sector and large populations that are becoming increasingly urbanized. Yet this group of countries still remains closer to an agrarian metabolic pattern than to an industrial one.

India's industrialization of agriculture in the 1960s 'Green Revolution' enabled it to develop self-sufficiency largely through improved management and yield increases, rather than large changes in land area. Since the 1970s, the area of land used for agriculture has changed very little (Figure 5.7a), with the expansion of cropland being the most notable alteration. The percentage of the total population employed in the agricultural sector has declined, as has the agricultural land available per capita and per agricultural employee. Agricultural GDP has grown since 1970, but the share of agriculture in the country's total GDP has declined from 39% to 17% in 2005. Forest land area increased at around 200,000 ha per year in the 16 years from 1990, and may be attributed to the strong afforestation and reforestation efforts in India started in the 1980s. Despite only small changes in land area for rural production, India's rural land use efficiency improved, intensifying from 28.0 m^2 per US$ GDP in 1990 to 18.8 m^2 per US$ GDP in 2005. Urban land use efficiency also improved during this same time period, with urban land use intensity deepening from 1.1 m^2 per US$ GDP to 0.6 m^2 per US$ GDP. Together India's total managed land use efficiency more than halved, intensifying from 10.4 m^2 per US$ GDP to 4.5 m^2 per US$ GDP. With continued industrialization and urbanization, improved land use efficiency is highly likely and essential if India is to support its future resource needs (Figure 5.8d).

Indonesia is richly endowed with natural resources, with vast areas of wilderness that support the world's second highest level of biodiversity, among which a large and growing population lives and economy operates. Significant deforestation of Indonesia's forests has decreased the country's forest area by around 15.5% since 1990 (Figure 5.7b). This has occurred at a net annual loss of a little under 1.9 million ha per year since 1990, the highest seen in the Asia-Pacific region and is second only to Brazil (FAO 2006, 2009). Commercial logging, some of which is illegal, is the greatest cause of forest losses in Indonesia, but fires during the droughts in 1982–83 and 1997–98 also contributed to their decline (Ramankutty *et al.* 2006). Changes in agricultural land area were minimal in comparison, increasing by about 5.5% since 1970, at a net annual rate of 210,000 ha per year from 1990 to 2005 (Figure 5.7a). Expansion occurred in both arable land and cropland areas, with the growth of cash cropping, specifically the oil palm industry, attributing significantly to changes in cropland area. Indonesia's population growth has resulted in a decline in agricultural land availability per capita, as well as per agricultural worker. While agriculture's contribution to the country's total economy has declined, the GDP generated by the sector increased. Through the beginnings of industrialization, Indonesia has improved its rural land use efficiency, intensifying rural land use from 44.8 m^2 per US$ GDP in 1990 to 28.2 m^2 per US$ GDP in 2005. Urban land use intensity appears to have changed very little, seemly stable at around 0.3 m^2 per US$ GDP. This may indicate that, while increases in both urban land area and GDP generated from its sectors has occurred, production efficiencies have generally not been made. Overall, Indonesia's total managed land efficiency has more than halved, intensifying from 11.0 m^2 per US$ GDP to 5.1 m^2 per US$ GDP from 1990 to 2005 (Figure 5.8d).

Thailand's agricultural and forest resources cover around two-thirds of the country's land area. With rapid industrialization, the importance of these land uses to Thailand's economy is declining. Since the 1970s, agriculture's contribution to GDP has decreased from 20% in 1970 to 5% in 2005, while that of goods and services sectors has increased. Agricultural land expansion peaked in the mid-1990s, with increases in both arable and cropland areas, but has since slowly declined (Figure 5.7a). Thailand's forest resources have also been in slow decline, recording an annual net loss of 90,000 ha per year from 1990 to 2005 (Figure 5.7b). Despite these decreases, industrialization of the rural sector has enabled increased production and steady growth in agricultural GDP. As a result, Thailand's rural land use efficiency has improved, intensifying from 24.2 m^2 per US$ GDP in 1990 to 16.9 m^2

per US$ GDP in 2005. The country's urban land use efficiency also improved a little during this period, with urban land use intensity deepening from around 0.4 m² per US$ GDP in 1990 to 0.2 m² per US$ GDP in 2005. Together, Thailand's total managed land efficiency halved, intensifying from 3.5 m² per US$ GDP to 1.7 m² per US$ GDP (Figure 5.8d).

China's economic development, industrialization, and urbanization have led to some of the most significant land use changes seen in Asia-Pacific region, including the largest net annual gains in both forest and agricultural areas. China holds the largest forest resource in the region, a resource which has long undergone heavy exploitation. In the 1980s, China began a large-scale afforestation and reforestation push through government programmes such as 'Grains for Green' (see Box 5.1). These programmes have been responsible for the expansion of forest land of around 2.5 million ha per year from 1990 to 2005, such that forests now cover around 22% of China (Figure 5.7b) (FAO

FIGURE 5.8.
Managed land use intensity for selected countries, grouped in their typology categories (Krausmann et al. *2008), expressed as the area of land (m²) used per unit of economic output (GDP constant 2000 US$) (FAO 2009; World Bank 2009).*

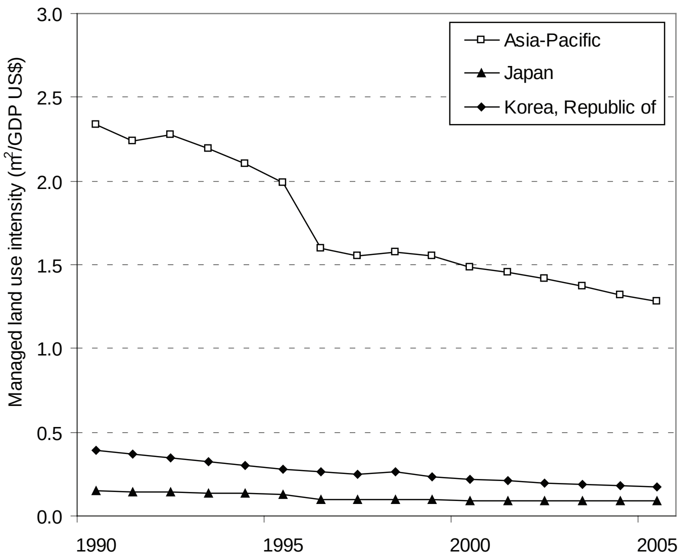


Figure 5.8.(a)

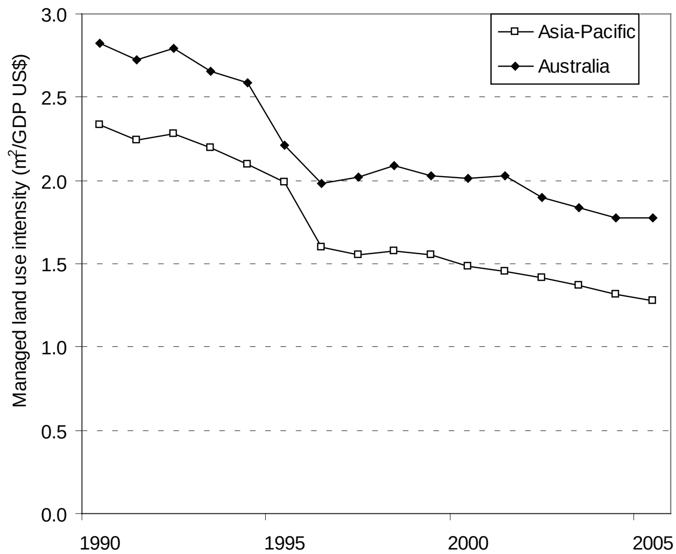


Figure 5.8.(b)

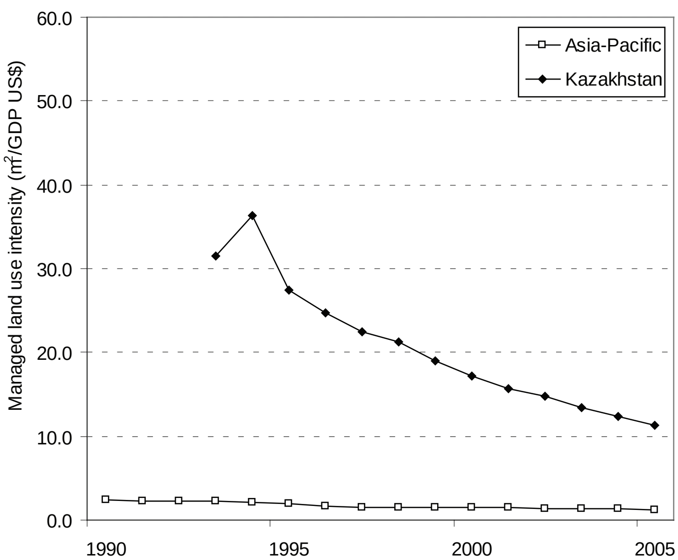


Figure 5.8.(c)

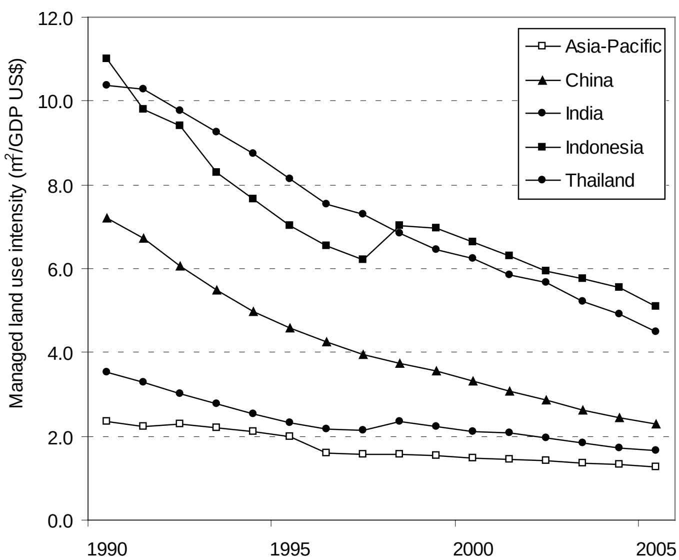


Figure 5.8.(d)

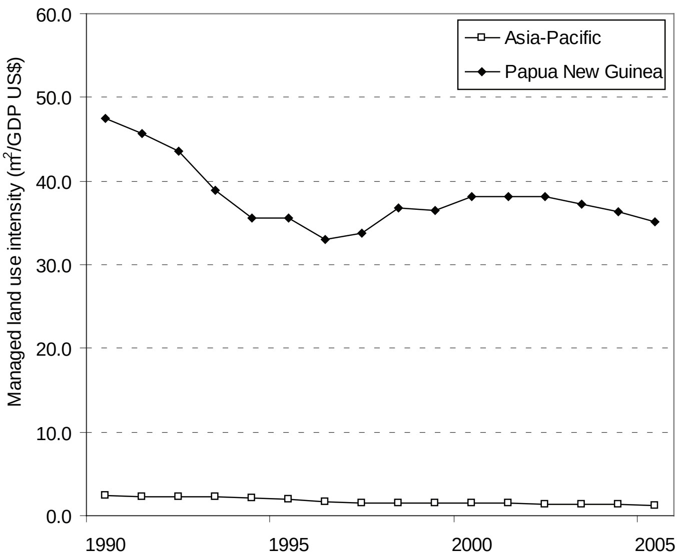


Figure 5.8.(e)

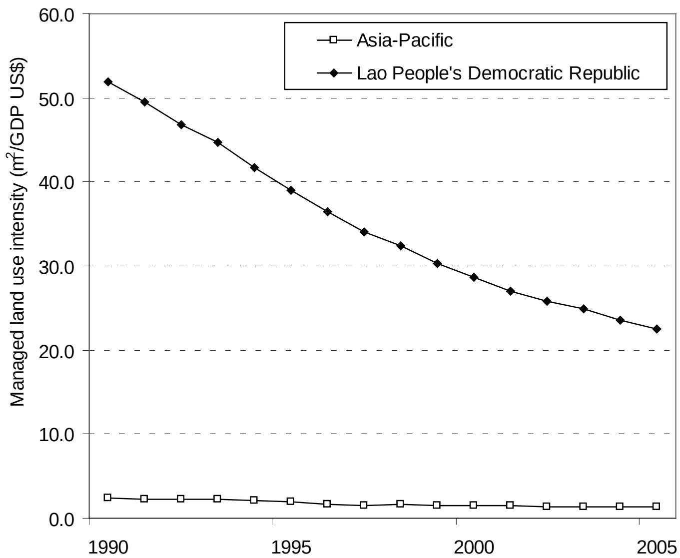


Figure 5.8.(f)

2006, 2009). Agricultural land also significantly expanded, increasing from 40% in 1970 to 59% in 2005: a net annual growth rate of some 4.8 million ha per year since 1970 (Figure 5.7a). Concerns of urban expansion encroaching on agricultural land have led to programmes of land protection, consolidation, reclamation, and development (Lichtenberg and Ding 2008). As a result, land that was previously considered unused, abandoned, or to be waste land has now been brought into production as reflected by the decline in 'other land' area (Figure 5.7c). This has led to improved land use efficiencies, with rural land use intensifying from 22.7 m^2 per US$ GDP in 1990 to 15.4 m^2 per US$ GDP in 2005 and urban land use intensity increasing from 0.6 m^2 per US$ GDP in 1990 to 0.2 m^2 per US$ GDP in 2005. In 2005, China's overall managed land use intensity was a third of its 1990 value, intensifying from 7.2 m^2 per US$ GDP in 1990 to 2.3 m^2 per US$ GDP (Figure 5.8d).

Papua New Guinea represents the group of low population density developing countries of the New World (LDD-NW). These countries are sparsely populated, rich in natural resources, and show a predominantly agrarian metabolic profile. Papua New Guinea has extensive forests, which covered around two-thirds of the country in 2005. Forests have been in decline (Figure 5.7b), reducing at around 130,000 ha per year from 1990 to 2005, with logging rates continuing to occur at two to three times the sustainable yield (Commonwealth of Australia 2006). Agricultural land area has marginally increased (Figure 5.7a), with growth largely occurring in croplands used for long-term crops such as coffee, cocoa, and coconut. The GDP generated by this principally subsistence-based sector has increased since 1980 (the start of available data) although its contribution to the country's total GDP has generally not changed. The agricultural sector still provides a substantial proportion of the population's income, food, and labor needs. Rural land use efficiency in Papua New Guinea has improved, with rural land use intensifying from 107.9 m^2 per US$ GDP in 1990 to 66.7 m^2 per US$ GDP in 2005. A marginal change was observed in urban land use, with its intensity increasing from 1.4 m^2 per US$ GDP to 1.3 m^2 per US$ GDP during the same period. In 2005, Papua New Guinea's overall managed land use intensity was two-thirds of its 1990 value, intensifying from 47.4 m^2 per US$ GDP in 1990 to 35.1 m^2 per US$ GDP in 2005 (Figure 5.8e).

The Lao People's Democratic Republic is an example of the group of low population density developing countries of the Old World (LDD-OW). Typically, these countries have low population densities, which are rapidly growing and have a high share in the agricultural sector. Agricultural development is also commonly hindered by geographical features. The Lao People's Democratic Republic consists of a densely forest mountainous landscape, with around 70% of its total land area covered by forests in 2005. The area of forest has been in decline (Figure 5.7b), reducing at an annual net rate of around 73,000 ha per year since 1990. Agricultural land area has steadily risen since 1970, largely in arable land that is principally used for rice production (Figure 5.7a). Agricultural GDP has increased, but growth in the industry, manufacturing, and services sectors has meant that its relative importance to the Lao People's Democratic Republic's economy has declined from a 56% share in 1984 to 37% in 2005. Rural land use efficiency in the Lao People's Democratic Republic improved, with rural land use intensifying from 79.8 m^2 per US$ GDP in 1990 to 43.9 m^2 per US$ GDP in 2005. Smaller improvements were also seen in urban land use, with its intensity increasing from 2.0 m^2 per US$ GDP to 1.5 m^2 per US$ GDP across the same time period. In 2005, the Lao People's Democratic Republic's overall managed land use intensity was around half of its 1990 value, intensifying from 51.8 m^2 per US$ GDP in 1990 to 22.4 m^2 per US$ GDP in 2005 (Figure 5.8f).

This diverse selection of countries, covering a very wide range of development stages, have all demonstrated a trend for improved land use efficiency. The degree to which improvements have been made vary, with those countries only just beginning the transition from an agrarian regime towards industrialization, such as the Lao People's Democratic Republic, generally having made greater improvements in land use efficiency than those further into the transition, such as China. Japan, an example of a highly industrialized economy with a high population density, recorded a slowing of improvements in land use efficiency gains, which may be attributed to the already high level of resource use efficiency.

Table 5.2 provides an overall summary of the trends in land use patterns, GDP and land use intensities for the selection of countries from the Asia-Pacific region reviewed above.

Table 5.2. Summary of the trends in land use, GDP, and land use intensities for selected countries from Asia and the Pacific region.

Country	Typology	Overall trend across the past 20 years				Rural land use intensity (m^2/US$GDP)		Urban land use intensity (m^2/US$GDP)		Managed land use intensity (m^2/US$GDP)	
		Forest land use	Agricultural land use	Agricultural GDP	Importance of agriculture to total GDP	1990	2005	1990	2005	1990	2005
Australia	LDI-NW	–	↓	↑	↓	65.0	43.8	0.2	0.1	2.8	1.8
China	HDD	↑	↑	↑	↓	22.7	15.4	0.6	0.2	7.2	2.3
India	HDD	↑	–	↑	↓	28.0	18.8	1.1	0.6	10.4	4.5
Indonesia	HDD	↓	↑	↑	↓	44.8	28.2	0.3	0.3	11.0	5.1
Japan	HDI	–	↓	↓	↓	3.0	3.7	0.04	0.02	0.13	0.09
Kazakhstan	LDI-OW	–	↓	↕	↕	127.4*	116.0	1.3*	0.6	31.5*	11.3
Korea, Republic of	HDI	–	↓	↑	↓	3.8	3.0	0.08	0.04	0.40	0.17
Lao People's Democratic Republic	LDD-OW	↓	↑	↑	↓	79.8	43.9	2.0	1.5	51.8	22.4
Papua New Guinea	LDD-NW	↓	↑	↑	–	107.9	66.7	1.4	1.3	47.4	35.1
Thailand	HDD	↓	↑	↑	↓	24.2	16.9	0.4	0.2	3.5	1.7

* 1993 data presented

Key drivers and ecosystem implications of land use change in the Asia and Pacific region

Key drivers

Land use change results from complex of situation-specific interactions among a large number of factors operating at different spatial and temporal scales (Lambin *et al.* 2001, 2003). Despite the diversity and interactions of land use change drivers, reviews of case studies have shown that there are generalized patterns of change that result from repeated interactions between driving forces (see Box 5.2). Typically, drivers of change may be generalized into a number of broad factors, namely biophysical, economic, technological, institutional, demographic, social, and cultural factors (Millennium Ecosystem Assessment 2005; UNEP 2007).

Box 5.2. Land use change pathways (Lambin et al. *2001, 2003, 2007)*

Despite the diversity and interactions of land use change drivers, reviews of case studies have shown that there are generalized patterns of change that result from repeated interactions between driving forces. These include: (1) forest frontier deforestation by weak state economies; (2) institutions in transition or absent in developing regions; (3) induced innovation and intensification, especially in peri-urban and market accessible areas of developing regions; (4) urbanization-driven changes in aspirations, consumption patterns and income distribution disparities with impacts on rural land use; (5) new economic opportunities linked to new markets, changes in economic policies, or capital investments; (6) inappropriate interventions creating rapid modifications of landscapes and ecosystems and/or loss of land productivity; (7) ecological marginalization of the poor due to the loss of access to resources and decreased land availability due to changes in land use/zoning for large-scale agriculture, water infrastructure, forest reserves, tourism, and conservation; and (8) ineffective social responses combined with the lack of political will to alter deterioration environmental situations.

Growth in the Asia-Pacific economy, as well as globally, has resulted in increased demand for many ecosystem services, thus stimulating markets and policies that create both opportunities and constraints for land use change. Increasing demand has affected the expansion of many land use forms, as well as their intensification, by encouraging rural producers to engage in land use practices beyond subsistence production while also providing increased access to goods and services and lifestyles, rising their consumer aspirations (Geist *et al.* 2006). Additionally, government policies can further add to the push towards land use change through altering access to markets (via transport and infrastructure), credit, trade, and technology. The agricultural intensification over the past 25 years in Bangladesh illustrates a typical response to such drivers, where the combination of improved market access, technological change, and institutional support has promoted changes in the rural system and living conditions, income, and land productivity (see Box 5.3).

Localized market pressures, especially proximate urban markets, have driven land use changes in many peri-urban areas in the Asia-Pacific region. A prime example is the changes from field crops and orchards to vegetable production in the surrounding peri-urban zones of Shijiazhuang, China, which has been attributed to increased economic returns and changes in urban food demand and preferences (Xiao *et al.* 2006). Competing land use demands and changing land values add further pressure for land use change, especially in these peri-urban zones. International market demands have also provided strong incentives for agricultural changes, especially for adoption of tree crops (Keys and McConnell 2005). The expansion of cash crops, including palm oil, coffee, and cocoa, in areas of the Asia-Pacific region is an illustration of the impact of such drivers in the region.

The Asia-Pacific region has a wide range of institutional factors, including policies, programmes, and fiscal considerations – both governmental and non-governmental – that directly or indirectly influence land use decisions. These may include activities such as income-affecting programmes, water-provisioning programmes, and infrastructure programmes. Subsides are important institutional drivers because they provide income support, enabling farmers to change or intensify production. Alternatively, price controls and taxation may be considered as negative subsidies, in that they tend to restrain farmer resources and limit their ability to alter production. The recent afforestation success in China (see Box 5.1) is an example of effective institutional drivers of land use change. Failure of government policy, either through ill-defined policy or weak enforcement, is also an important factor, with the widespread illegal logging linked to corruption and management failure in Indonesia an example of possible outcomes of policy failure (Jepson *et al.* 2001).

Key drivers of land use change in urban centres include indirect forces, such as those associated with globalization, economic changes, technological development, institutional modifications, and demographic shifts, as well as direct forces such as property rights. The example of China illustrates urban growth resulting from such driving forces. A complex combination of changes in national policies in the agricultural sector and those controlling population mobility, policy decentralization, the implementation of growth-oriented development strategies, changes to property rights, adoption of a state-guided process within a market system, and the administrative reclassification of rural settlements as demographics shift, have brought about the rapid urbanization of many population centres in China today (Geist *et al.* 2006; UN Habitat 2008). A specific example is the Pearl River Delta (see Box 5.4), which is one of the most economically vibrant regions in China, where nearly all land use changes can be attributed to a collection of economic policies and factors associated with remarkable economic growth and increased population mobility (Geist *et al.* 2006). Similarly, the increased urbanization in Kiribati, and its associated pollution and sociality problems, can largely be attributed to economic, institutional, and demographic shifts in the country. The increased monetization of the country's economy, poor delivery of services, unemployment on the outer islands, and growing aspirations for an urban lifestyle have together contributed to a rise in inward migration from the outer islands to main urban centres (ADB 2002).

Research shows that demographic alterations rarely work in isolation to effect land use change; rather, other economic and social factors mediate between population attributes and land use systems (Keys and McConnell 2005). Population dynamics, usually together with national economic policy, tend to play an important role in explaining regional land use change. But, at a finer scale, such as at the household level, characteristics of the household life-cycle often become more important (Geist *et al.* 2006).

Historically, population redistribution has played a key role in land use change, especially in agricultural land expansion. These large-scale migration or resettlement events create rapid land use change as a result of the interaction of technological innovations and infrastructure programmes government policy, consumption changes, and economic integrations. Although such policies can have positive results, some cases have been linked to increased desertification, including the prominent Asian examples of the Tarim and Hei River Basin, the Aral Sea Basin (Geist *et al.* 2006) and Khrushchev's 'Virgin Lands' programme in Kazakhstan (de Beurs and Henebry 2004).

Box 5.3. Agricultural intensification in Bangladesh (Ali 2007)

Bangladesh experienced significant agricultural intensification and rural system change during the 25-year period from 1975 to 2000. Population pressure and market incentives were identified as the key drivers of change resulting in increased cropping intensity and land productivity.

Agricultural intensification was achieved through new farming systems, specifically the expansion of irrigation, dry season cultivation, and increased cultivation of irrigated rice, vegetables and shrimps. Changes to the rural economic and social conditions followed this rapid growth in commodity production and markets, along with the establishment of new infrastructure and increased access to urban centres. Increased farm income, off-farm income, and cash remittances from relatives working overseas allowed many rural residents to improve their living conditions.

The combined factors resulted in increased total food and commodity production, farm income, and land productivity. In contrast, labour and technological productivities declined due to substantial increases in the total agricultural labour force, deteriorating efficiency of chemical fertilizers and irrigation under severe flooding and drought. These environmental, technological, and institutional factors meditated agricultural growth and intensification, although they were reduced somewhat through institutional support for technological change from government and non-government organizations.

Box 5.4. Drivers of urbanization in the Pearl River Delta, China (Geist et al. *2006; Seto* et al. *2004)*

The Pearl River Delta is one of the most economically vibrant regions in China. For over two decades, the region has witnessed land use changes dominated by economic growth and urbanization at an unprecedented scale. Much of the land use change has been the result of conversion of agricultural land, wilderness, and wetlands to urban areas, with an estimated three-quarters sourced from land previously used for agricultural production. Government recognition of the threat of declining agricultural land in the province led to initiatives to reclaim Delta areas for agricultural purposes; however, the gains achieved still do not fully offset the losses experienced.

The drivers behind the land use changes in the Pearl River Delta consist of numerous compelling forces operating at multiple scales. They include indirect forces, such as those associated with globalization, economic changes, technological development, institutional modifications, and demographic shifts, as well as direct forces such as property rights. Policies supporting economic growth, such as the establishment of special economic zones and the Pearl River Delta Economic Open Region in the 1980s, encouraged foreign investment, transforming the area into an export-oriented region. The economic return from land used for industrial purposes outstripped that gained from agricultural uses. Renting or leasing agricultural land to non-agricultural users generated higher incomes than farming, providing little incentive to keep land under cultivation. In addition, the household responsibility system, which divided land based on family size, promotes a fragmented landscape, which, in turn, discourages economies of scale and the cultivation of large-scale cash crops. Foreign investment brought large monetary flows, access to technological innovations, and managerial expertise. Employment opportunities rose as a result, as did incomes, living standards consumption, and population migration to the region, combing to provide further incentives for urban-orientated land conversions.

Key ecosystem implications

The implications of land use/land use change can be just as complex as those that drive it. Like drivers, implications of land use are scale dependent, with some affecting the local environment (e.g. local water quality), while others extend far beyond the immediate site of impact (e.g. climate change). Often, various impacts of land use change may overlap and strengthen each other, with some having a mitigating effect or even cancelling each other (Chhabra *et al.* 2006). The most profound ecosystem impacts generally occur during the transition phase between different land uses (Chhabra *et al.* 2006), a condition that many countries in the Asia-Pacific region are presently experiencing as they make the transition from an agrarian system into industrialization.

One of the key implications that land use/land use change may have on ecosystems is on their ability to provide services for human consumption. Land cover modifications resulting from agricultural expansion and intensification can result in detrimental consequences for ecosystem conditions at the local scale. They can trigger factors that may limit production, including a reduction of biological productivity, increased water scarcity, pollution, declining effectiveness of fertilizers and pesticides, loss of soil quality, soil erosion, and contribute to climate change (Chhabra *et al.* 2006). Ecosystem impacts at a regional scale can also emerge, such as the effect that air pollution has on crop production. Research in China found that haze from regional air pollution reduced the yield of about 70% of the crops grown, with yield losses of between 5 and 30% (Chameides *et al.* 1999). A similar study in Pakistan demonstrated that atmospheric pollutants affected both the yield (causing a 43% yield reduction) and the nutritional quality (a reduction in starch content) of the country's key cereal crop, wheat (Wahid 2006).

History has demonstrated how land use driven changes to the environment may potentially have an impact, positively or negatively, on animal and human health and well-being (Chhabra *et al.* 2006; Millennium Ecosystem Assessment 2005). In the Asia-Pacific region, it is seen commonly in the distribution of disease-transmitting insects, and of irritants and pathogens in water and air. Vector-borne infectious diseases are particularly sensitive to land use/land cover changes because such developments influence the availability of suitable habitat, and therefore their distribution and abundance, as well as their interactions with hosts (people and/or animals) (Vanwambeke *et al.* 2007). For example, in Thailand a reduction of malaria incidence has been reported in areas where deforestation has resulted in the replacement of natural breeding habitat of the malaria vectors by field crops, such as cassava (Chhabra *et al.* 2006). Conversely, where such field crops were replaced with a tree crop, such as rubber plantations, malaria incidences increased, with the vector adapting to the new habitat (Molyneux 1998).

Like the global trend, land use pressures in many countries of the Asia-Pacific region are affecting the agro-diversity and biodiversity of the region. The rapid urban expansion in Greater Dhaka, Bangladesh is one example where the substantial development of water bodies, vegetated areas, and low-lying areas has resulted in substantial loss of natural resources, habitat degradation, and threats to biodiversity (Dewan and Yamaguchi 2009). In Australia, threats to biodiversity are occurring because of the country's history of widespread land clearing for agricultural production, forestry, and urbanization. One study reported that nearly half of the bird species recorded in a particular habitat type during the early 20th century had declined or disappeared by the end of the century (Woinarski and Catterall 2004).

The Asia-Pacific region currently experiences a wide range of soil-related problems, including erosion, presence of free soluble salts leading to salinity and sodicity, and reduced soil fertility, with only 28% of the total land area considered not to be degraded to some degree (Chhabra *et al.* 2006). Many of these issues are the result of land uses such as overgrazing, deforestation, agricultural mismanagement, fuel wood consumption, and urbanization. These implications are evident in the desertification and degradation of the grasslands in China, which has been driven by over-population, overgrazing, cropland misuse, and excessive exploitation of natural resources (Akiyama and Kawamura 2007; Cui and Graf 2009). Soil erosion from these affected areas has resulted in increased sand deposition in the rivers, raising riverbeds, and increasing downstream flooding problems (Cui and Graf 2009). This issue is now becoming a widespread concern in Asia, especially in China and India. However, some progress in reversing desertification is being made, such as in Ningxia Hui Autonomous Region in Northwest China (Government of Ningxia Hui Autonomous Region 2010).

It is well recognized that land use/land use changes hold considerable potential to modify or disrupt hydrological cycles (DeFries and Eshleman 2004). This is especially so for land use practices associated with agricultural intensification, particularly where improper techniques are applied in highly variable and sensitive environments. A prime example is that witnessed in Central Asia, such as in the Hei and Tarim River basins of northern China and the Aral and Caspian Sea Basin regions (see Box 5.5) (Chhabra *et al.* 2006).

The potential future impact of climate change on land use and the ecosystems' ability to function is also a concern facing the Asia-Pacific region. A study on recent warming trends on the Tibetan plateau provides an example of the possible implications of climate shifts on the local ecosystems. Significant land use change on the Tibetan plateau during the last half century has resulted in permafrost and grassland degradation, urbanization, deforestation, and desertification (Cui and Graf 2009). These changes have not only had an impact on the local climate and environment, but have also had hydrological implications for rivers originating from the plateau (Cui and Graf 2009). This may provide an insight into the potential future consequences of a loss of the Himalayan glaciers, which flow into the rivers watering the Indian, West China, and Central Asian grain bowls on which billions of people rely.

Box 5.5: Land- and water-use transition and its impact on lowland sites in Central Asia

The dry, hot river and lake basin ecosystems of Central Asia, such as the Hei and Tarim River basins of northern China and the Aral and Caspian Sea Basins, had long supported traditional land use based on small-scale irrigation. During the second half of the 20th century the land and water use transitioned from this traditional agrarian model towards industrialization. Advances in water technology, mainly through the establishment of large hydro-technical installations, combined with policies motivated by economics and demographic changes, led to the expansion and intensification of irrigated agriculture in these regions. Intensification also brought changes in crop composition, largely the adoption of less water efficient crops and monocultural practices, as well as an influx of other industries, infrastructure, and human settlement. The result was a disruption of the fragile hydrological ecosystems, with severe water degradation (salinization, lower water tables, and reduced discharge volumes), soil, and vegetation degradation, and desertification of the river and delta ecosystems. The resulting array of environmental, social, and economic impacts from this land- and water-use transition help to demonstrate those typically observed in the transformation from a predominantly agrarian regime to a largely industrialized approach to agriculture and society (Chhabra *et al.* 2006; Geist 2005; Geist and Lambin 2004).

Ecosystem management economics

The use of ecosystem management economics to guide land use activities is wide and varied throughout the Asia-Pacific region and its outcomes have been equally varied. What has worked in one country does not necessarily work in another, even if situations appear similar. Its application has tended to occur more in the Asian subregions than in the Pacific.

Ecosystem management economics uses policy instruments that increase the comparative advantage of one desired outcome over another, thus stimulating its establishment and management. Strategies include both direct incentives – that is, those that influence returns to investment directly – and indirect incentives, which have an indirect effect through setting or changing the overall conditions inside or outside a sector. Direct incentives include grants, tax concessions, subsidized loans, cost-sharing arrangements, and the supply of inputs such as seedlings and fertilizers. Indirect incentives include exchange rates, trade restrictions, interest rate policies, taxes, subsidies, land tenure, resource security, producer support services, and infrastructure. It is important to note that the use of any of these strategies needs to be carefully considered to ensure that they achieve the desired land use change, with reduced negative trade-offs and without stimulating perverse outcomes.

Policy instruments are typically used to support activities that are primarily in the public interest. However, many schemes bridge public and private goals (Enters *et al.* 2003). Examples include the 'Grain for Green' project in China (see Box 5.1), the Landcare deductions for capital expenditures for land degradation prevention in Australia, and the benefit-sharing arrangements under Joint Forest Management (JFM) in India (see Box 5.6) (Enters *et al.* 2003). Although many schemes tackle environmental concerns, others focus on generating employment, controlling internal migration, and stimulating development in a particular industry, such as plantation forestry.

Payments for ecosystem services (PES) have received considerable attention as a way of obtaining desired ecosystem management outcomes, especially since the 2005 Millennium Ecosystem Assessment found that 60% of the Earth's ecosystem services are depleting faster than they can recover. These schemes are typically structured so that those responsible for the management of ecosystem services receive payments for doing so and/or those who benefit from the ecosystem services provide the revenue for such payments. This revenue may be linked to a fee on the use of the ecosystem service, which can also create incentives for improved resource efficiency. Countries from the region that have successfully implemented PES schemes include China, Indonesia, India, Cambodia, Viet Nam (see Box 5.7), Nepal, and Australia, just to name a few. One example from Australia, is the Liverpool Plains Land Management Tenders, where farmers in New South Wales receive payments for undertaking conservation-orientated land management, funded by central government revenue, and other partners (e.g. World Wide Fund for Nature (WWF) Australia), and distributed by a regional catchment management authority (LPLMC 2005). At the end of 2005, this programme had invested around A$1.8 million of public funds and A$5.6 million from local landholders, with approximately 16 700 ha having undergone land management changes (Hajkowicz *et al.* 2009; LPLMC 2005).

Box 5.6: Ecosystem management economics in India's forest sector.

India's Joint Forest Management (JFM) programme is an example of a non-monetary positive incentive that has been successful in encouraging conservation and management of biodiversity. The programme, started in 1990, is based on a co-management relationship between the local people, who are dependent on forest resources, and the forestry department (Balooni and Singh 2007). It uses non-monetary incentives such as policy level changes, local empowerment, and awareness programmes in the promotion of sustainable forest management and, in 2007, included some 17 million ha of forest (Balooni and Singh 2007). In the majority of cases, local JFM members have full rights to all non-timber forest products except for minor forest produce such as cashew nuts, as well as around 50% of the net benefits from the final felling of trees.

Box 5.7: Payments for Forest Environment Services, Lam Dong province, Viet Nam

Viet Nam launched a national pilot policy on Payment for Forest Environment Services (PFES) in the Lam Dong province in 2008. The policy considers forest protection and development as well as the conservation of the forest ecosystems, biodiversity, and natural amenity, as services that users (individuals, businesses and organizations) must pay for to those providing them (forest owners/ households contracted for forest protection). Since its implementation, more than 300,000 ha of forest land have been contracted to around 14,000 local households. Major buyers of ecosystem services have been hydropower, tourism, and the bottled water industry. The scheme has raised the awareness of the local people and sectors who now understand that the PFES scheme is an investment in sustainable development of hydropower, ecotourism, and a clean water supply. It has also resulted in the improved livelihoods of households involved in forestry, reduced the incidences of illegal logging, and reduced the pressure to convert forest land (Rankine *et al.* 2009).

Carbon trading and its land use implications

Land use and land cover change are responsible for a significant portion of anthropogenic carbon emissions both in the Asia-Pacific region and worldwide. The development of carbon trading markets has become a key economic mechanism in the reduction of these resulting emissions. Globally, carbon markets have developed rapidly in recent years, resulting in a great diversity, with varying degrees of overlap, and markets that operate at a range of scales, from international to local (Reeson 2009). Their future, however, is hard to predict because of their evolving nature and the uncertainty of the present market place.

Carbon trading markets in the Asia-Pacific region have the potential to bring about major land use change, and to some degree have already done so. An increasing price for carbon is likely to change the cost of land management practices and commodities, depending on their emissions profiles (Garnaut 2009), and thus facilitate land use change. It is important, however, to carefully consider the use of these markets to affect and prevent land use change to ensure that desired outcomes are achieved without creating perverse incentives.

Globally, more than US$118,287 million (consisting of 4,269.5 $MtCO_2e$) was traded on carbon markets in 2008. This was composed of approximately US$117,582 million (4,146.1 $MtCO_2e$) on the compliance market and US$704.8 million (123.4 $MtCO_2e$) on the smaller, but growing, voluntary market (Hamilton *et al.* 2009). Both markets approximately doubled in value and in transaction volumes from 2007 to 2008 (Hamilton *et al.* 2009).

The Asia-Pacific region is a major participant in both the compliance and voluntary markets, hosting nearly 75% of the registered clean development mechanism (CDM) projects in 2009 and around 45% of the transactions on the 'over-the-counter' (OTC) voluntary market in 2008 (Hamilton *et al.* 2009). China and India are the largest sellers in these markets, with other participating countries including Cambodia, Malaysia, the Philippines, the Republic of Korea, Indonesia, and Thailand. Japan is the only significant investor in the region, and has major investments in China (Coulter *et al.* 2007; Hamilton *et al.* 2009).

The bulk of the compliance market projects in the Asia-Pacific region occur in the energy industry sector, with only a limited number of projects in the afforestation and reforestation sector. Land use, land use change and forestry (LULUCF) projects – largely afforestation and reforestation activities – were an early mainstay of the voluntary carbon market (Hamilton *et al.* 2009). However, in the past 5 years, projects have diversified and the forest-based carbon projects' share of transactions has declined. This decline is in part due to concerns of additionality, permanence, leakage, and accounting uncertainty: the same concerns that have prevented this type of project of playing a major role in the Kyoto Protocol markets (Hamilton *et al.* 2009; UNFCCC 2007). There is, however, a growing interest in 'avoidance deforestation' carbon credits, also known as 'reduced emissions from deforestation and degradation' (REDD) and in projects that promote agricultural best practices (Hamilton *et al.* 2009). REDD works via a series of financial incentives that are designed to make sustaining a forest more attractive and profitable than for timber production or conversion for agriculture or other uses (Ogonowski *et al.* 2009). Currently REDD projects are conducted in Indonesia, Viet Nam, and Australia.

Conclusion

The land use changes witnessed in the Asia-Pacific region reflect the transitioning of the economies of many countries from a dominantly agrarian socio-ecological regime into industrialization (Schandl *et al.* 2009). This has resulted in an adjustment in agricultural activities as pressures drive land use practices beyond subsistence farming, resulting in changes in production methods, a decreasing importance of the agricultural sector and corresponding rising importance of manufacturing and services sectors, as well as increased movement of people to urban centres. These changes have enabled improvements in land use efficiency across the Asia-Pacific region.

Despite the witnessed land use changes, many urban and rural people of the Asia-Pacific region still partly rely on agriculture as a means of subsistence, demonstrating that the transition from the agrarian socio-ecological regime to industrialization is still in its early phases (Schandl *et al.* 2009). It can therefore be hypothesized that the transition's effect on land use in the Asia-Pacific region, while already substantial, will continue to evolve into the future, with further change in land use patterns and in land use efficiency to come.

References

Akiyama T and Kawamura K (2007) Grassland degradation in China: methods of monitoring, management and restoration. *Grassland Science* **53**: 1–17.

Ali AMS (2007) Population pressure, agricultural intensification and changes in rural systems in Bangladesh. *Geoforum* **38**: 720–738.

ADB (Asian Development Bank) (2002) Kiribati - Monetization in an Atoll Society, managing economic and social change. Asian Development Bank: Manila, Philippines.

ADB (2008) Toward resource-efficient economies in Asia and the Pacific. Asian Development Bank: Manila, Philippines/Kanagawa, Japan.

Balooni K and Singh K (2007) Prospects and problems of afforestation of wastelands in India: a synthesis of macro- and micro-perspectives. *Geoforum* **38**: 1276–1289.

CIESIN (Center for International Earth Science Information Network) Columbia University, International Food Policy Research Institute (IFPRI), The World Bank, and Centro Internacional de Agricultura Tropical (CIAT) (2004) Global Rural-Urban Mapping Project (GRUMP), Alpha Version: Urban Extents. Socioeconomic Data and Applications Center (SEDAC), Columbia University: Palisades, New York.

Chameides WL, Yu H, Liu SC, Bergin M *et al.* (1999) Case study of the effects of atmospheric aerosols and regional haze on agriculture: an opportunity to enhance crop yields in China through emission controls? *Proceedings of the National Academy of Sciences U. S. A.* **96**: 13626–13633.

Chhabra A, Geist HJ, Houghton RA, Haberl H *et al.* (2006) Multiple impacts of land-use/cover change. In *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. (Eds EF Lambin and HJ Geist) pp. 71–116. Springer-Verlag: Berlin.

Commonwealth of Australia (2006) 'Pacific 2020 – challenges and opportunities for growth'. AusAID: Canberra.

Coulter L, Canadell P and Dhakal S (Eds) (2007) 'Carbon reductions and offsets'. A GCP report for the ESSP. The Global Carbon Project: Canberra.

Cui X and Graf HF (2009) Recent land cover changes on the Tibetan Plateau: a review. *Climatic Change* **94**: 47–61.

de Beurs KM and Henebry GM (2004) Land surface phenology, climatic variation, and institutional change: analyzing agricultural land cover change in Kazakhstan. *Remote Sensing of Environment* **89**: 497–509.

DeFries R and Eshleman NK (2004) Land-use change and hydrologic processes: a major focus for the future. *Hydrological Processes* **18**: 2183–2186.

Dewan AM and Yamaguchi Y (2009) Land use and land cover change in Greater Dhaka, Bangladesh: using remote sensing to promote sustainable urbanization. *Applied Geography* **29**: 390–401.

Ediger L and Chen HF (2006) Upland China in transition – the impacts of afforestation on landscape patterns and livelihoods. *Mountain Research and Development* **26**: 220–226.

Enters T, Durst PB and Brown C (2003) What does it take? The role of incentives in forest plantation development in the Asia-Pacific region. UNFF intersessional experts meeting on the role of planted forests in sustainable forest management. Ministry of Agriculture and Forestry: Wellington, New Zealand.

Erb KH, Gingrich S, Krausmann F and Haberl H (2008) Industrialization, fossil fuels, and the transformation of land use. *Journal of Industrial Ecology* **12**: 686–703.

FAO (2006) 'Global forest resources assessment 2005: progress towards sustainable forest management, FAO Forestry Pater 147'. Food and Agriculture Organization of the United Nations: Rome.

FAO (2009) FAOSTAT data. FAO: Rome.

Fragkias M and Seto KC (2008) Urban land-use change and policymaking in rapidly growing developing world cities: evidence from China. In *Land Use Change – Science, Policy and Management*. (Eds RJ Aspinall and MJ Hill) pp. 139–160. CRC Press: Boca Raton.

Garnaut R (2009) Transforming rural land use. In *The Garnaut Climate Change Review*. pp. 531–563. Cambridge University Press: Melbourne.

Geist HJ (2005) *The Causes and Progression of Desertification*. Ashgate Publishing: Aldershot, UK.

Geist HJ and Lambin EF (2004) Dynamic causal patterns of desertification. *Bioscience* **54**: 817–829.

Geist HJ, McConnell WJ, Lambin EF, Moran E, Alves D and Rudel TK (2006) Causes and trajectories of land-use/cover change. In *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. (Eds EF Lambin and HJ Geist) pp. 41–70. Springer-Verlag: Berlin.

Government of Ningxia Hui Autonomous Region (2010) Governmental guiding, projects motivating and public participation to push forward the progress combating desertification. Summary Report Combating Desertification in Ningxia. Government of Ningxia Hui Autonomous Region, Ningxia.

Grübler A (1994) Technology In *Changes in Land Use and Land Cover: A Global Perspective* (Eds WB Meyer and BL Turner), pp. 287–328. University of Cambridge Press, Cambridge, UK.

Hajkowicz S, Collins K and Cattaneo A (2009) Review of agri-environment indexes and stewardship payments. *Environmental Management* **43**: 221–236.

Hamilton K, Sjardin M, Shapiro A and Marcello T (2009) Fortifying the foundation: state of the voluntary carbon markets 2009. In *Ecosystem Marketplace & New Carbon Finance*. (Ed. EMNC Finance) p. 108. Ecosystem Marketplace: Washington DC.

Jepson P, Jarvie JK, MacKinnon K and Monk KA (2001) The end for Indonesia's lowland forests? *Science* **292**: 859–861.

Keys E and McConnell WJ (2005) Global change and the intensification of agriculture in the tropics. *Global Environmental Change* **15**: 320–337.

Krausmann F, Erb KH, Gingrich S, Lauk C and Haberl H (2008) Global patterns of socioeconomic biomass flows in the year 2000: a comprehensive assessment of supply, consumption and constraints. *Ecological Economics* **65**: 471–487.

Lambin E, Geist HJ and Ellis E (2007) Causes of land-use and land-cover change. In *Encyclopedia of Earth*. (Ed. CJ Cleveland). Environmental Information Coalition, National Council for Science and the Environment: Washington DC.

Lambin EF, Geist HJ and Lepers E (2003) Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources* **28**: 205–241.

Lambin EF, Turner BL, Geist HJ, Agbola SB *et al.* (2001) The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change: Human Policy Dimensions* **11**: 261–269.

Lichtenberg E and Ding CG (2008) Assessing farmland protection policy in China. *Land Use Policy* **25**: 59–68.

LPLMC (2005) Land management tenders: a new way of landcare. Liverpool Plains Land Management Committee: Gunnedah, NSW.

Millennium Ecosystem Assessment (2005) ‘Ecosystems and human well-being: synthesis. World Resources Institute: Washington DC.

Molyneux DH (1998) Vectorborne parasitic diseases – an overview of recent changes. *International Journal for Parasitology* **28**: 927–934.

Ogonowski M, Guimaraes L, Ma H, Movius D and Schmidt J (2009) Utilizing payments for environmental services for reducing emissions from deforestation and forest degradation (REDD) in developing countries: challenges and policy options. Center for Clean Air Policy: Washington DC.

Ramankutty N, Graumlich L, Achard F, Alves D, *et al.* (2006) Global land-cover change: recent progress, remaining challenges. In *Land-Use and Land-Cover Change: Local Processes and Global Impacts*. (Eds EF Lambin and HJ Geist) pp. 9–39. Springer-Verlag: Berlin.

Rankine H, Watkins M and Kasemsawasdi W (2009) Innovative socio-economic policy for improving environmental performance: payments for ecosystem services. The greening of economic growth series. United Nations Economic and Social Commission for Asia and the Pacific (ESCAP): Bangkok.

Reeson A (2009) Carbon markets and their implications for natural resource management in Australia. Socio-Economics and the Environment in Discussion CSIRO Working Paper Series 2009-09 June 2009. CSIRO: Canberra.

Schandl H, Fischer-Kowalski M, Grunbuhel C and Krausmann F (2009) Socio-metabolic transitions in developing Asia. *Technological Forecasting & Social Change* **76**: 267–281.

Seto KC and Shepherd JM (2009) Global urban land-use trends and climate impacts. *Current Opinion in Environmental Sustainability* **1**: 89–95.

Seto KC, Woodcock CE and Kaufmann RK (2004) Changes in land cover and land use in the Pearl River Delta, China. In *Land Change Science – Observing, Monitoring and Understanding Trajectories of Change on the Earth’s Surface*. (Eds G Gutman, AC Janetos, CO Justice, EF Moran, JF Mustard, RR Rindfuss, D Skole and MA Cochrane) pp. 223–236. Kluwer Academic Publishers: Dordrecht.

UN Habitat (2008) ‘State of the World’s Cities 2008/2009: harmonious cities’. United Nations Human Settlements Programme: Nairobi, Kenya.

UN Population Division (2007) ‘Urban population, development and the environment 2007’. United Nations Department of Economic and Social Affairs Population Division: New York.

UNEP (2007) *Global Environment Outlook: GEO 4 Environment for Development*. United Nations Environment Programme: Malta.

UNFCCC (2007) *Uniting on Climate: A Guide to the Climate Change Convention and the Kyoto Protocol*. United Nations Framework Convention on Climate Change: Bonn, Germany.

Vanwambeke SO, Lambin EF, Eichhorn MP, Flasse SP *et al.* (2007) Impact of land-use change on dengue and malaria in northern Thailand. *EcoHealth* **4**: 37–51.

Wahid A (2006) Influence of atmospheric pollutants on agriculture in developing countries: a case study with three new wheat varieties in Pakistan. *Science of the Total Environment* **371**: 304–313.

Woinarski JCZ and Catterall CP (2004) Historical changes in the bird fauna at Coomooboolaroo, northeastern Australia, from the early years of pastoral settlement (1873) to 1999. *Biological Conservation* **116**: 379–401.

World Bank (2009) World Development Indicators 2009. World Bank: Washington DC.

Xiao J, Shen Y, Ge J, Tateishi R, Tang C, Liang Y and Huang Z (2006) Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. *Landscape and Urban Planning* **75**: 69–80.

Chapter 6: **Emissions and waste**

Heinz Schandl and Karin Hosking

Main findings

- Greenhouse gas (GHG) emissions have grown substantially since the 1990s with particular acceleration since 2000. Annual GHG emissions had reached 16 billion tonnes of CO_2 equivalent by 2005: a growth of 60% in just 15 years (World Bank 2009).

- The externalization of production by some countries is leading to decreasing efficiency and increasing emissions in Asia and the Pacific. There is an indication, though, that a considerable proportion of GHG emissions are related to the Asia-Pacific region producing goods for consumers in the rest of the world.

- The intensity of GHG emissions has been stagnant in the Asia-Pacific region since 1990, while the rest of the world has improved its emission intensity substantially. Also sulfur dioxide emissions, a major cause of acidification, have increased. Urban air quality in many cities in the region is causing significant environmental disruption and health problems.

- There has been considerable success in phasing out the new production and consumption of the first group of human-made ozone-depleting substances (ODS) , in all countries including those in the Asia-Pacific region, due to sound policy (Velders *et al*. 2007).

- Solid waste is an increasing problem, but many countries have started to develop an understanding of waste management, allowing for a reduction in overall resource use, the reuse of materials and increased recycling.

Despite the great importance of emissions and waste flows to environmental quality and human health, the availability of internationally comparable data linking emissions and waste to the activities causing them is less than satisfactory. Countries should continue to invest in establishing credible data. A comprehensive database on waste and emissions would greatly support policy planning and programmes that aim to reduce waste and emissions, and also assist in monitoring the success of emission reduction, waste, and recycling policies that many countries are implementing.

Introduction

The environmental impacts of production and consumption are usually associated with the output side of industrial metabolism and the analysis of the material cycle. It is important to acknowledge that waste and emissions occur at all stages of the resource extraction, production, distribution, consumption, and disposal continuum. Despite the importance of material outflows for understanding the potential environmental impact of economic systems, there is little empirical evidence to date from full material analyses of socio-economic systems. The most comprehensive approach to linking the input and output sides of material flows within a material balance approach has been the 2000 report *'The Weight of Nations'* by the World Resources Institute and its research partners (Matthews *et al.*

2000). Although Japan was a partner in the report, no similar studies exist for the Asia-Pacific region as a whole or for important large economies such as China, India, Australia, and Indonesia.

Accounting for output flows shows us that industrial economies are ultimately once-through systems. One critical variable for measuring environmental impact is the physical scale of an economy; that is, total material throughput. The larger the throughput, the greater the potential for environmental impacts along the material cycle from the source to the sink. Because a large number of materials are added to the biophysical stock of an economy (buildings, roads, production infrastructure, and household equipment) the second important variable is the total quantity of waste and emissions. Data on most Asia-Pacific region economies for this assessment are weak, which hampers the establishment of full material flow accounts on a country by country basis.

A second critical variable for resource efficiency is the retention time of materials in the economy, which can be increased by reuse and recycling of materials. It is also influenced by the quality of the material stock and its average lifetime. In Japan, one of the most material efficient countries in the world, half of the material inputs still become waste and emissions within a year (Matthews *et al.* 2000) while the other half is added to physical stocks. This is especially the case for biomass and fossil fuels, which are materials that have little potential for recycling but make up an important proportion of the material flows in Asia-Pacific countries. Eventually, physical stock will be demolished and become waste too.

The third important variable is the destination of the material once it leaves the economy via what has been termed the 'environmental gateway' (Matthews *et al.* 2000), indicating the first point of entry into the environment. Of the three gateways – air, land, and water – the atmosphere is by far the biggest recipient of outflows (see Box 6.1 for definitions of types of flows). Results for Japan for the year 1996 show that 80% of emissions go to air, 20% to landfill and less than 1% to water (still a significant amount) (Matthews *et al.* 2000); and because most countries are industrializing, very similar trends may be expected for other Asia-Pacific economies.

Many of today's key environmental problems can be linked back to the waste and emissions generated in production and consumption activities. Three major environmental problems related to material and energy flows and land use are climate change, ozone depletion, and acidification; other problems include the pollution of freshwater (by nitrogen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and bacteria such as *E. coli*), particles to outdoor air, and indoor pollution due to heating and cooking.

Anthropogenic climate change is caused by the emissions of greenhouse gases, such as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). CO_2 originates from the oxidization of organic materials, mainly the burning of fossil fuels. Energy consumption is by far the biggest and fastest increasing driver of CO_2 emissions, but a number of industrial processes (such as steel and cement production) further contribute to rising emission levels. N_2O emissions originate mainly from agriculture and are often caused by over-fertilization. The main source of CH_4 emissions is cattle production, but some methane is emitted from rice paddy fields.

Box 6.1. Definitions of indicators and output flows

Domestic processed output (DPO): the total weight of materials, extracted from the domestic environment or imported, that have been used in a domestic economy and were disposed to the environment. These flows occur at all stages of extraction, manufacture, and use of materials. Exports are excluded because their waste occurs in different economies. DPO consists of emissions to air from burning fossil fuels and other industrial processes, industrial and household waste deposited in landfills, material loads in wastewater, dissipative flows, and emissions from incineration. Recycled materials are subtracted from DPO.

Gateway flows: the share of DPO that exits the economy by each of three environmental gateways: namely air, land and water. Gateways are the first point of entry of a material flow into the environment. Differentiating outputs by gateways provides information about the potential environmental impact of flows.

Sector flows: refer to the share of DPO that can be attributed to the activities of different sectors.

Dissipative flows: the quantity of materials dispersed into the environment as a deliberate or unavoidable (with current technology) consequence of product use.

Net additions to stock (NAS): The quantity of construction materials used in buildings and other infrastructure, and materials incorporated in durable goods such as cars, industrial machinery, and household appliances. Net additions balance new materials added (gross additions) with discarded materials.

(Source: Matthews *et al.* 2000)

Stratospheric ozone depletion is caused by ozone-depleting substances (ODS), both human-made such as chlorofluorocarbons (CFCs) and naturally occurring such as N_2O. There has been considerable success in phasing out the new production and consumption of the first group of human-made ODS, in all countries including in the Asia-Pacific region, but new challenges have emerged related to substitutes and links to climate change (UNEP 2009).

Acidification is caused by the emission of sulfur dioxide (SO_2), ammonium (NH_4^+) and nitrogen oxides (NO_x). SO_2 emissions are caused by the burning of coal and crude oil containing sulfur, but may be mitigated by filter and fuel technologies. NH_4^+ is a by-product from livestock production and manure management in intensive agriculture. NO_x originate spontaneously from high-temperature burning and industrial processes.

There are significant human health risks related to emissions and waste that occur when humans are exposed to the health damaging effects of small amounts of toxic, mutagenic, carcinogenic, or otherwise biologically active substances. Six common pollutants are usually monitored by regulatory agencies to indicate air pollution. These pollutants include suspended particulate matter, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), tropospheric ozone (O_3), and lead (Pb).

Data access and quality

Emissions to air are adequately documented in national official statistics and international databases for major greenhouse gases, sulfur dioxide and particulate matter.

Emissions to water are small in quantity relative to all other emissions. The statistical data available for emissions to water are less than satisfactory, given the range of substances discharged that affect ecosystems and human health.

The **dissipative use of materials** such as manure, compost or sewage sludge used on agricultural land or of artificial fertilizer and pesticides is usually well documented. The amount of materials lost through dissipation is not subject to statistical accounting.

Solid waste: In most of the Asia-Pacific countries, reliable data on solid waste are not available. Due to the implementation of the 3R (reduce, reuse, recycle) initiative in many Asia-Pacific countries, there are efforts to improve data availability. Waste statistics in many OECD countries are also of low reliability, and underestimate the actual amounts. A material balance can help in building comprehensive and credible waste accounts.

Emissions to air

Anthropogenic climate change is mainly caused by three greenhouse gas (GHG) emissions, comprising carbon dioxide, methane, nitrous oxide and some negligible other emissions of hydro-fluorocarbons (HFC), per-fluorocarbons (PFC) and sulfur hexafluoride (SF6). Although carbon dioxide data exists for 1960 to 2005, all other emissions are reported for 1990, 1995, 2000 and 2005. Since 1990, global GHG emissions have grown from 32.3 billion tonnes to 40.2 billion tonnes in 2005, an average yearly growth of 1.5%. Annual growth of GHG emissions in the Asia-Pacific region was more pronounced at 3.2% and overall GHG emissions increased from 10 billion to 16 billion tonnes in only 15 years.

At a closer look, there are two distinct growth trajectories for the 1990s and for the years from 2000 to 2005. Although growth in the 1990s was more moderate and slowed considerably during the Asian economic crisis in 1997, growth resumed after that at an accelerated speed, which is represented in a doubling of the annual growth rate from 2.4% to 4.7% (World Bank 2009).

North-East Asia (including China and Japan) and South Asia (including India) had the largest contributions to GHG emissions in the Asia-Pacific region. The fastest growth between 1990 and 2005 was recorded for South-East Asia at 4.7% annual growth, followed by the Pacific (4.1% from a very low level) and North-East Asia at 3.5% (but with an annual growth of 6% since 2000). Figure 6.1 shows the growth in GHG emissions in the Asia-Pacific region between 1990 and 2005.

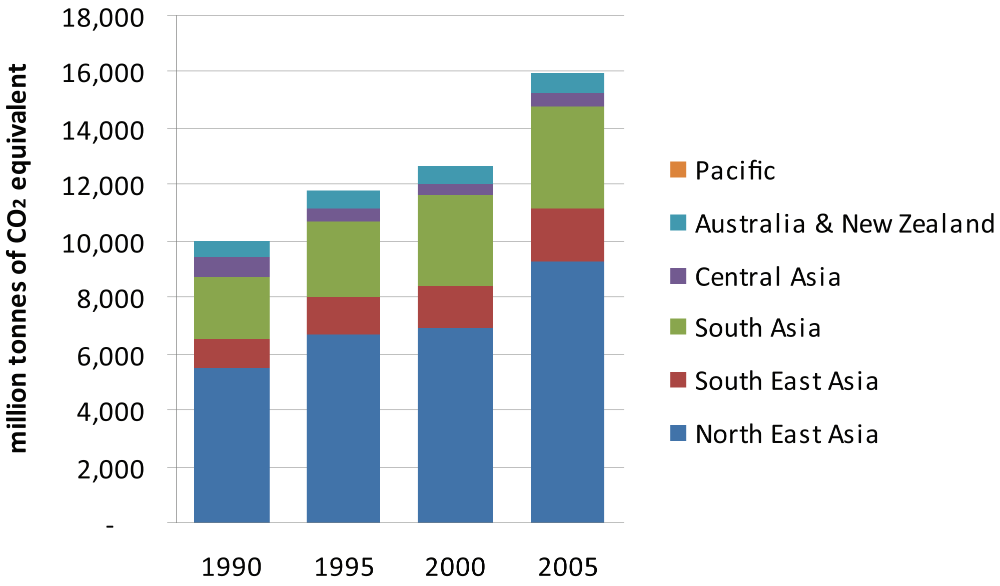


FIGURE 6.1.
GHG emissions in Asia and the Pacific region. Source: World Development Indicators (World Bank 2009)

As Figure 6.2 shows, two-thirds of all GHG emissions in the Asia-Pacific region in 2005 originated from three countries: namely China (45%), India (15%) and Japan (9%). CO_2 comprises the biggest proportion of GHG emissions, at 11.3 billion tonnes, followed by 2.9 billion tonnes of methane, 1.5 billion tonnes of nitrous oxide and 200 million tonnes of other greenhouse gases.

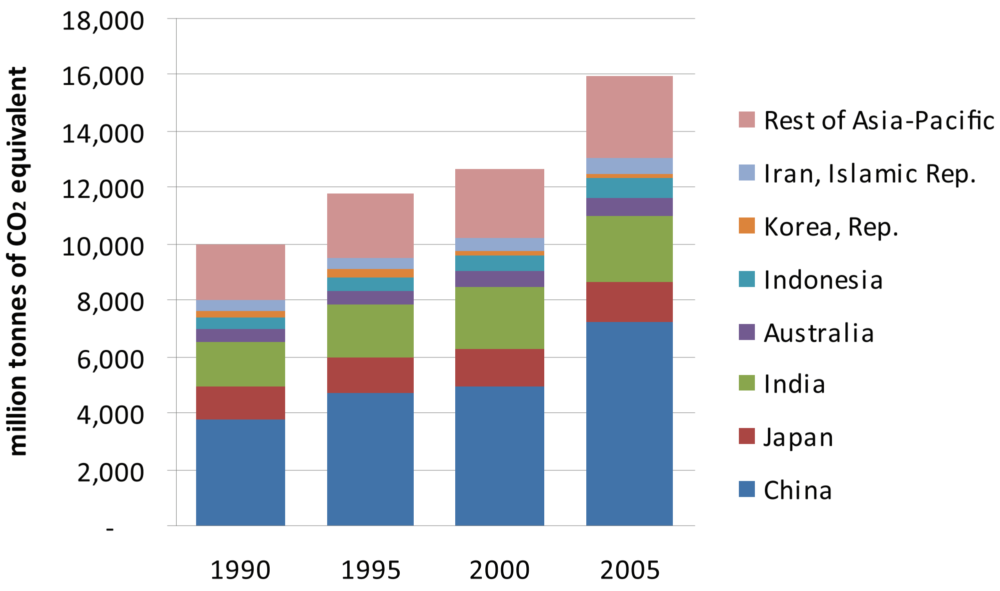


FIGURE 6.2.
GHG emitting countries in Asia and the Pacific. Source: World Development Indicators (World Bank 2009)

Per-capita GHG emissions of a country are a useful indicator, but only tell part of the story. Research by Hertwich and Peters (2009) looked at the carbon footprints of 73 countries, taking a consumption perspective and calculating the embedded GHG emissions of household and government consumption and investments. They used a multi-regional input–output approach to allocate all upstream emissions to different consumption categories and to establish the GHG footprint of each country for the year 2001. Comparing their results against direct emissions shows whether a country's GHG emissions result largely from servicing foreign consumers, or if emissions have been externalized to other producing countries.

Table 6.1 shows large differences in direct GHG emissions and embedded emissions for Australia, of about eight tonnes per capita of CO_2 equivalent, because of Australia's large export sector. However, China, the Republic of Korea, India and Indonesia also have larger direct emissions than embedded emissions, meaning that some of the emissions that occurred domestically should be attributed to foreign consumption. Japan shows the inverse situation, as a country that has externalized major resource and emission-intensive activities, therefore contributing to lower domestic GHG emissions than would have occurred if all production of what had been consumed in Japan had occurred in Japan. It is acknowledged, however, that Japanese industry is more efficient than that in most other countries, so if Japan had produced all of its consumption domestically the global GHG emissions would have been lower than is the actual case.

Table 6.1. Per-capita GHG emissions and GHG footprint for selected countries in 2000/2001

	Direct GHG emissions (t CO_2-e)	GHG footprint (t CO_2-e)
China	3.9	3.1
Japan	10.7	13.8
India	2.1	1.8
Australia	28.9	20.6
Indonesia	2.8	1.9
Republic of Korea	10.4	9.2

(Sources: Hertwich and Peters 2009; World Bank 2009)

Table 6.2 shows changes in GHG emission intensity since 1990. While GHG emission intensity improved globally, the trend in the Asia-Pacific over the last 15 years has been stagnant. Some subregions, such as South Asia and Central Asia, made huge progress but both regions remain the highest emitters per unit of GDP. North-East Asia improved its emissions intensity only slightly in the 1990s, and has since started increasing its GHG intensity.

Table 6.2. GHG emission intensity, kg per US$ (constant 2000 prices)

	1990	1995	2000	2005
North-East Asia	1.14	1.19	1.08	1.23
South-East Asia	2.71	2.56	2.55	2.55
South Asia	5.18	4.89	4.50	3.75
Central Asia	13.80	14.50	11.42	8.48
Australia and New Zealand	1.78	1.59	1.41	1.29
Pacific	0.77	0.60	0.64	0.92
Asia-Pacific	1.66	1.65	1.55	1.62
ROW	1.23	1.07	0.95	0.91
World	1.33	1.23	1.11	1.10

(Source: World Bank 2009)

Developing countries in Asia and the Pacific region are especially vulnerable to climate change. High population densities, low incomes, long (and inhabited) coastlines, and the region's reliance on agriculture and fishing for livelihoods mean that the people of the Asia-Pacific region, and particularly the rural poor, will be very susceptible to changes resulting from global warming. These include droughts, extreme weather events, crop and livestock losses, increased incidence of disease, and reduced productivity of land and water resources (ADB and IGES 2008).

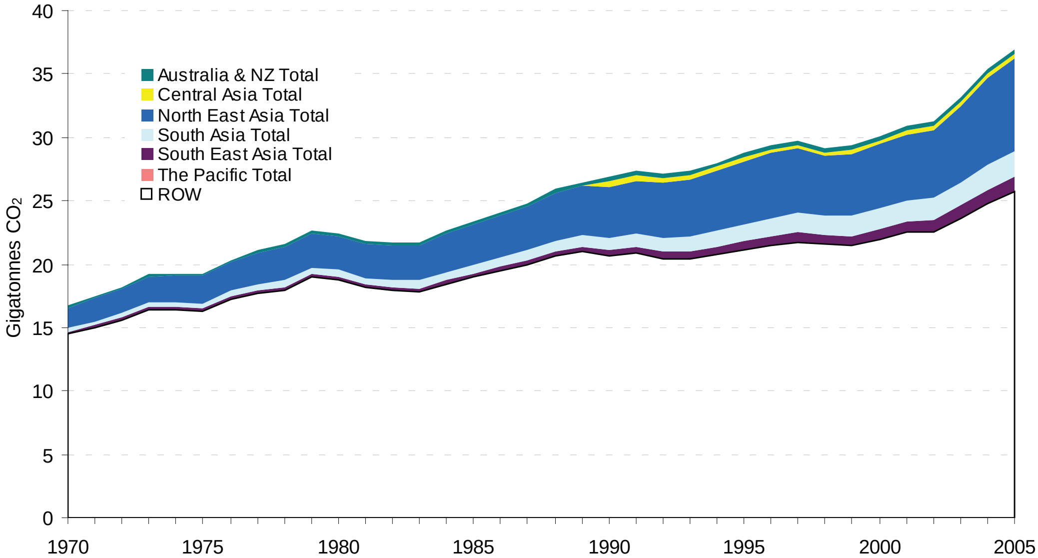


FIGURE 6.3.
Global CO_2 emissions in billions of tonnes, for the period 1970–2005. The Asia and the Pacific region's contribution is broken out into subregions. (Source: based on World Bank 2009 data)

Figure 6.3 shows total global emissions of CO_2, with the contribution from the rest of the world (ROW) grouped into one category, and the Asia-Pacific region's contributions grouped by subregion. The base data for Figure 6.3 is from the World Bank's WDI series, and includes total CO_2 from all sources, not just energy-related activities. The strong growth in CO_2 emissions for most of the Asia-Pacific region's subregions relative to ROW is striking. Whereas emissions from ROW over the period grew by less than 80%, those for the Asia-Pacific region as a whole grew by over 400%, accounting for nearly 45% of all growth in emissions and increasing the Asia-Pacific region's share of global CO_2 emissions from 13.5% to 30.5%.

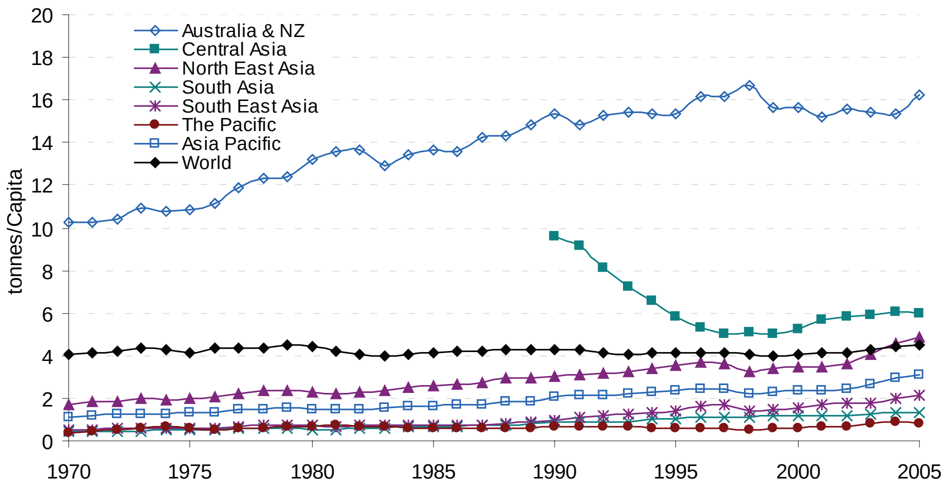


FIGURE 6.4.
Carbon dioxide emissions per capita for Asia and the Pacific and its constituent subregions, compared with the world average. (Source: based on World Bank 2009 data)

Figure 6.4 enables comparisons to be made between per capita emissions for the Asia-Pacific region, its constituent subregions, and the world[1] average. CO_2 emissions for the Asia-Pacific region remain lower than the world average, but whereas the world's average has been nearly static for over three decades, the Asia-Pacific region's emissions have been growing at around 2.9% per annum. Three of the subregions had per capita CO_2 emissions higher than the world average by 2005, including the largest and most important, North-East Asia. Furthermore, there was a marked acceleration in emissions for North-East Asia from 2002 onwards. The growth in emissions in this subregion in large part accounts for the acceleration upward of the trend for the region as a whole, and indeed for the whole world. The trends for the other two subregions with above average emissions intensities were somewhat more encouraging, decelerating in Australia and New Zealand and declining in Central Asia since the early 1990s, but Figure 6.4 clearly shows that these subregions are unlikely to significantly affect overall Asia-Pacific region emissions.

Over the full period, both South-East Asia and South Asia had growth rates for CO_2 above the regional average, at 4.1% and 3.3% respectively. In both cases, there was a clear break in the trends from the mid 1990s, with most of the growth occurring before that time, so these rates may not be a good guide to current emissions trajectories (see Figure 6.4).

Figure 6.5 shows CO_2 intensities (CO_2I) per unit of economic output, for the region, its individual subregions,[2] and the world. It indicates whether the economies of the region are acquiring the ability to deliver more economic output while having less impact on the environment. Unfortunately, as was the case for materials intensity and energy intensity, the CO_2I for the region as a whole deteriorated somewhat over the period 1970–2005, with a CAGR in CO_2I of 0.65%.

This is contrary to the trend for the world as a whole, which had a compounding annual increase in efficiency of around 1.2%. Consistent improvements in world CO_2I ceased around the beginning of the new millennium, and have deteriorated slightly since that time. This coincides with an acceleration in CO_2I growth for the Asia-Pacific region, and shows how the greatly increased participation of the Asia-Pacific region in the world economy means that that any pronounced trend in the Asia-Pacific region now heavily influences the emissions trajectory of the world as a whole.

As well as contributing to global warming, the combustion of fossil fuels also degrades local environments. Many cities in Asia already have severe problems with their ambient air quality, and ultra-fine particles, such as those emitted by uncontrolled diesel vehicles, contribute to ill-health and early deaths (ADB and IGES 2008).

1 World re-includes the Asia-Pacific, unlike ROW. Note also that the intensities of CO_2 emissions per capita, and per $ GDP, were calculated using a different estimate for subregional and Asia-Pacific CO_2 emissions to that used for the total emissions in Figure 6.3. Although the best estimate for total emissions should add all available data for a subregion, a better estimate of subregional intensities should be achieved by excluding data for both emissions and population/GDP where data for either is missing for a country/year. This approach has been adopted for Figure 6.4.

2 Central Asia is not shown because its CO_2I was so high relative to other subregions (ranging up to 9.9 kgCO_2/$US) that its inclusion would have made it hard to discern the trends of other regions.

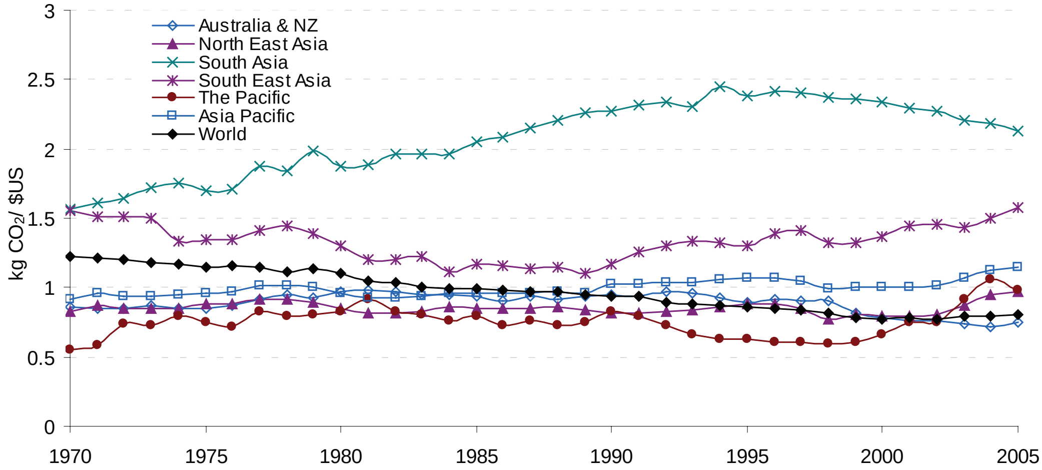


FIGURE 6.5.
Carbon dioxide emissions intensities per $ GDP (dollars used are constant year 2000 $US, exchange rate based). (Source: based on World Bank 2009 data)

Emissions of ozone depleting substances (ODSs) such as chlorofluorocarbons (CFCs) have caused the thinning of the stratospheric ozone layer and resulted in seasonal ozone depletion over the Antarctic: the ozone hole. As a consequence, increased ultraviolet radiation (UV-B) is reaching the Earth's surface, with important public health implications, increasing rates of skin cancer and eye cataracts and affecting immune systems. In response, the universally ratified Montreal Protocol on Substances That Deplete the Ozone Layer has successfully phased out the first group of ODS (CFCs, halons, and carbon tetrachloride) and is now tackling other substances such as hydrochlorofluorocarbons (HCFCs) (Velders *et al.* 2007, UNEP 2009). Asia and the Pacific's production (excluding Central Asia) of HCFCs was 83% of the global share and consumption was 61% in 2009 (UNEP Compliance Assistance Programme calculation based on figures from the Ozone Secretariat).

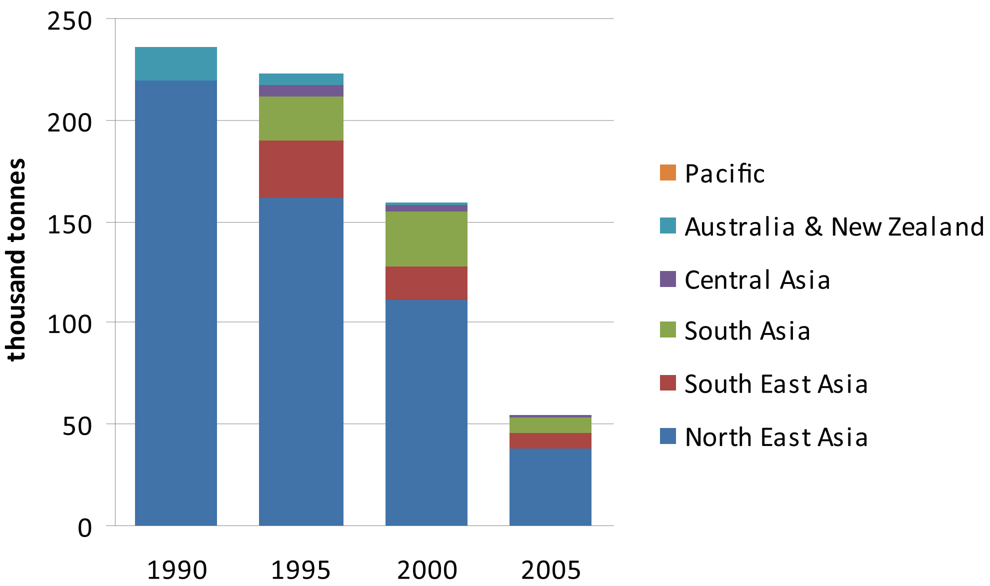


FIGURE 6.6.
Use of ozone-depleting substances in Asia and the Pacific, 1990, 1995, 2000 and 2005. Source: Statistical Yearbook for Asia and the Pacific (UNESCAP 2009). No data available for South-East Asia, South Asia, Central Asia and the Pacific for 1990.

Velders *et al.* (2007) used scenario analysis to explore historic and projected emissions of ODSs, finding that 'the ODS contribution to radiative forcing most likely would have been much larger if the ODS link to stratospheric ozone depletion had not been recognized in 1974 and followed by a series of regulations' and that the 'climate protection already achieved by the Montreal Protocol alone is far larger than the reduction target of the first commitment period of the Kyoto Protocol' (Velders *et al.* 2007, p. 4814).

Sulfur dioxide from the burning of fossil fuels (especially coal) is a main contributor to acidification. Many Asia-Pacific economies have entered the first phase of their energy transition from a biomass and wood fuel-based to a fossil fuel-based energy system, which usually involves a massive increase in the use of coal. Coal is a cheap energy source for producing electricity and the growth in coal fired thermal power plants in the Asia-Pacific region has been tremendous. The increase in coal use is reflected in fast rising SO_2 emissions, which have grown substantially in North-East Asia, South Asia, and South-East Asia. In contrast, Central Asia shows a massive decline in SO_2 emissions because of the economic slowdown and deindustrialization that followed the political independence of Central Asian economies.

Between 1990 and 2000, SO_2 emissions grew by annually 3.1% while they decreased in the rest of the world by 2.1%, mainly enabled by improvements in Europe and the United States. This resulted in a decline of global SO_2 emissions from 154 million tonnes in 1990 to 150 million tonnes in 2000 (a 0.3% annual decline).

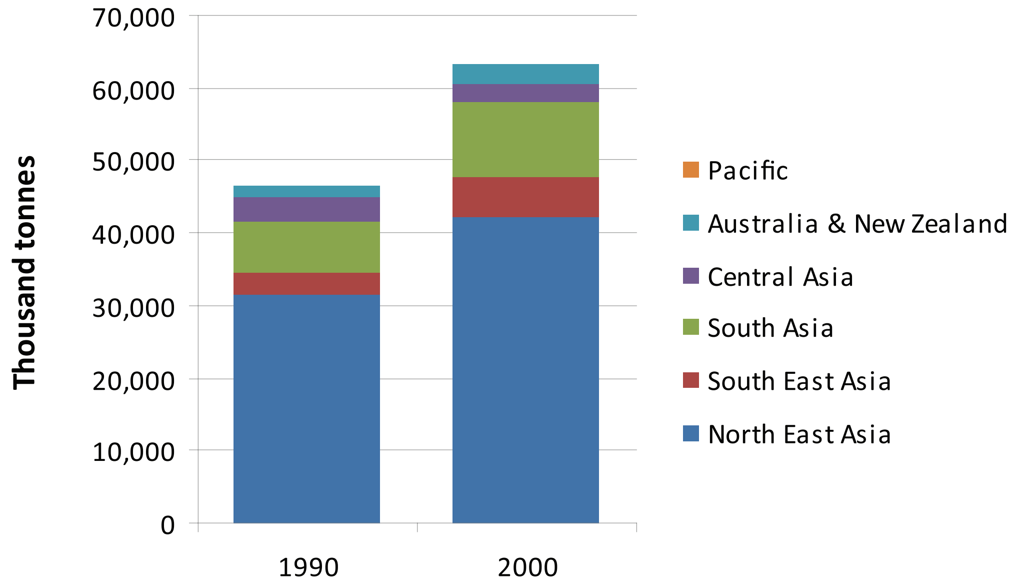


FIGURE 6.7.
Sulfur dioxide emissions for Asia and the Pacific, 1990 and 2000. (Source: UNESCAP 2009)

Other contributing substances including nitrogen oxides and ammonium are less well documented. Box 6.2 provides more detailed information on acid deposition in recent years in East Asia.

Box 6.2. The state of acid deposition in East Asia

East Asia is vast and characterized by considerable contrasts and differences. The regional geography and climatology have a substantial influence on the spatial and temporal distribution of acid deposition. Precipitation in the entire region is influenced by the Asian monsoon, which causes alternating dry and rainy seasons in the subtropical and temperate regions. Tropical cyclones and typhoons also deliver a large amount of precipitation to these regions, mainly in summer and autumn.

Atmospheric deposition consists of both wet and dry deposition. In wet deposition, sulfuric acid (H_2SO_4) and nitric acid (HNO_3) were identified as the major acidifying substances. Figure 6.8 shows the trend of annual pH of precipitation (2000–2007) at the monitoring sites in the Acid Deposition Monitoring Network in East Asia (EANET) countries. The lowest pH values observed were comparable with those in Europe and North America. Figure 6.9 shows the average of the annual values of wet deposition of sulfate and nitrate ions from 2000 to 2007 at the same sites. Some

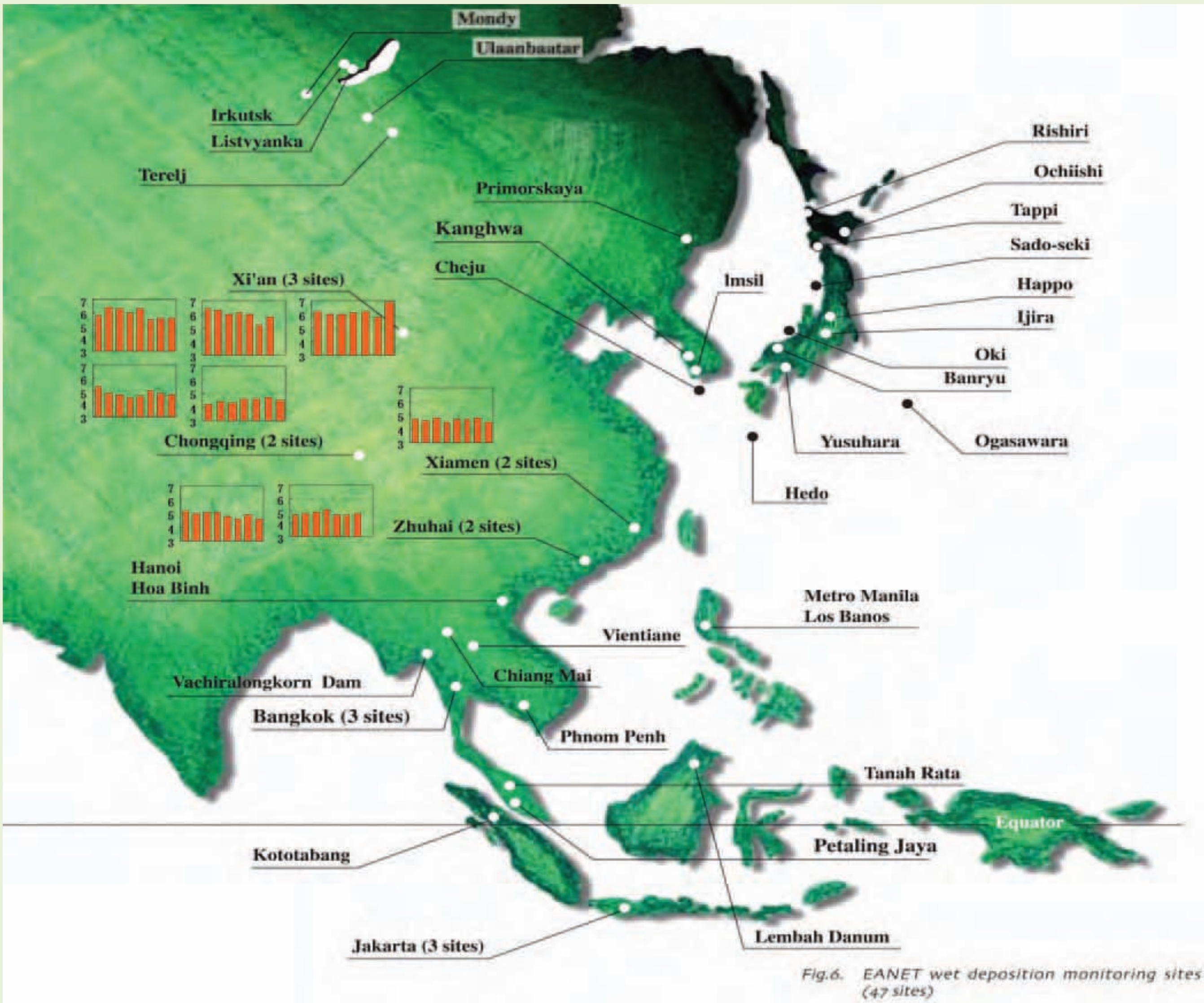


FIGURE 6.8.
Trend of annual pH of precipitation (2000–2007) (Source: EANET 2009)

sites in China receive high deposition of sulfate ions with relatively low precipitation amounts. High deposition of sulfate ions was also detected at several sites in Japan, Indonesia, Malaysia, and the Philippines, but this was mainly due to the large amounts of precipitation. Large amounts of nitrate ions are deposited at the urban sites of South-East Asia. Their annual deposition rates varied widely, reflecting the difference in precipitation in the region. The lowest levels of deposition were at remote sites in Mongolia, Russia, Thailand, and Japan, due to either low atmospheric concentrations or low precipitation levels.

Air concentrations of sulfur dioxide ranged widely, with higher concentrations found in or near the urban areas. The concentrations of gaseous nitric acid and nitrate particles were also higher at rural and urban areas than at remote sites. Figure 6.9 shows their distribution between 2000 and 2007.

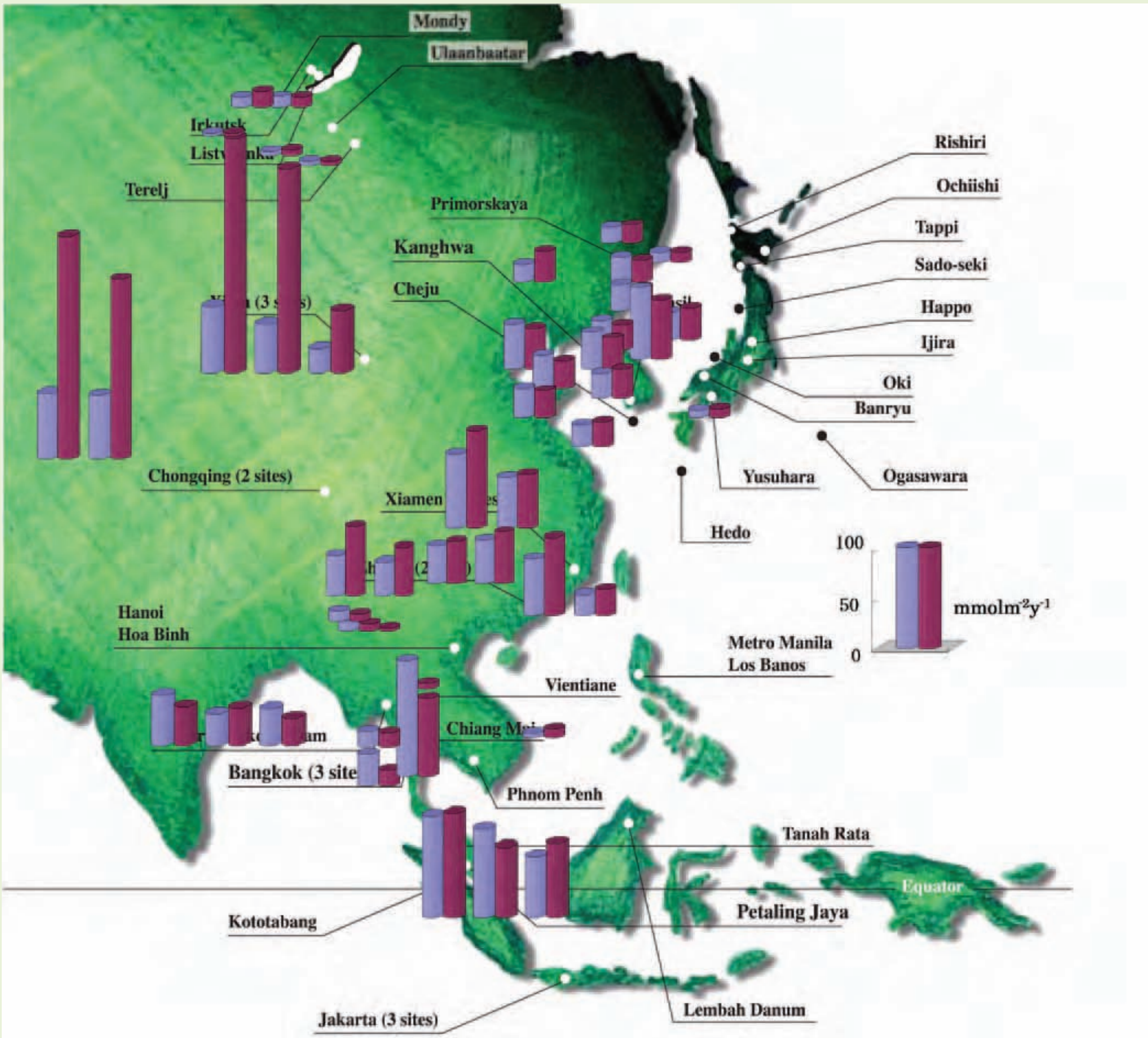


FIGURE 6.9. *Distribution of average annual wet deposition of non sea-salt sulfate (nss-SO_4) and nitrate (NO_3) for 2000–2007 (Source: EANET 2009)*

Air pollution in cities

Air quality in cities, both indoor and outdoor, has been a major issue for environmental quality and human health. In a situation where coal is becoming increasingly dominant in electricity generation (particularly in South Asia) and the capacity of steel mills and other industrial processes is growing, and in the absence of effective dust control, high levels of urban air pollution are common. Domestic heating adds to the problem, especially when fuels such as dung, wood, crop wastes, and coal are burned on open stoves. As already mentioned, sulfur and nitrogen dioxide emissions contribute to acid rain and other acid deposition, locally and globally. The emission of particulate matter is a major cause of urban health problems such as respiratory diseases. The World Bank Development Indicators database includes data from urban monitoring sites for cities for particulate matter concentration, sulfur dioxide and nitrogen dioxide. The data, however, only provide a general indication of the problem of urban air pollution, and comparisons are to be made with caution.

According to the World Bank (2009) cities such as Delhi and Kolkata in India, as well as Beijing, Chongqing, Jinan, Lanzhou, Shenyang, Tianjin and Zhengzhou in China, show very high levels of particulate matter concentrations – that is, above 90 $\mu g/m^3$ of particulate matter concentration. (In comparison, the European Union has set two objectives for PM_{10}. These are an annual mean of no more than 40 $\mu g/m^3$ and a daily mean of 50 $\mu g/m^3$. In the latter case, the objective is for no more than 35 exceedences of this limit per year.)

Chongqing in China showed very high sulfur dioxide emission in 2001 as did Taiyuan and Tehran, capital of Iran. Nitrogen dioxide emissions were highest in Beijing and Guangzhou in China.

Emissions to water

There is little centralized time series data on emissions to water for the region generally. The World Bank provides data on biochemical oxygen demand (BOD) in its World Development Indicators (World Bank 2009). Unfortunately, the time series is very incomplete for the region, with only three countries (the

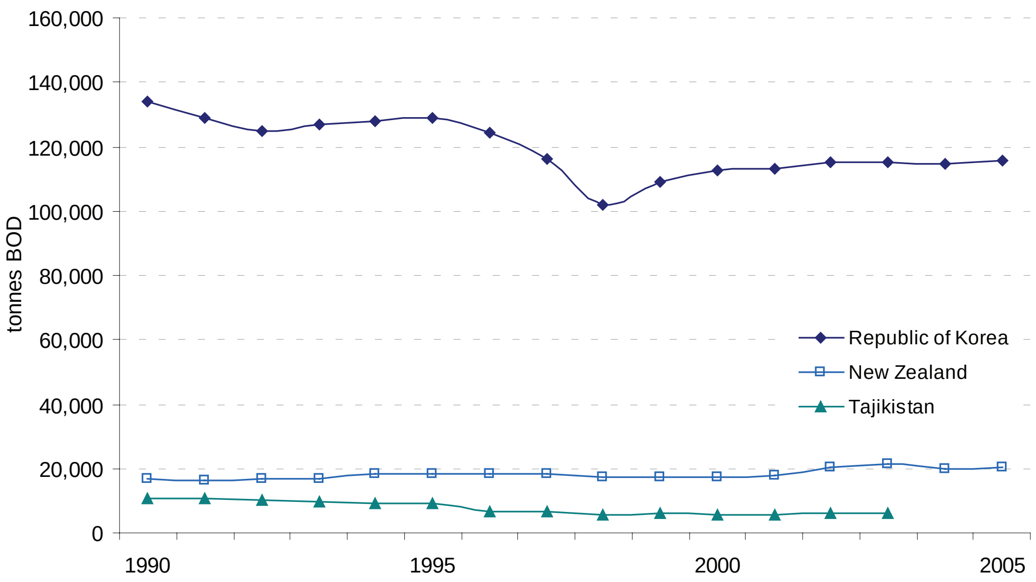


FIGURE 6.10. Biochemical oxygen demand (BOD) emissions to water for the Republic of Korea, New Zealand, and Tajikistan (Data source: World Bank 2009)

Republic of Korea, New Zealand, and Tajikistan) having data extending back to 1990. The trajectories for these countries are shown in Figure 6.10. In addition to this, it was possible to construct snapshots of BOD for a subgroup of 12 nations (Azerbaijan, Indonesia, Iran, Japan, Kazakhstan, Republic of Korea, Kyrgyzstan, New Zealand, Philippines, the Russian Federation, Tajikistan, and Viet Nam). Growth in BOD in those three countries appears to have been quite moderate over recent years.

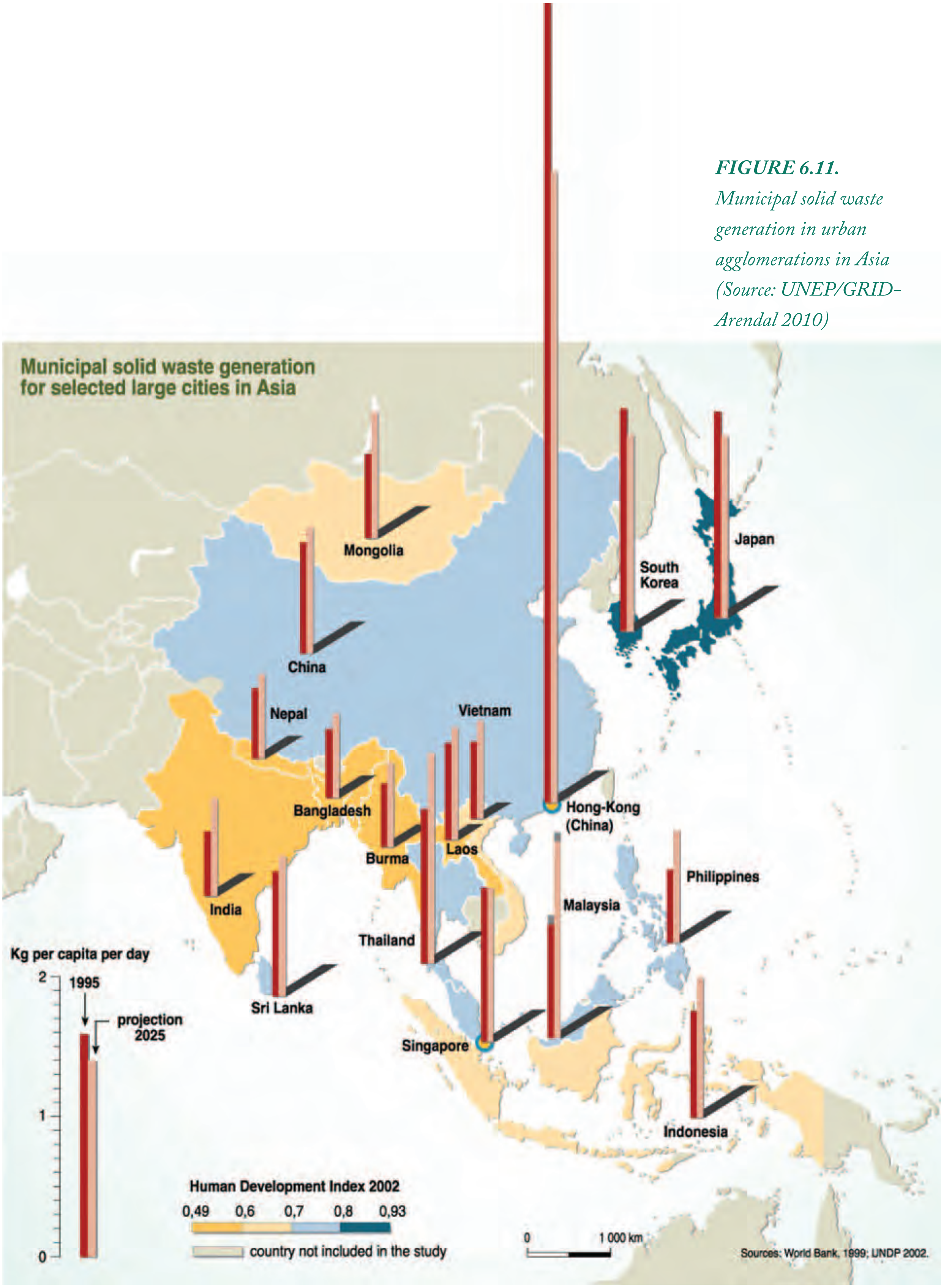
Solid waste

Amounts of waste have increased in the Asia-Pacific region due to growing industrial and manufacturing capacity and changes in urban lifestyles and associated material standards of living. The growth in manufacturing capacity has led to increases in industrial waste and hazardous waste, which are often not well regulated. Municipal waste has increased substantially, requiring increased capacity for urban waste management and treatment. In this context, the notion of material cycles and 3R – reduce, reuse, recycle – strategies becomes a new policy imperative to deal with solid waste that is either added to landfill or burned, depending on existing infrastructure. Figure 6.11 illustrates the rapidly increasing waste problem in a range of Asian cities.

Countries with a high population density and limited land resources usually have limited capacity for existing and new landfills and have to rely on waste incineration, which creates emissions and pollution. As Asian developing countries continue to industrialize, the region is producing ever greater volumes of toxic chemicals and hazardous waste. The composition of waste is also changing, with the proportion of compostable waste declining, and a substantial increase in packaging materials, plastics, and electronic waste going into to landfill (ADB and IGES 2008). Most Asian cities continue to use conventional solid waste management techniques (such as landfills and incineration) while failing to pursue options that would reduce overall waste loads. Even the most state-of-the-art landfill systems and incinerators are unsustainable in the long term. Waste disposal must be viewed as just one component of solid waste management, with more attention required to upstream options such as reducing quantities of waste produced, reusing 'waste' products and recycling (ADB and IGES 2008).

The 3Rs attend to increased waste streams in a holistic way, starting from the total throughput of materials that has to be reduced in order to avoid final waste flows. It also looks at sufficiency and the potential for longer lifetime of products and the reuse of products and components, as well as for the potential of recycling of strategic and scarce materials such as metals and some industrial materials. Recycling wastes is the third priority in the '3R hierarchy' after the reduction and reuse of waste (ADB and IGES 2008). It is cheaper and easier to prevent wastes from occurring in the first place, or to reuse waste products in their existing forms, than to transform them through reprocessing. Recycling often requires new inputs of materials, energy, and water (ADB and IGES 2008) so may be uneconomic unless the recovered resources are particularly valuable. There has been a trend toward transboundary movement of secondary materials in Asia in recent years, whereby secondhand goods are exported from developed countries to developing countries for recycling or reuse. This practice has both positive and negative aspects – potentially improving resource efficiency across a whole region (such as the Asia-Pacific), yet transferring pollution and waste to low-income countries, with possible environmental and health risks for the workers and residents in the recipient countries (ADB and IGES 2008).

FIGURE 6.11. *Municipal solid waste generation in urban agglomerations in Asia (Source: UNEP/GRID-Arendal 2010)*



References

ADB and IGES (2008) 'Toward resource-efficient economies in Asia and the Pacific'. Asian Development Bank and the Institute for Global Environmental Strategies: Manila, Philippines.

EANET (2009) 'Second report for policy makers: clean air for a sustainable future'. Acid Deposition Monitoring Network in East Asia [EANET]: Pathum Thani, Thailand. Available at http://www.eanet.cc/product/RPM/RPM2.pdf.

Hertwich EG and Peters GP (2009) Carbon footprint of nations: a global, trade-linked analysis. *Environmental Science & Technology* **43**(16): 6414–6420.

Matthews E, Layke C, Amann C, Bringezu S *et al.* (2000) 'Weight of nations: material outflows from industrial economies'. World Resources Institute: Washington DC.

UNEP (2009). Vital ozone graphics 2.0: climate link. Available at http://www.unep.fr/ozonaction/information/mmcfiles/6348-e-VOG2.pdf.

UNEP/GRID-Arendal (2010) 'Vital waste graphics.' Retrieved 18 May 2010, from http://www.grida.no/publications/vg/waste/.

UNESCAP (2009) 'Statistical yearbook for Asia and the Pacific 2008.' Retrieved 23 March 2010, from www.unescap.org/stat/data/syb2008/27-Water-use.asp.

Velders GJM, Andersen SO, Daniel JS, Fahey DW and McFarland M (2007) The importance of the Montreal Protocol in protecting climate. *Proceedings of the National Academy of Sciences* **104**(12): 4814–4819.

World Bank (2009) *World Development Indicators 2009*. World Bank: Washington DC.

Chapter 7:
Integrated assessment and scenarios

Graham Turner, Steve Keen and Franzi Poldy

Main findings

- Two novel models of the economy and physical activity of the Asia-Pacific nations were developed for the 'Resource Efficiency: Economics and Outlook (REEO) for Asia and the Pacific' report, and these have been linked to simulate future resource use and economic outlook over the years 2010–2050. A dynamic non-equilibrium monetary model produced economic growth and business cycles for the region as a whole, and was linked to a technology-based physical model of each economy through corresponding productivity and unemployment rates.

- This is the first ever economic model to work explicitly in terms of monetary flows. The driving principles in the development of the model were the importance of structural realism, and recognition that actual business cycles are largely driven by financial factors, which are not incorporated in most economic models.

- Three scenarios were established for the REEO to show how resource use and emissions could develop under different scenarios: business as usual, which demonstrates marginal improvement in resource efficiency; a resource efficiency scenario that implements large-scale efficiency in material and energy use across all sectors; and a system innovation scenario that assumes transition to new industrial infrastructures for commercial and residential buildings, mobility, energy, and water, as well as food production and lifestyle changes.

- The business as usual scenario embodied a 25% increase in efficiency in both material and energy use by 2050, and a 1% per annum increase in labour productivity. Historical trends in types of technology used were continued. Consumption and wider economic activity increases to achieve employment targets and stable trade balances.

- The REEO modelling indicates that business as usual leads to continued growth in energy use, carbon dioxide emissions, and materials use, which are most likely to ultimately challenge the capacity of the Earth's resources and ecosystems. For example, emissions of CO_2 approximately triple 2010 levels by 2050 for the Asia-Pacific region.

- High resource efficiency builds on business as usual by incorporating 50% increases in material and energy use efficiency by 2050.

- Making use of all technological potential within existing systems, as assumed in the resource efficiency scenario, will not significantly reduce impacts on resources and the environment. The potential efficiency gains may be far reaching but will not keep pace with a growing population and growing per-capita income. Emissions of CO_2 virtually stabilize for about two decades before resuming growth to about double 2010 levels by 2050. Domestic material consumption for the region climbs steadily to increase by about 150% above 2010 levels. Resource efficiency may contribute to constraining the global environmental impact of rapid development and modernization in the Asia-Pacific region, but efficiency used in isolation will not avoid the undesirable environmental consequences.

- Large structural change complements high resource efficiency in the system innovation scenario. In 2050: consumption intensity is reduced by 50%; electricity is generated from a portfolio of technologies (typically 30% biomass, 30% hydro, 20% solar/wind, remainder fossil and nuclear fuels); and rail dominates passenger and freight transport (50% and 80% shares, respectively). The share of employment increases in service activities that do not contribute to or support traditional economic activities using resources.

- The structural change assumed in the system innovation scenario may eventually lead to sustainability, but requires substantial changes in economic behavior and societal aspirations. Emissions of CO_2 are reduced by about 50% on 2010 levels by 2035, while material consumption is also reduced, though not to the same extent. It will require a new "industrial revolution" to establish the wellbeing of nations and people on a very different economic basis. Asia-Pacific economies need to invent and implement new industrial infrastructures that require less energy and materials, and allow for higher flexibility and lower risks in the face of global environmental change and resource scarcity. If the potential of these strategies for environmental savings is to be realised, it will be necessary to avoid rebound by moving to reduced labour force participation, that is, leisure-based lifestyles with lower consumption.

- Massive investment in infrastructure, skills, and institutional and governance capacity is required to achieve resource efficiency and transition to a new sustainable economic regime in keeping with the system innovation scenario, global resources, and the capacity of ecosystems. The strategies will need to enable policies and programmes to be integrated across public policy domains, and identify trade-offs as well as synergies.

Background

Previously, the central concern of mainstream economics has been to optimize (even maximize) the rate of economic growth because this has been seen as the main path to full employment and the eradication of poverty. Economic theory, of course, includes the concept of constrained optimization, and the trade-off between growth and the costs of growth makes the optimal growth rate less than the maximum growth rate. However, economists have tended to advise that because the gains from growth exceed the losses, the winners from growth could compensate the losers in a political rather than economic settlement.[1] An economic recommendation for policies that achieve maximal growth is thus the norm, with the issue of the distribution of gains and losses from growth translated to the political sphere.

1 This is a common argument in international trade theory – see for example http://internationalecon.com/Trade/Tch60/T60-13.php

This has worked well during an era of resource abundance and limited environmental impact. However, the emergence of concerns over climate change, peak oil, and water scarcity as global and regional issues, among others, can no longer be ignored. Major reports by leading economists on the economic impact of climate change, in particular, have recently received much attention (Garnaut 2008; Stern 2006). These issues demand much greater attention to biophysical processes and the stocks and flows of materials and energy that underpin all economic activity at one extreme, and to the financial flows that characterize most economies at the other.

Conventional economic analyses continue to rely primarily upon computable general equilibrium (CGE) modelling of both the economy and alternative environmental policies, such as mitigation of climate change. These models assume that smooth adjustments can be made to resource usage patterns via changes in individual and corporate behaviour due to changes in prices. This relies on the economy and the ecology being in a state of equilibrium, even if the equilibrium is modelled as shifting over time.

Assuming equilibrium is inherently problematic from both an economic and environmental perspective. Firstly, environmental policies are likely to be represented as a cost in these models for the simple reason that they move the economic system away from the assumed optimal equilibrium (Barker *et al.* 2002, pp. 142–143). Secondly, an equilibrium state is not in keeping with our empirical observations of both the ecology and the economy; the Global Financial Crisis is the most recent and outstanding example of economic processes occurring in disequilibrium rather than equilibrium. Ecological and economic systems that may overshoot equilibrium levels cannot be considered within the framework of CGE models. Vicious cycles – that is, feedbacks with time delays – cannot occur if all variables exist in a pervasive equilibrium.

In contrast, feedbacks are the mainstay of economic and biophysical system dynamics models. These models can incorporate, for example, 'a concern with financial assets as distinct from real-sector assets,[2] with the credit flows that finance both forms of wealth, with the debt growth accompanying growth in financial wealth, and with the accounting relation between the financial and real economy' (Bezemer 2009, p. 8).

This report, Resource Efficiency: Economics and Outlook for Asia and the Pacific, presents new approaches to simulating and analyzing resource and economic issues by employing a combination of dynamic biophysical and monetary economic modelling. A technology-based stocks and flows model covering all relevant biophysical interactions in the economy was used to uncover the physical feasibility of alternative resource futures. A multi-sectoral model of a dynamic monetary economy based on non-equilibrium assumptions is used to simulate economic growth (as opposed to it being an input assumption to CGE models) and to capture the inherently cyclical nature of this growth. The economic model captures the non-equilibrium dynamics of the monetary economy (loans, investment, etc.), and its interaction with the productive economy (labour, consumption, etc.). This enables scenarios with realistic economic cycles to underpin the resource use trajectories in the biophysical

2 'Real-sector assets' refers to the non-financial aspects of the economy, such as labour, infrastructure and capital that is used to produce economic outputs.

model. Such an integrated approach describes different aspects of a single overall economic reality (i.e. material and monetary).

The specific models used incorporate novel features, though such integrated modelling is occurring more frequently in contemporary Integrated Sustainability Assessment (ISA) (Lotze-Campen 2008). The approach used falls into Lotze-Campen's class of integrated modelling, and aligns with both 'integrated assessment models' and 'scenario building and planning tools'. Integration occurs through 'soft-coupling' of the output of one model being the input of the other, and vice-versa. The two models are also designed to create and analyse scenarios for policy-planning purposes, similar to other scenario building models, such as Threshold-21 and QUEST.

For all types of ISA models, there are common aspects that the design or use of the model should consider (Lotze-Campen 2008), such as: complexity versus simplicity; quantitative versus qualitative aspects; endogenous versus exogenous processes; and specialization versus integration.

In both the biophysical and economic modelling, the approach was to comprehensively represent the key processes in simple terms, greatly improving transparency. It does not necessarily mean that the output of the models will be simple. Importantly, the comprehensive coverage of the variety of physical and financial processes in the models leads to complex output that reflects the dynamic nature of real economies.

Both models are quantitative tools, providing rigor and further transparency. However, some qualitative aspects of the REEO modelling are necessarily introduced through the scenario process. This is important in order to deal with unavoidable uncertainties that are characteristic of long-term analysis.

The REEO analysis incorporates (or makes endogenous) important driving forces for understanding economic development and environmental implications. The economic model implicitly incorporates growth and business cycles, with implications for consumption and employment. The biophysical model couples with these factors to provide the resource use and waste/emissions flows. However, some aspects must be dealt with as external inputs to the models: in particular, technological progress and productivity. These exogenous factors are largely socially based and modelling of future technological developments is limited.

A balance between specialization and integration is achieved in the present REEO modelling. The economic model has been developed initially to simulate a multi-sector economy to incorporate the gross dynamics of the financial economy, and the non-equilibrium nature is very novel among ISA models. The biophysical model provides relatively rich detail on the dynamics of physical capital, as well as the various material and energy types, and their transformations from resources to commodities, goods, capital, and eventually wastes. The model involves simplification of minor input–output dependencies between industries and sectors, so that the key drivers of resource and environmental impacts can be more easily identified.

Overview of the monetary stocks and flows model

The monetary model is a dynamic simulation of the financial and physical flows that must occur in an economy, augmented by simple behavioral relationships. Consequently, this monetary circuit theory (MCT) model is a nonlinear, disequilibrium, medium-scale simulation, under which money is created endogenously (Keen 2010). This is the first ever economic model to work explicitly in terms of monetary flows. The driving principles in the development of the model were the importance of structural realism, and recognition that actual business cycles are largely driven by financial factors (which are not incorporated in most economic models).

Therefore, the MCT simulation is driven by the financial sector, which is treated as an aggregate private bank that maintains bank accounts for itself and the two main classes in society: firms (or capitalists) and households (or workers) (see Figure 7.1). The firm sector is disaggregated into four production sectors that are notionally labelled 'capital goods', 'consumer goods', 'agriculture' and 'energy' (the number of sectors can easily be increased for added realism). Households are treated as one aggregate, consisting solely of workers who receive a money wage for working in one of the four firm sectors (or who are unemployed).

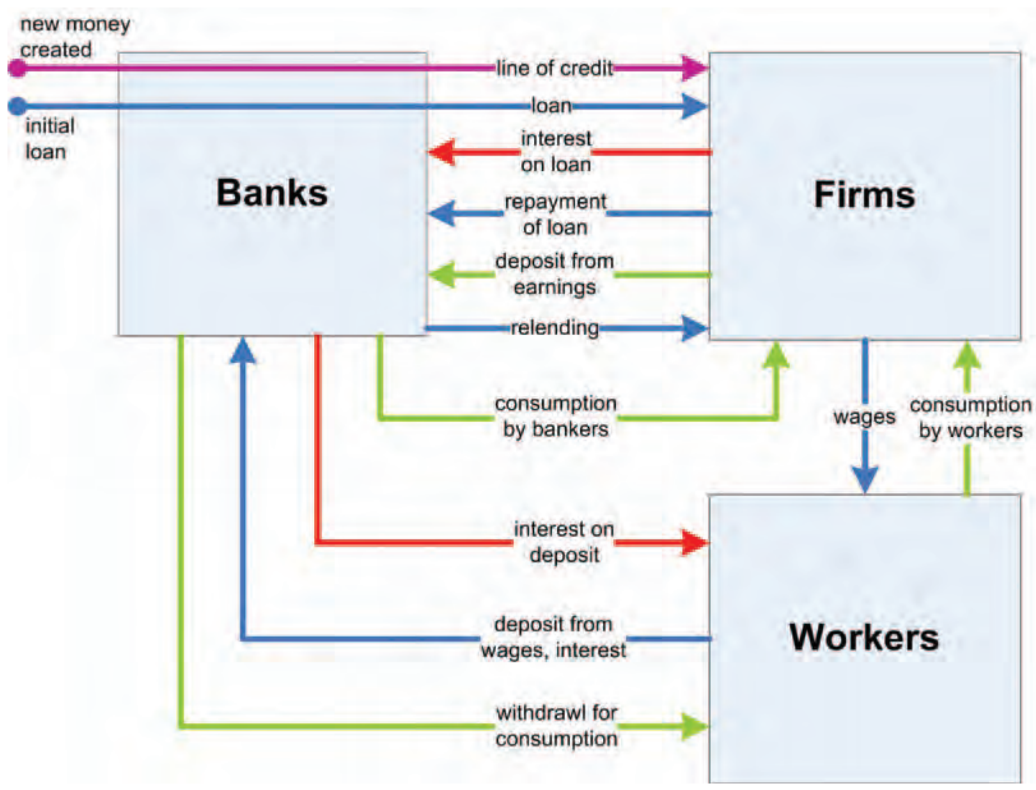


FIGURE 7.1.
Schematic diagram of the major elements and flows of the monetary circuit theory model.

The financial sector creates "credit money" by crediting each firm sector with money (and simultaneously the debt of each sector is increased by the same amount). This enables firms to invest, purchase intermediate inputs from the other sectors, and hire workers. The money supply can expand in response to firms' demands, and the level of debt grows commensurately with this increase in the money supply.

Output in each sector is proportional to its capital stock, while labour employed and intermediate goods purchases are proportional to output. All goods purchases and labour hires are paid for by monetary transfers between sectoral accounts, including purchases by one sector of its own output as an input to production.

Prices are set according to empirical research, which finds that prices are set largely as a mark-up on wage costs and with a lag of about a year (Blinder 1998; Lee 1998). The model uses a mark-up on the monetary costs of production – both money wages and the monetary cost of intermediate goods – discounted by the level of labour productivity.

The five key behavioral responses in the model are all modelled as exponential functions. The level of investment is determined by a non-linear response to the rate of profit, and money wages are set by a 'Phillips curve' response to the level of employment. Neither of the preceding is unusual in economic modelling, though their form and significance are subject to debate.

However, the unique monetary nature of the MCT model means that three additional monetary behavioral functions exist: the rate of loan repayment, the rate of circulation of existing money, and the rate of creation of new money are all modelled as non-linear functions of the rate of profit. Conventional finance theory – the 'capital assets pricing model' and its derivatives – treated financial behaviors as both stable and stabilizing; the Global Financial Crisis has pointed out that such financial behaviors are in fact very volatile and potentially destabilizing. The model captures this volatility.

Additionally, non-linear behavior occurs due to structural features: profit is net of the wage bill, which is the product of the number of workers times the money wage; the rate of profit reflects the ratio of net monetary income divided by the monetary value of the capital stock, which, in turn, is the product of the physical capital installed times its market price.

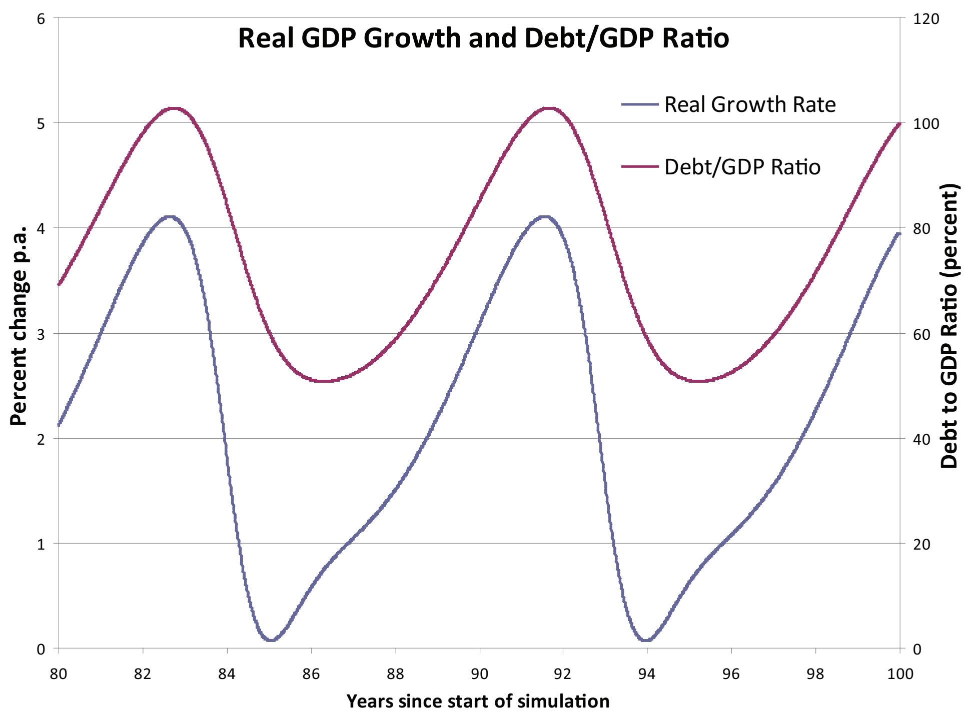


FIGURE 7.2.

Debt dynamics drive the (a) business cycle, and (b) cycles in sectoral profit rates. In both graphs, the growth rate in real GDP is shown, varying between about 0% and 4%.

Figure 7.2.(a)

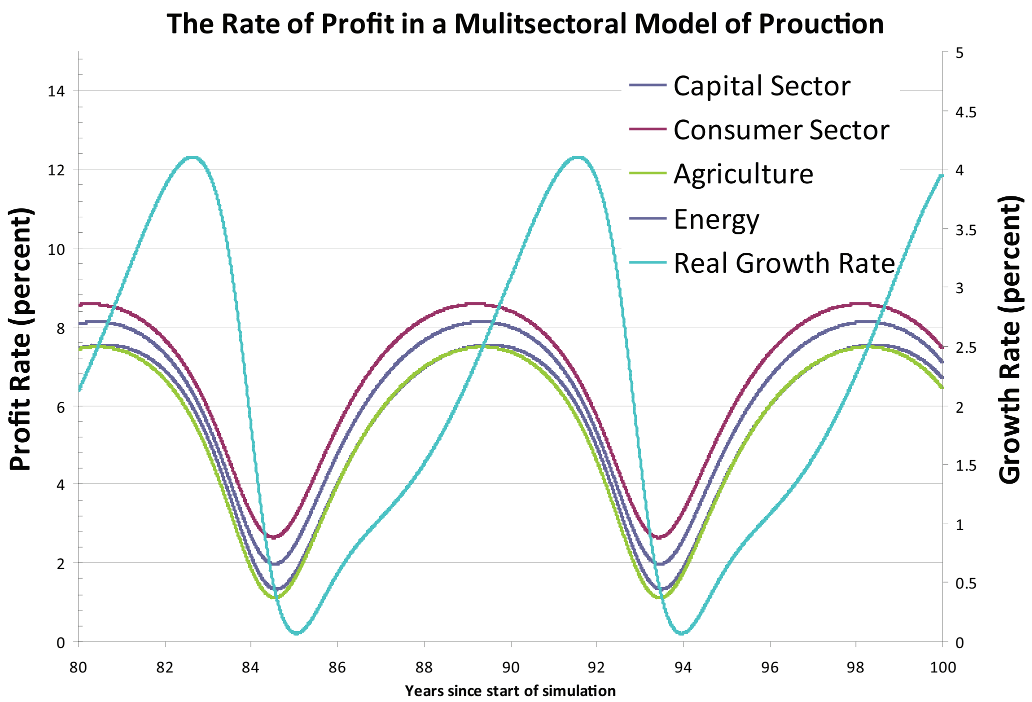


Figure 7.2.(b)

This model generates cyclical predictions for future output (Figure 7.2), unlike the vast majority of economic models that predict an equilibrium outcome in the future. Mathematically, such models of a multi-sectoral economy inherently embody unstable dynamics (Blatt 1983). Cycles in aggregate variables such as GDP and the debt to GDP ratio (Figure 7.2a) are matched by cycles in sectoral variables, such as the rates of profit in the model's four sectors (Figure 2b). The cycles in the model, while emanating from the inherent instability of balanced growth, are also dominated by financial factors – specifically the impact of rising debt during a boom and falling debt during a slump (Figure 7.2a).

These model outputs match economic behavior seen in the historical record, which shows that cycles are inherent to a capitalist economy. When 'laissez-faire' dominated economic policy, booms were brought to an end by 'financial panics', and 'the actual interval between panics ranged from a low of 7 years, to more than 11 years ...' (Blatt 1983). The cycles are not symmetrical, but 'go up on a gradual plane on one side and drop precipitately on the other' (Galbraith 1975, p. 104). These observations have led to the perspective that 'the trade cycle is not a mere fluctuation superimposed on a state of steady, balanced growth; rather, the trade cycle is part of the very process of growth in a competitive economy' (Blatt 1983).

Crucially, the shape of the simulated growth path matches the 'sawtooth' shape noted by Blatt and Galbraith: gradual upswings followed by sudden, sharp downswings. The 9-year period of the cycles also matches that seen in the 19th century data. In addition, variations in the parameters of the key financial factor – the willingness of the financial sector to create new credit money – altered the length of the cycle within the range noted by Blatt (1983). Importantly, particular settings in the model can also generate a financial crisis as an outcome, with a series of cycles leading to rising debt to income ratios that eventually become economically and socially unsustainable.

Building on this demonstration of a sophisticated non-equilibrium economic model requires further research to precisely fit the model parameters to historical records. This is a significant computational task due to the non-linear behaviour of the model[3], and is likely to require dedicated fitting software and hardware. Some constraint is also imposed by the lack of suitable empirical data. Previously, international statistical agencies have not collected financial data with the same attention to detail they apply to other economic data because existing economic models do not use such data.

Overview of the biophysical stocks and flows framework

The biophysical model is a technology- and process-based simulation of the physical activity in all sectors of the economies in the Asia-Pacific region. Within each economy, the Asia-Pacific Stocks and Flows Framework (APSFF) simulates the dynamics of major capital and resource pools, and the flows associated with these stocks (as illustrated in Figure 7.3) such as inputs of natural resources, manufacturing output, and changes in capital including buildings, infrastructure, and machinery. The economy and environment are simulated in physical terms – that is, throughout the framework, goods and commodities are counted or measured in tonnes, litres, joules or other appropriate physical units, rather than in terms of their monetary value.

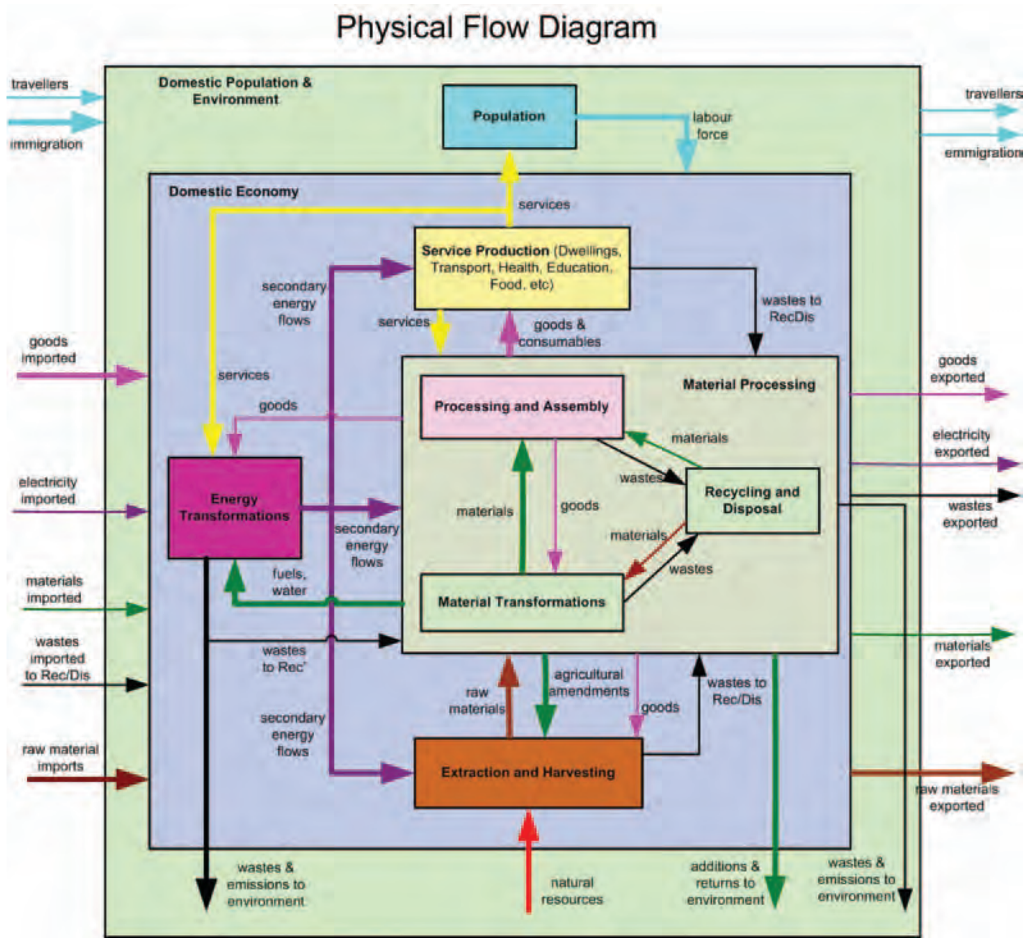


FIGURE 7.3.
Physical flows simulated in the Asia-Pacific Stocks and Flows Framework (APSFF) for each nation in the region.

3 For example, if each simulation of the model took only 1 second, it would take 317 years to find the best fit for a model with just 10 parameters, each of which can take only 10 values.

Geographically, the APSFF represents nations as discrete entities. Distinctions are also made between rural and urban areas, but these are not explicitly located. The model is run over an historical period of 1970–2009 and scenario simulations extend to 2050. The collection of databases, raw data, and subsequent calibration of the simulation model is made fully available in a complementary framework using the same software platform as the simulations and provides a visual interface to the data and calculations.

Structurally, the APSFF borrows many of its features from the detailed Australian Stocks and Flows Framework (Foran and Poldy 2004; Lennox *et al.* 2005; Poldy *et al.* 2000; Turner and Poldy 2001; Turner *et al.* 2011). Starting with the population's need for food, consumables, housing, and transport, the model determines the domestic requirements for commodities, buildings, vehicles, infrastructure, water, materials, and energy. Separately, a range of agricultural commodities, fish, wood production, and mineral resources (including fuels) are supplied by the primary industry sectors. This production is combined with imports to meet domestic requirements minus exports. Trade flows of goods and commodities implicitly link each Asia-Pacific economy with the others and the rest of the world. The economic activity draws on natural resources, which are represented explicitly with separate accounts of land, water, biomass, and mineral resources. In addition to producing goods and services, the economic activity also results in wastes and emissions to air, which are also represented explicitly in separate accounts. Estimates of emissions are calculated by applying IPCC data of emission intensities to the activities simulated in the APSFF.

Much of the physical capital in the APSFF, such as vehicles, buildings, and factories, is categorized according to the year the additional capital or machinery was introduced. Consequently, efficiencies can be associated with particular vintages, and the aging and decommissioning of depreciated capital is simulated.

The APSFF is calibrated for the period 1970–2009, in annual steps using data from a wide range of sources, such as UN trade statistics, the FAO food and agriculture database, IEA energy production and consumption data, and the USGS mineral resource database. In this approach, the aim of calibration is to reproduce historical data *exactly* at each time step, in order to preserve widely recognized and available data. This is quite different from the calibration of an econometric or regression model, where the aim is to fit mathematical functions to data. When complete sets of high-quality data are available, this is straightforward. In practice, real datasets are characterized by absences, gaps, inconsistencies, and multiple and ambiguous definitions, and disaggregation. For some aspects of the physical model, such as stocks of vehicles and buildings, limited historical data is available in UN or related databases and auxiliary data were obtained in some cases (e.g. for vehicles, production data was obtained from the International Organization of Motor Vehicle Manufacturers). In other cases, the capital stock and its vintage were derived from related factors such as demographic and production data. Calibration to date has focused on eight major economies[4], representing 74% of the Asia-Pacific population and 84% of its economic activity.

4 The eight countries used in the model are Australia, China, India, Indonesia, Japan, Kazakhstan, Republic of Korea and Thailand. They all have large economies, and were chosen to represent a range of different economic structures.

Linking the biophysical and economic models

Forming a link of between the biophysical and economic models described above presents a challenging research task. There are both conceptual and technical issues to be considered. Conceptually, there remain open questions about which elements of the biophysical and economic/financial systems influence or interact with the other, and in what ways. Technically, the integration of the two models must deal with differences in model detail and structure, such as discrete and continuous time (APSFF operates with an annual time-step, while the MCT uses continuous time), and with models implemented on different software platforms.

Consequently, this work adopted a 'soft coupling' between the APSFF and MCT, because this provides flexibility and transparency. That means key data from one model is passed to the other in a manual process that is not automated by additional software. This approach allows modelers and policy analysts to examine and refine the design of the coupling as insights are generated from observing the model interactions. A disadvantage of this approach (Lotze-Campen 2008) is that the number of scenario simulations that can be created in a given time is far more constrained, which limits the possibilities for undertaking sensitivity analysis, for example.

Given the empirical fitting difficulties of the economic model, a tight coupling of the economic and the biophysical model are not performed at this stage. Instead the coupling is limited to the one undeniable reality of economic data that is denied by conventional economic models: that the future, like the past, will be cyclical. Linkage from the MCT to the APSFF gives the latter cyclical predictions of future demand rather than smoothly growing demand from population growth, technical change, and changes in living standards. This linkage is communicated via unemployment levels generated first by the MCT monetary model, with both models using the same background assumptions of growth in labour productivity. The simulations in this work focus on overall growth in the economies of the Asia-Pacific nations and the associated resource and environmental implications. They have not otherwise explored the issue of poverty, but assumed that alleviating poverty is more likely with economic growth.

The creation of biophysical scenarios was initiated from simple projections of historical trends. Subsequently, two major feedback calculations were used in the APSFF to ensure that specified employment levels, and typical trade balances (relative to GDP or an equivalent measure), are maintained for each nation (illustrated in Figure 7.4). The employment level to be simulated was specified by the economic model. The APSFF feedback calculation then adjusts consumption rates and production activity until the specified employment level is reached.

Similarly, the scenarios generated here maintain the cumulative trade balance (exports minus imports integrated over time) at typical historical levels, relative to the physical activity in the economy. The latter is a physical measure related to GDP, and the ratio of the trade balance to GDP indicates the stability of a national economy. The second feedback calculation in the APSFF adjusts primary and secondary industry activity, and the import share of domestic consumption, until the target trade balance to GDP ratio is reached. (GDP estimates in monetary units were not modelled in the APSFF, though this is possible as demonstrated in the Australian framework.)

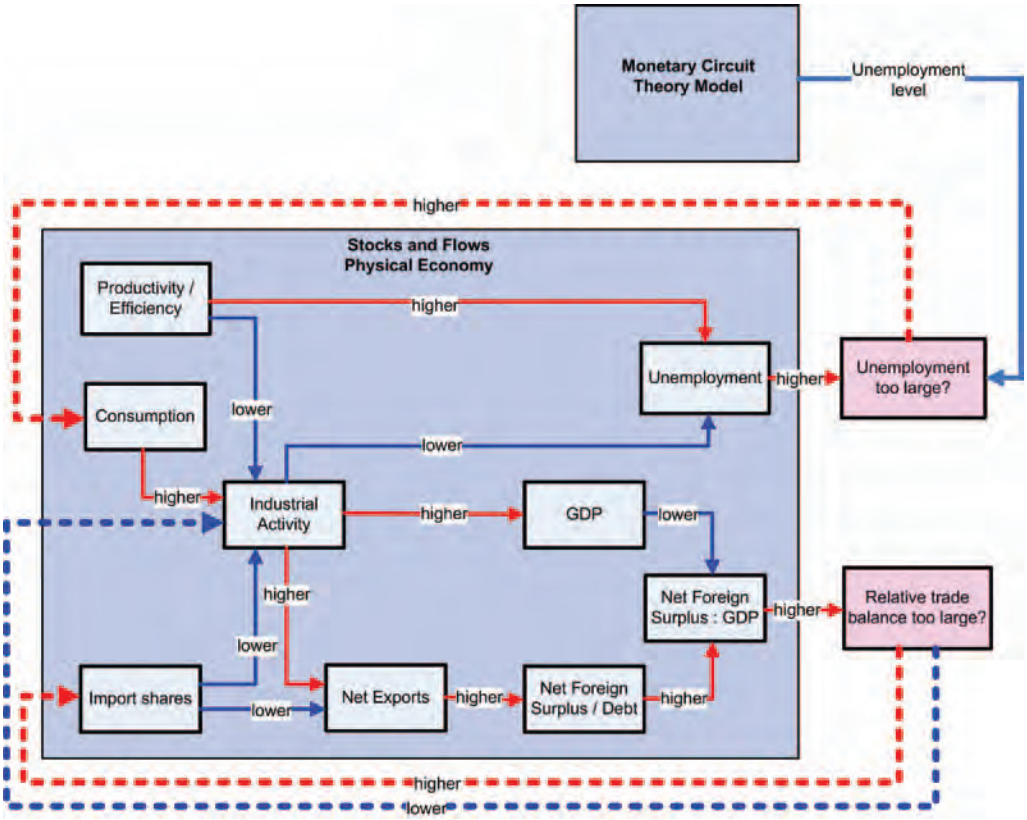


FIGURE 7.4.
Schematic of the linkage between the MCT and APSFF, and the two macro-economic feedbacks employed in the APSFF. The MCT provides the unemployment level, which acts as a target for one of the feedback calculations. The arrows indicate the direction of influence of economic aspects; for example, increasing productivity/efficiency leads to higher unemployment and lower industrial activity (everything else being equal).

Linkage from the APSFF to the MCT can be undertaken at a later stage to increase the realism of its modelling of production. This will replace the simple proportionality between inter-sectoral inputs and sectoral outputs with the possibility of input-constrained output levels in at least one sector. This will, in turn, alter the price and monetary outputs of the model. For example, a manifestation of a 'peak oil' constraint on output from the energy sector will cause price and monetary disturbances and constraints on the other sectors of the model.

Outline of major environmental issues

Before describing in the following section the assumptions used for the three scenarios simulated in this study, we first summarize several major environmental issues that the Asia-Pacific region faces, or may be faced with. These cover climate change, deforestation, water shortages, supply shortages of strategic materials, and food shortages. These issues provide context for the scenario settings.

Climate change

Climate change is one of the most difficult sustainability issues because it is intimately associated with, and aggravated by, almost every aspect of 'business as usual' – including those actions aimed at the alleviation of poverty and social injustice. Its main causes include greenhouse gas emissions from fossil energy use, land use change and practices in agriculture and forestry, and cement manufacture for construction. All are central to the economies and lifestyles that have been adopted in developed countries and to which the populations of developing countries aspire.

The possible impacts of climate change have been described at length (IPCC 2007), but it is difficult to take them into account in the traditional marginal trade-off approach to policy making that dominates business as usual. For example, the proposal to restrict temperature rises to 2°C (which may be too high) is not based on a comparison of the costs of doing so with the burden of climate change at 2°C, but with the need to reduce the (unknown but probably significant) risk of exceeding a threshold beyond which run-away processes are triggered.

Deforestation

Deforestation is a major contributor to climate change. Its principal drivers are timber demand for export, domestic fuel wood demand, and land clearing for agriculture and, more recently, biofuel plantations. Although it is, in principle, possible to manage forests as a renewable resource on a sustainable basis, the historical data shows that, in practice, in a number of countries, the timber asset is being liquidated rapidly, with potentially serious consequences for other forest assets and ecosystem services such as carbon storage, biodiversity, and support for a range of viable though less developed livelihoods. At too high a harvest rate, such forests are being 'mined'.

Beyond a certain point, deforestation, particularly in tropical areas, may trigger positive feedback processes that contribute to climate change (Bonan 2008). Carbon dioxide emissions and the loss of cooling via evapotranspiration contribute, through warming, to an increased frequency and severity of drought and fire. This leads to further loss of forest (Bowman *et al.* 2009), eventually converting forests from sinks to sources of carbon dioxide.

Water shortages

Shortages of water (as of everything else) result from growing demand meeting limited supply. Agriculture remains, by far, the largest user of water, its needs (amplified by losses and inefficient application) rising in line with the food needs of a growing population, as well as that population's increasing demand for meat. Urban residential, commercial, and industrial water demand is also growing in line both with the underlying activities and their increasing water intensities (see also Chapter 4).

Not only is demand not met because it exceeds supply, but excessive extraction actually reduces supply. A number of large rivers periodically no longer reach the sea, huge lakes (such as Lake Chad) are drying, underground aquifers are being depleted, and upstream developments threaten the livelihoods of downstream communities.

Supply shortages of strategic materials

Modern economies are dependent on fossil energy resources – liquid fuels from oil for transport, coal for electricity, and an increasing contribution to both from natural gas (see also Chapter 3). Business as usual projections indicate continued growth in demand, in some cases at an accelerating rate. Against this background, depletion concerns (the 'peak oil' phenomenon), long ridiculed by some commentators, are being taken much more seriously (Hirsch 2007), although a clear understanding of the situation is hampered by poor data quality exacerbated by vested interests. Unfortunately, much of the debate has focused on predictions of the date of peaking, while neglecting the more important issue of the economic implications of declining oil availability post-peak. Hirsch *et al.* (2005) have emphasized the long lead times for any response to peak-oil, and concluded that a successful response would have to be initiated 20 years before anticipated shortages.

While awareness of peak-oil has been growing, it has generally been assumed that coal reserves are so large as not to be of concern. Indeed, 'coal-to-liquids' is frequently proposed as a response to 'peak-oil'. However, recent studies (Kavalov and Peteves 2007; Zittel and Schindler 2007) question these assumptions, again emphasizing the poor quality of data. They observe large and unexplained downward revisions of reserves in a number of countries. Taking currently published figures at face value, Zittel *et al.* (2007) suggest a global peak of coal production could occur as early as 2025.

These considerations take no account of climate change. It has been argued that fossil fuel depletion supports the case for moving away from carbon-based fuels altogether. On the other hand, there will also be pressure to try alternatives such as coal-to-liquids, tar sands, and oil shales, which may appear more immediately viable but which have very much greater carbon dioxide emissions.

Food shortages

The spectre of food shortages has been kept at bay for most of the world's population for the last 40 years by the products of the 'green revolution' that provided a major increase in grain yields – though at the expense of increased requirements for water and fertilizer, and the concentration of agricultural production in the hands of a smaller number of larger producers able to finance the new technology. During that period, the population of the Asia-Pacific region almost doubled, putting additional pressure on regional food security.

However, the maintenance of past gains is in question because access to water (see above) and energy resources (for fertilizer and irrigation) becomes problematic. As further substantial yield increases seem unlikely for physiological reasons, maintaining and increasing food production is likely to require increased agricultural land area. As noted above (regarding deforestation) there is already competition for land between forests and agriculture – a competition in which, in current circumstances, agriculture has the advantage. On the other hand, agriculture is not likely to be able to withstand the expansion of cities and their peri-urban catchments over what is often prime agricultural land. Competition may also increase from alternative land use, such as production of bio-fuels and bio-based plastics.

Resource use scenario descriptions

Three scenarios have been constructed to illustrate future resource use possibilities and their consequences for Asia and the Pacific. As discussed, the *business as usual* or *reference* scenario represents the continuation of current policies and provides a measure of the scale of some of the problems that have been anticipated to flow from them. A qualitative outline of these problems is provided in the preceding section. The other two scenarios examine measures that might be adopted in response to the problems. The *high resource efficiency* scenario is a preferred option among government and industry players who recognize the reality and seriousness of the problems. It is a commonly proposed option because efficiency is already a widely accepted idea, and the implementation of policies that emphasize efficiency is not markedly at odds with current policies that emphasize technology as the engine of growth. The *system innovation* scenario is arguably less favoured because, while it seeks to build on the strengths of the resource efficiency scenario, it also recognizes that there may be a need for reorganization, behavioural change, and even review of societal goals and motivations.

Aspects of the three scenarios are described below. The same assumptions and objectives summarized below are imposed separately on each Asia-Pacific nation simulated. Consequently, details of actual changes for each nation may differ depending on the individual countries' parameter values, particularly where macro-economic targets relating to unemployment and trade balances are established by feedback processes.

Business as usual

The essential feature of the business as usual scenario is that major historical trends are continued. These trends vary from country to country but, broadly, they include:

- population growth, stabilization or decline as projected in the UN medium fertility scenario *World Population Prospects* (United Nations Population Division 2008)
- labour productivity grows within each economic sector, with rates taken from the dynamic economic modelling of 1% pa
- growth in urbanization, at different rates, in some countries steadily from a low base, in others saturating at levels over 90% typical of highly developed countries
- growth in passenger travel at very high rates in some developing countries, at lower rates and even declining rates in developed countries
- steady growth in the extraction of minerals, and in particular of construction materials, in support of urbanization and infrastructure development
- growing levels of wood production overall, but masking growth and decline in different countries – and associated, in some countries, with unsustainable rates of forest clearing
- growing crop production based on increasing crop yields from expanding or varying areas of crop land
- strong growth in the production of animal products associated with growing meat consumption in developing countries
- associated with all of the above, at least steady growth, and in some cases (particularly China) very rapid growth in the production or import of primary energy materials and the consumption of electricity and other final demand fuels.

Simulating these trends in APSFF involves appropriate settings of the relevant inputs. In general, these will be projections of the historical values of the inputs. None of the scenarios is a prediction. The resulting scenario outputs are not predictions *per se*, but provide a means to compare quantitatively the impacts of the different settings between scenarios. The business as usual scenario is the starting point for the other two scenarios. Their settings are derived from business as usual except in so far as they implement or derive from policies with this aim.

Table 7.1. Summary of key business as usual scenario settings			
General factor	**Components of change**	**Degree of change imposed**	**Year when change is achieved**
Labour productivity	All labour sectors	1% pa growth	Ongoing
Energy intensity	Transport, dwellings and commercial building, industrial, construction, primary industries	25% increase in efficiency	2050
Material intensity	Transport vehicles, building, industrial products	25% increase in efficiency	2050
Consumption rates	food, consumables, building space, building contents, travel propensity, travel distance	adjusted to eliminate excess unemployment, and to stabilize net trade	All years
Primary production	Agricultural crops and livestock, fishing, forestry, mining production	Adjusted to stabilize net trade	All years
Type of technology	Passenger and freight transport; electricity generation	Historical trend extrapolated	All years

High resource efficiency

A second scenario involves widespread technological progress, in the form of efficiency gains. This high resource efficiency scenario applies to physical processes used in the current economic structure. The amount of material, energy, and water resources used per unit output is continuously decreased in compounding annual growth. Similarly, emission intensity can be reduced through tailpipe pollution control. In some cases, this may involve some other cost, such as increased energy, materials or labour inputs. Durability of large capital can also be extended to reduce solid waste flows. Consequently, investment rates may vary in some sectors, though not necessarily in the same way. Where physical capital is maintained for longer, investment rates decrease; where there are efficiency gains made through replacement of machinery, for example, higher investment rates may be necessary.

Table 7.2. Summary of key high resource efficiency scenario settings			
General factor	**Components of change**	**Degree of change imposed**	**Year when change is achieved**
Labour productivity	All labour sectors	1% pa growth	Ongoing
Energy intensity	Transport, dwellings and commercial building, industrial, construction, primary industries	50% increase in efficiency	2040
Material intensity	Transport vehicles, building, industrial products	50% increase in efficiency	2040
Consumption rates	Food, consumables, building space, building contents, travel propensity, travel distance	Adjusted to eliminate excess unemployment, and to stabilize net trade	All years
Primary production	Agricultural crops and livestock, fishing, forestry, mining production	Adjusted to stabilize net trade	All years
Type of technology	Passenger and freight transport; electricity generation	Historical trend extrapolated	All years

System innovation

The third scenario adds to the changes in the resource efficiency scenario by also invoking structural change. This system innovation scenario incorporates changes to consumption and lifestyle habits, urban form, transportation modes, energy production, and economic structure. These include food consumption shifts/reversion to lower meat diets, and total food intake rates that are lower than the excessive levels of affluent developed countries. The growth in per capita consumption of material goods is also curbed. In order for these reduced intensities to be realized in developing countries, the scenario assumes that technological improvements permit efficiency gains to be achieved without impinging on nutritional budgets or quality of life. The scenario therefore explores what level of change and progress is required without examining the more detailed technological challenges that would need to be answered. Urban form is assumed to change toward greater density housing in new developments. Where possible, allowance is made for local food production, resulting in decreased freight. Passenger transport shifts from growing dependence on the car, toward bicycle and public transit. Electricity generation comes increasingly from renewable sources, such as solar and wind, which are phased in as fossil-fuel based thermal power stations are decommissioned at the end of their life. Investment rates for the large structural changes involved in this scenario will have to be high. Additionally, the share of employment in the service sector, excluding the services that support productive sectors, is assumed to increase. This reflects a move to higher uptake of services that embody minimal physical resources, such as cultural entertainment, and extended leisure.

Table 7.3 Summary of key system innovation scenario settings			
General factor	**Components of change**	**Degree of change imposed**	**Year when change is achieved**
Labour productivity	All labour sectors	1% p.a. growth	Ongoing
Energy intensity	Transport, dwellings and commercial building, industrial, construction, primary industries	50% increase in efficiency	2040
Material intensity	Transport vehicles, building, industrial products	50% increase in efficiency	2040
Consumption rates	Food, consumables, building space, building contents, travel propensity, travel distance	50% decrease in intensity	2050
Primary production	Agricultural crops and livestock, fishing, forestry, mining production	As for high resource efficiency scenario	All years
Type of technology	Passenger transport	Shares: 50% rail, 25% walk/cycle, 20% road	2050
	Freight transport	Shares: 80% rail, 9% road, 9% sea	2050
	Electricity generation	30% hydro, 30% biomass, 20% solar/wind, 15% fossil fuel 5% nuclear	2050

Resource use trajectories

Results are presented in this section from the modelling of the Asia-Pacific region using the coupled biophysical and economic models. Both the modelling and calibration using historical data covered a subset of the Asia-Pacific nations, which accounts for the majority of biophysical and economic activity of the region (covering approximately 75% of the region's population, 50% of land area, and 84% of GDP). [5]

5 The eight countries used in the model are Australia, China, India, Indonesia, Japan, Kazakhstan, Republic of Korea and Thailand, and these form a majority of the subset of countries covered in depth in this report.

The results show the simulation outputs for the scenarios over 2010–2050, as well as the simulated history[6] from 1970. Indicators are provided on material flows (domestic material consumption), energy flows (primary energy consumption), resource use (oil consumption), wastes (solid waste) and emissions (GHG emissions). This section describes the trajectories of these indicators, focusing on how the outcomes differ between scenarios, with the differences explained at the macro-level. The specific outcomes are a complex mix of factors across multiple sectors and materials, contingent on domestic economic activity and import/export flows that are driven by macro-level feedbacks, which establish unemployment levels and trade balances appropriate to stable economies. Further analysis of the scenario outcomes is required to understand the complex interactions.

Generally, the model outputs have been aggregated over the detailed breakdown available in the biophysical model, such as various materials and energy carriers. Totals have been produced over the countries in the biophysical model; while country totals for China and Australia provide some individual comparisons for countries with substantially different characteristics. Per capita material and energy intensities are shown in the following section. These are derived from the aggregate outputs and the national population figures. The long-term environmental and resource focus of the scenarios and modelling is presented in Figure 7.5 below using smoothed trajectories of indicators to 2050. This emphasizes the effect of slow moving variables for policy making, because these variables are likely to require sustained attention. Nevertheless, significant cyclical variations occur in the simulated outputs, driven by the dynamic economic model. Such temporal variability confounds the management of resource use and environmental impacts because short-term departures from the long-term trend may be misinterpreted as undue success or failure of policy and management strategies.

All the indicators are presented for two scenarios, and some for three scenarios. The two common scenarios are business as usual' (BAU) and high resource efficiency (HRE). For the indicators of domestic material consumption (Figure 7.5) and primary energy consumption (Figure 7.9), an intermediate scenario is also shown. This is the outcome of moving from business as usual to high resource efficiency without altering any other inputs to the model. A consequence is a high and growing level of unemployment because less labour is required as throughput of materials and energy is lowered. Although the particular level of unemployment in 2050 depends on the details for each country, it varies from at least 30% to about 60%. The efficiency improvements (50% less inputs per unit output by 2040 compared with recent values) are sufficient to keep DMC at about contemporary levels (Figure 7.5), and primary energy use to be even lower (Figure 7.9). (Note that the BAU scenario also employs efficiency gains, achieving 25% less inputs per unit output by 2050.)

However, without any other change in the underlying economic or social conditions, very high levels of unemployment are unacceptable to stable societies. Therefore, in both the BAU and high resource efficiency scenarios, excessive levels of unemployment were eliminated by increasing consumption and primary production rates (using a feedback process described above). The consumption and production rates are adjusted until the biophysical model achieves the unemployment rate simulated by the dynamic economic model. In general, per capita consumption rates approximately double over

6 The simulated history approximates the MFA data analysis presented elsewhere in this report. Differences occur due to issues of data inconsistency that are highlighted by the use of a biophysical model that attempts to account for physical flows comprehensively.

the scenario period, with some variation across countries. This rate of growth is consistent with that of the observed historical data. When the per capita rates are combined with population growth the resulting DMC increase is substantial, as illustrated in Figure 7.5.

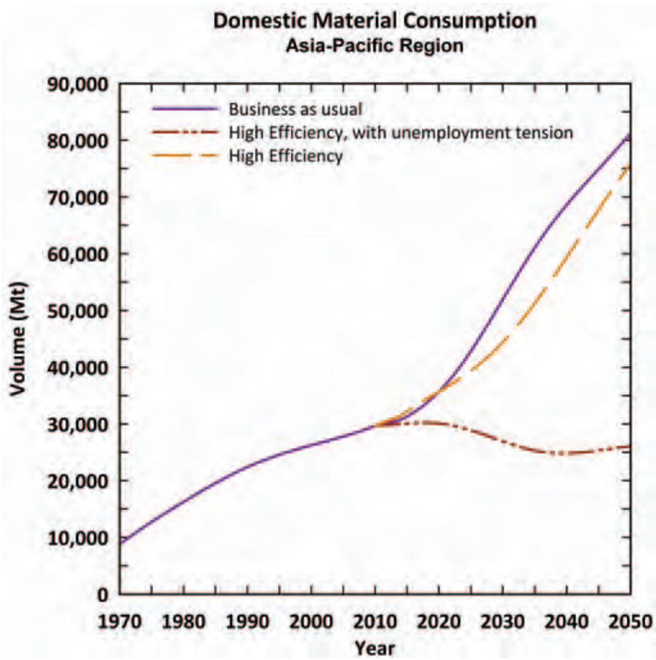
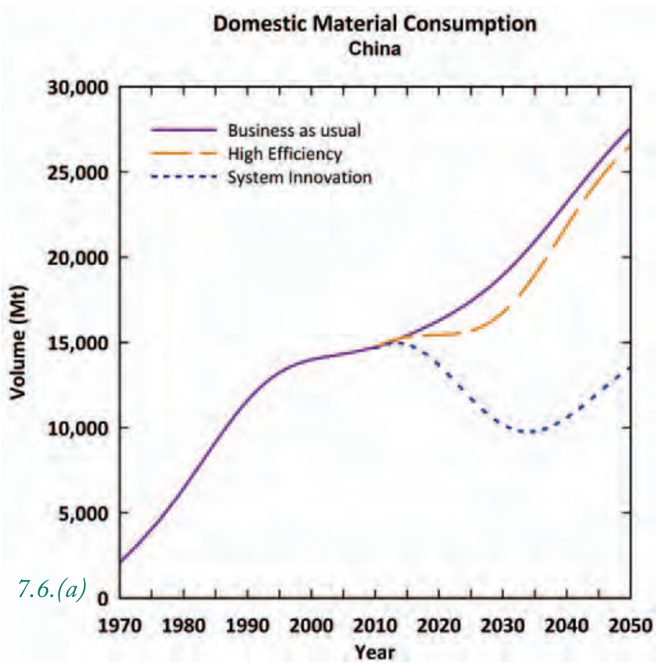


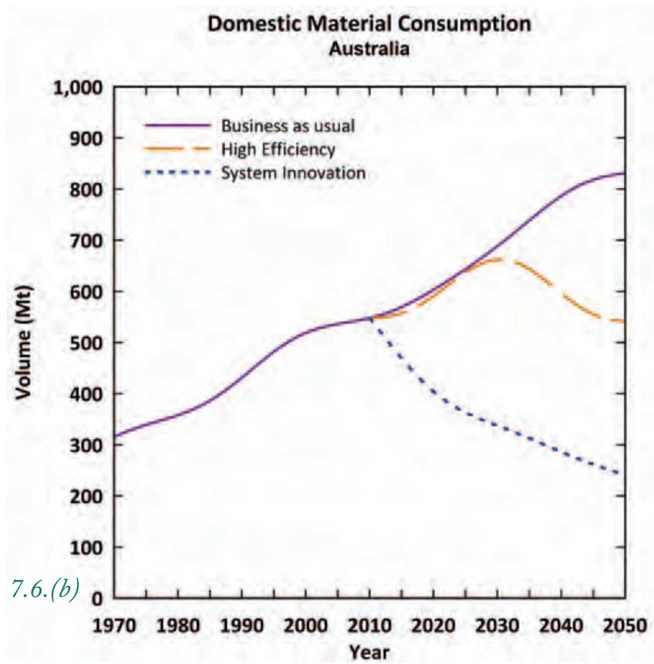
FIGURE 7.5.
Domestic material consumption in the Asia-Pacific region, for business as usual, and high resource efficiency scenarios over 2010–2050. (An intermediate scenario shows the effect of high resource efficiency where large excessive unemployment levels have not been taken into consideration. When the excess unemployment is removed by economic growth, 'rebound' in material consumption clearly occurs.)

The simulations indicate that a substantial increase in throughput of materials and energy occurs, even when high resource efficiency is implemented. DMC doubles over the scenario period, as does primary energy consumption. The fact that strong growth in resource use and emissions occurs even with high resource efficiency follows from the rebound effect caused by economic growth required to keep unemployment low.

FIGURE 7.6.
Domestic material consumption in (a) China and (b) Australia for three scenarios over 2010–2050.



7.6.(a)



7.6.(b)

A substantially different alternative is presented in the system innovation scenario[7]. As described above, this scenario not only employs high resource efficiency but combines this with structural changes such as shifts in modes of transport. Additionally, the system innovation scenario also seeks to avoid the rebound affect by not employing displaced labour in traditional jobs. This dynamic is discussed in more detail in the last section of this chapter. The important social question concerning the role or occupation of the population not otherwise employed is not explored in this analysis. There are several different ways that lower employment might be absorbed within society, such as general reduction in working hours. The scale of the change is illustrated across a range of countries in the biophysical model by about a 20–60% decrease in labour participation rates by mid-century from current levels, in order to eliminate the excess unemployment level.

Comparison is made between the DMC of China and Australia[8] in Figure 7.6. These graphs also incorporate the system innovation scenario, along with the business as usual and high resource efficiency scenarios. There are clear differences between China and Australia, and between the scenarios. The high resource efficiency scenario achieves somewhat less DMC in Australia, and only the system innovation scenario achieves lower DMC in both China and Australia. In China's case, the reduction in DMC is not maintained after about 2035, and an initial rapid increase occurs due to a surge in building construction (which has lower material and energy intensities per unit floor space). Temporal variation due to cyclic economic drivers is also more evident in the Australian simulation.

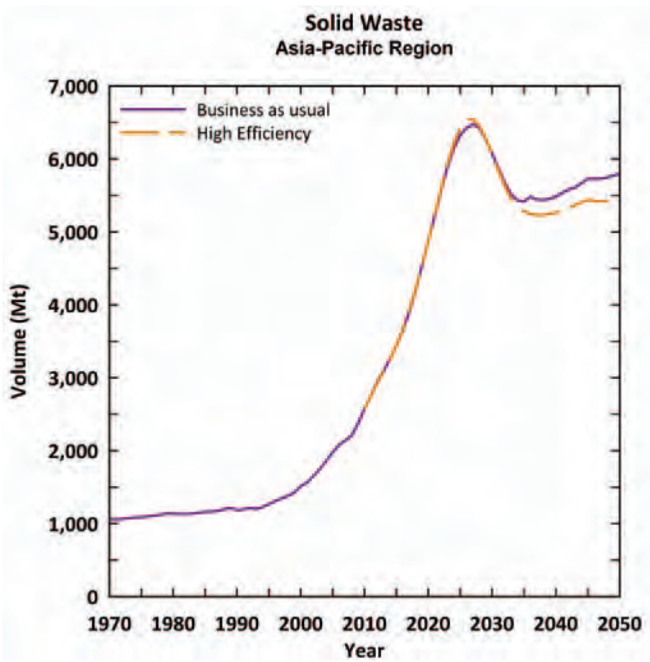


FIGURE 7.7.
Total solid waste in Asia and the Pacific, for three scenarios over 2010–2050

7 Modelling focused on China and Australia as two illustrative nations with contrasting levels of development and magnitudes of environmental flows, and where there was sufficient calibrated historical data on which to base the scenario simulations.

8 Unreliable data for many other countries prevented the system innovation scenario being implemented for the whole Asia-Pacific region.

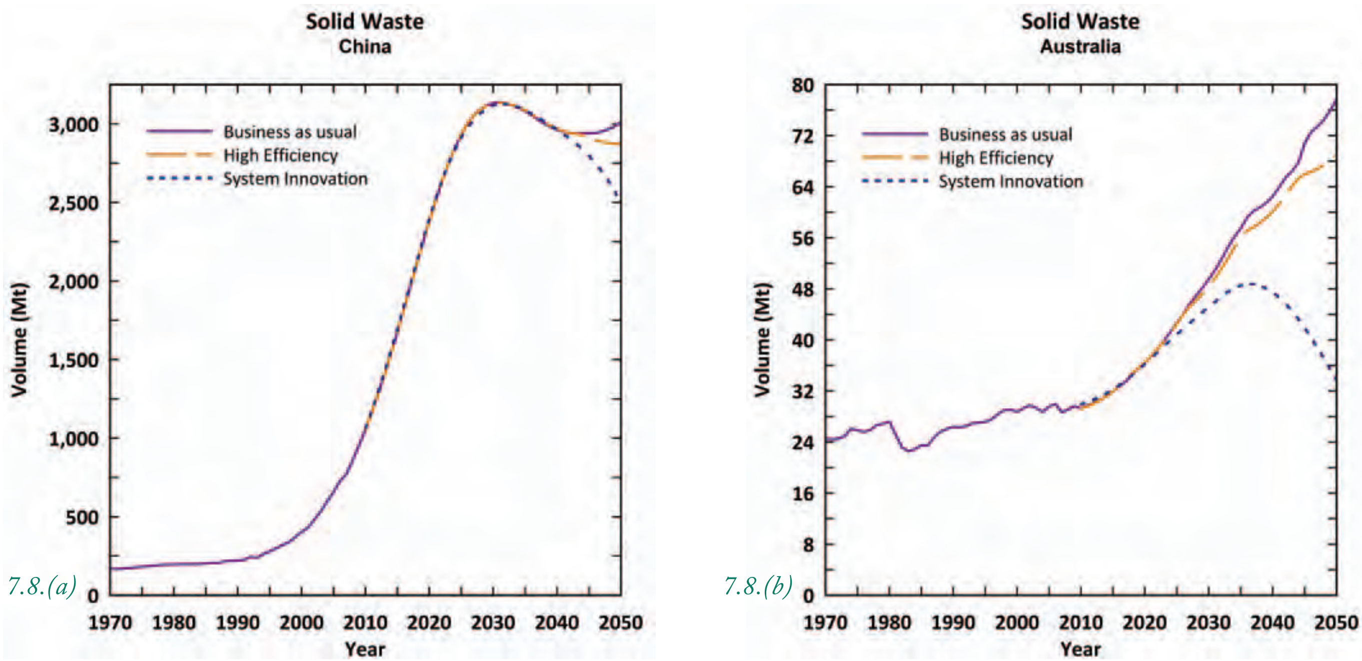


FIGURE 7.8.
Total solid waste in (a) China and (b) Australia for three scenarios over 2010–2050

Despite modest growth in DMC, as shown above, the generation of solid waste accelerates for China (Figure 7.8) and the region as a whole (Figure 7.7). The dynamics of the production of waste vary by country, as illustrated by the comparison of China with Australia (Figure 7.8).

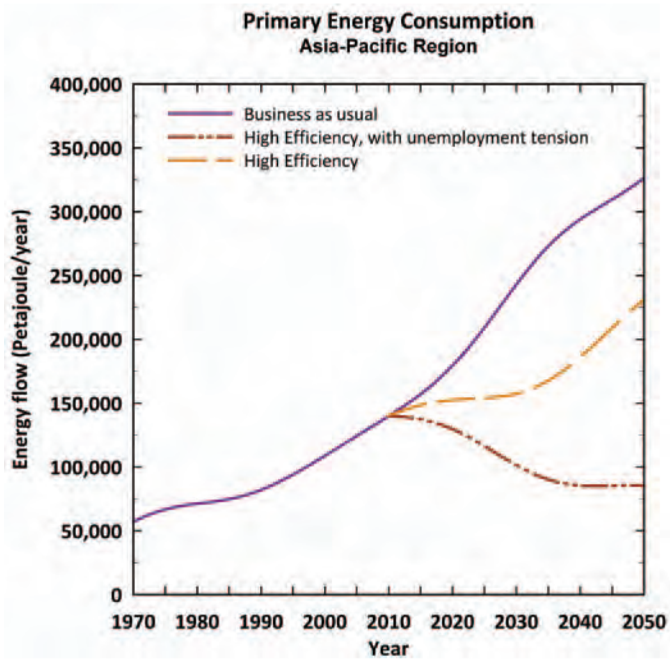
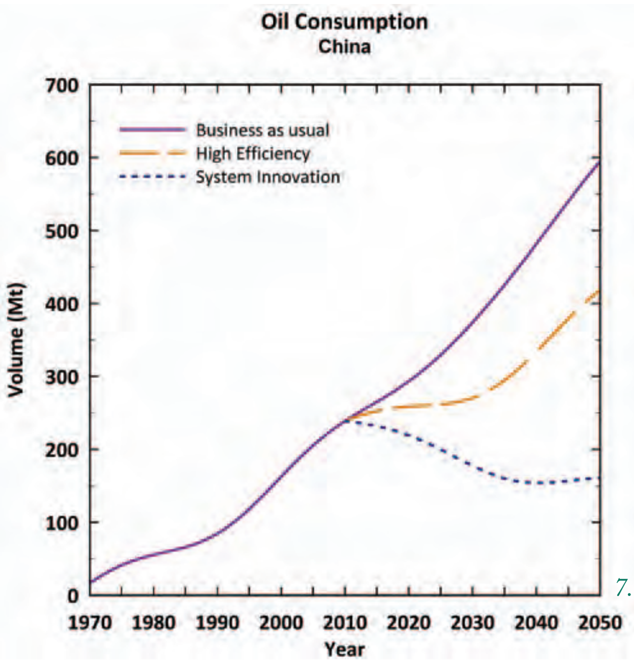


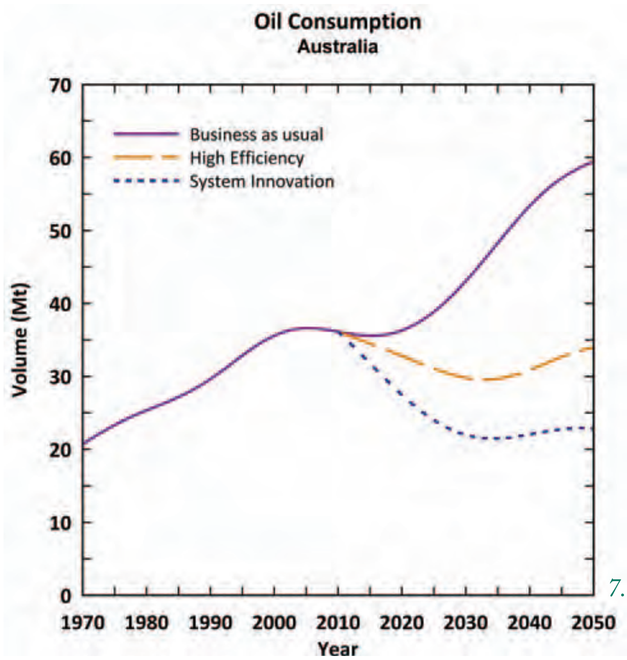
FIGURE 7.9.
Total primary energy use in Asia and the Pacific, for business as usual and high resource efficiency scenarios over 2010–2050. (An intermediate scenario shows the effect of high efficiency where large excessive unemployment levels have not been confronted. When the excess unemployment is removed by economic growth, 'rebound' in energy consumption clearly occurs.)

Vulnerability to constraints in the oil supply appears certain under a business as usual scenario in the Asia-Pacific region as illustrated for both China and Australia (Figure 7.10). Demand for oil remains high and grows in this scenario. This vulnerability to oil supply may by eased somewhat in the high resource efficiency scenario, which sees demand for oil stabilized for several decades. The further reduction in demand in the system innovation scenario is not uniform across countries, but may be greater in China than Australia.

The scenarios created have not, to date, incorporated any explicit constraints or implications of possible disruptions in domestic or international supply of oil, or any other critical resource. Doing so would require the scope and data of the model to be expanded. Consequently, the scenarios have not simulated the effects of price changes to induce additional technological efficiencies or substitution to other fuels or transport modes (to the extent this is physically possible), beyond that assumed to occur in the high resource efficiency and system innovation scenarios. Nor do the scenarios explore the deleterious impact that price increases and fluctuations might have on economic growth and stability.



7.10.(a)



7.10.(b)

FIGURE 7.10.
Oil consumption in (a) China and (b) Australia for three scenarios over 2010–2050

Greenhouse gas emissions (Figure 7.11 and Figure 7.12) vary in a similar manner to primary energy, though some differences in the trends over time occur. This is because, in addition to the burning of fuels, the emissions are also influence by agricultural activity, forestry (where carbon is absorbed by growth in forests), industrial production, landfill, and fugitive emissions from mining[9].

For the Asia-Pacific region as a whole, continued growth in GHG emissions occurs under the business as usual scenario, despite implementing efficiency improvements that are generally in keeping with past trends. Using even higher levels of efficiency reduces the growth rates for about two decades, but accelerated growth resumes after about 2030 (Figure 7.11). The corresponding scenario trends for individual nations are somewhat different, as shown for China (general increase for some years, followed by a decrease for more than a decade, then a sustained increase; Figure 7.12a) and Australia (a general decrease to about 2040, with signs of a growth after this; Figure 7.12b). Emissions for

9 Greenhouse gas emissions are dominated by those from burning of fuels, because the data and processes for other emissions have been limited to the key components only.

the region and individual nations remain stubbornly higher than contemporary levels, and well above suggested targets of 60–90% reduction (of 1990 levels).

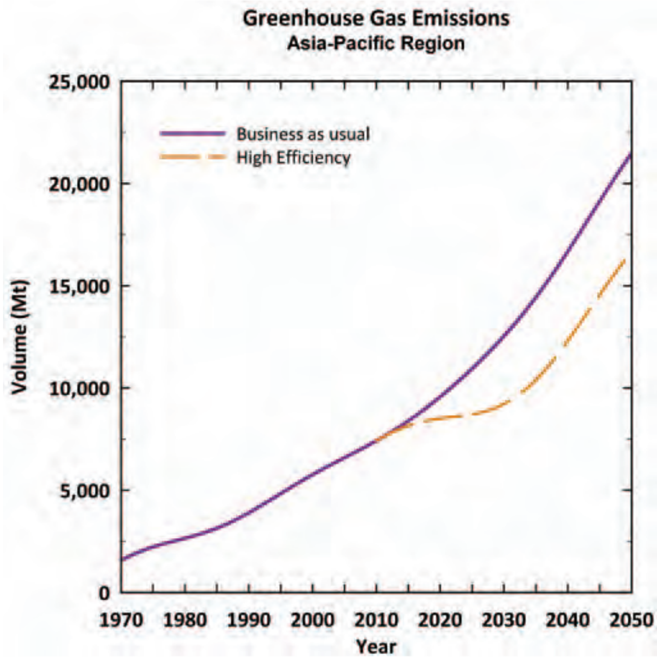
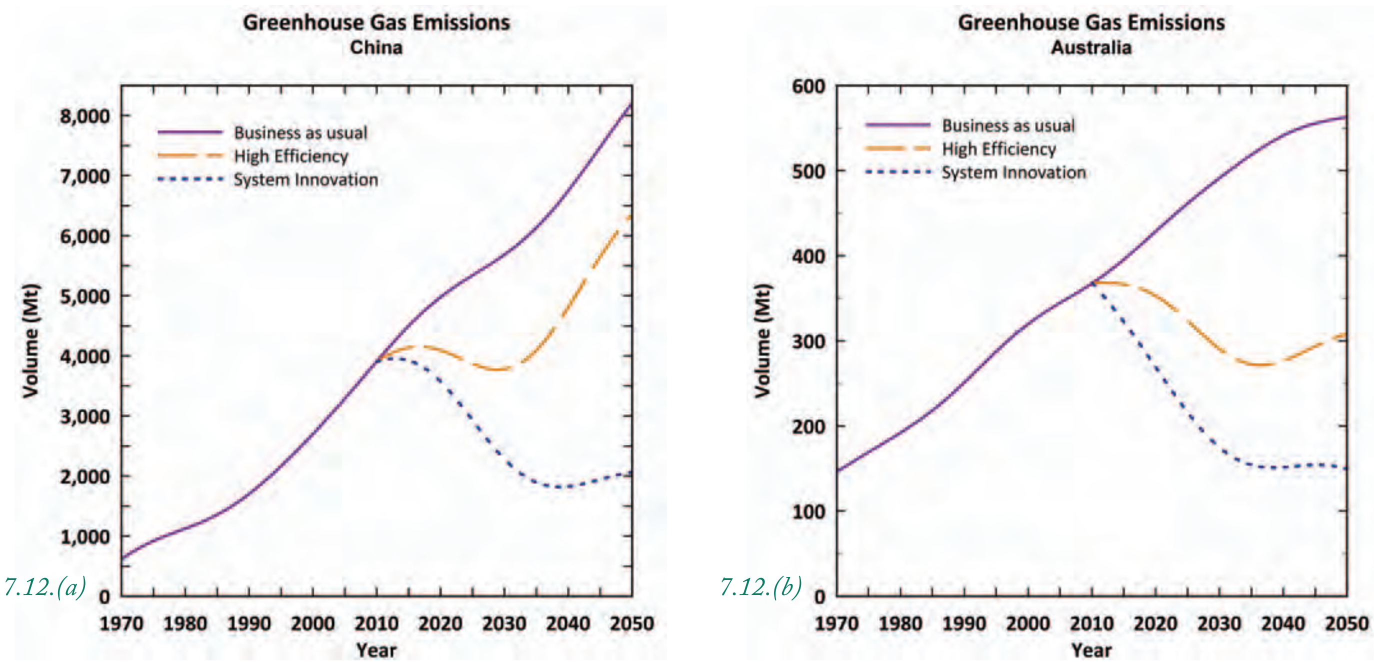


FIGURE 7.11.
Greenhouse gas emissions (CO_2-e) in Asia and the Pacific, for two scenarios over 2010–2050



In contrast, substantial emission reductions do occur in the system innovation scenario, but, even so, suggested targets of 60–90% reduction are not achieved. Australia achieves a reduction of about 40% on 1990 levels, while China's emissions are increased by about 50%.

FIGURE 7.12.
Greenhouse gas emissions (CO_2-e) in (a) China and (b) Australia for three scenarios over 2010–2050

Resource efficiency trends

Resource efficiencies are presented here for total material and energy use per capita. In the business as usual and high resource efficiency scenarios, China and the region as a whole increase the per capita resource use in 2050 to levels comparable with contemporary Japanese rates (Figure 7.13 and Figure 7.14), of about 14 tonnes/capita or more.

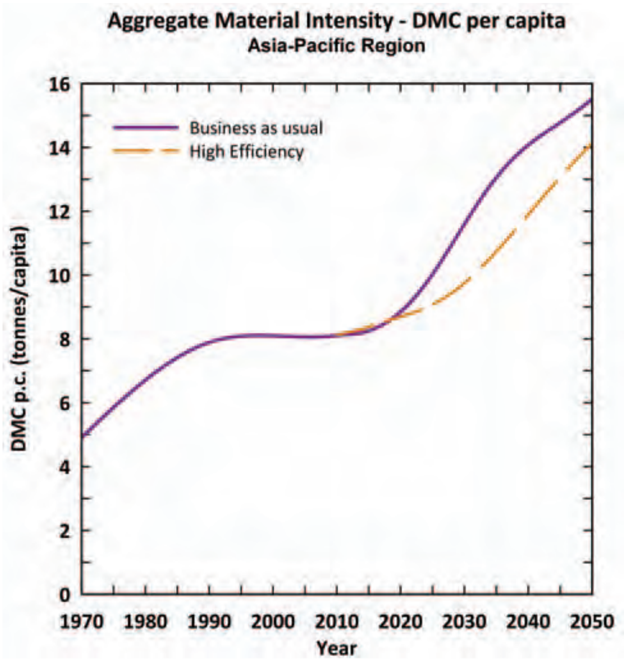
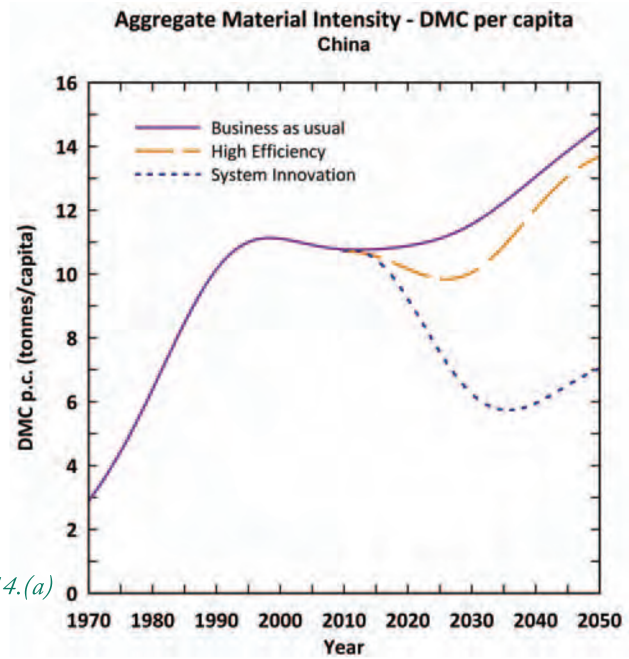


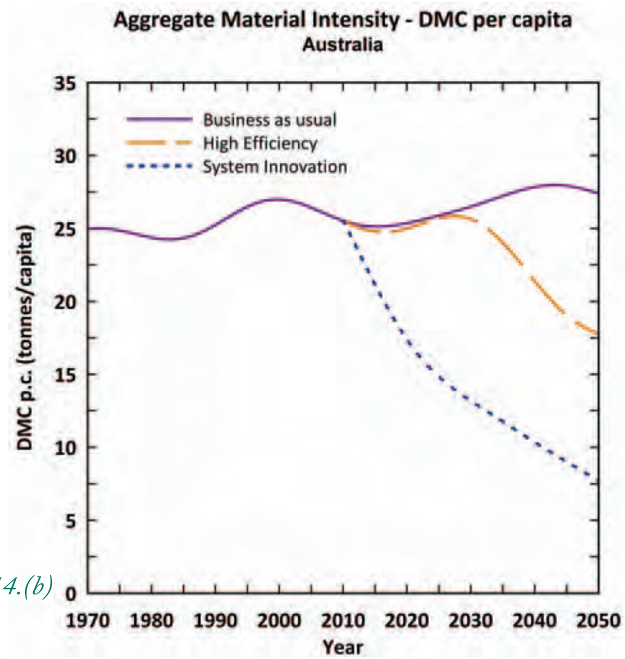
FIGURE 7.13.
Material intensity in Asia and the Pacific, for two scenarios over 2010–2050

With business as usual, Australian per capita resource intensity oscillates around an average historical figure of about 25–30 tonnes/capita (Figure 7.14). In contrast, when high resource efficiency is used, per capita resource intensity generally decreases in Australia, towards the contemporary Japanese level. This appears to show a convergence in the resource intensity trends in the high resource efficiency scenario among nations, which is an outcome of the simulation rather than an assumption imposed on it. Under system innovation, China and Australia also show a convergence, but to a substantially lower level of material intensity, being about 50% less than the high resource efficiency scenario.

Resource intensity for energy use per capita also demonstrates a continuation of past trends in the business as usual scenario (Figure 7.15). In comparison, the high resource efficiency scenario causes the energy intensity to approximately stabilize.



7.14.(a)



7.14.(b)

FIGURE 7.14.
Material intensity in (a) China and (b) Australia for three scenarios over 2010–2050

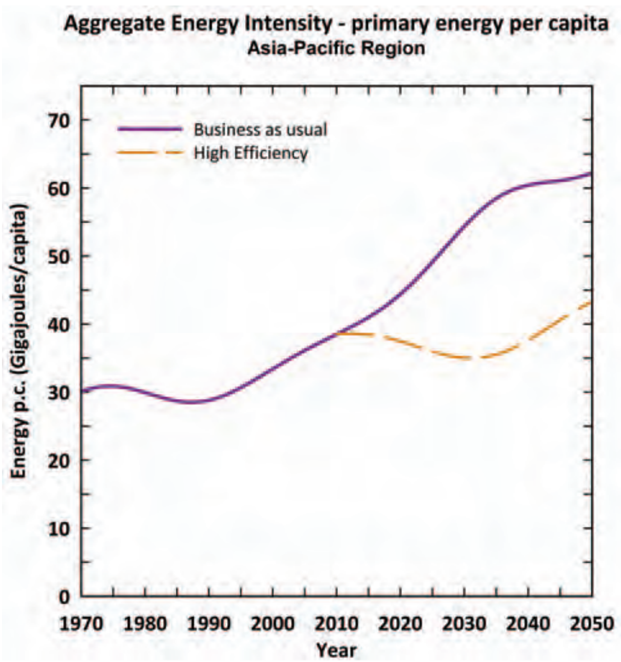


FIGURE 7.15.
Energy intensity in Asia and the Pacific, for two scenarios over 2010–2050

Qualitative assessment of trade-offs and regional dilemmas

It is important to recognize the necessary policy context for resource efficiency to be an appropriate response to resource consumption and environmental pollution issues. As noted above, resource efficiency is a favoured response because its focus on technological innovations seems to fit in well with current policies. However, technological innovation and its associated efficiency improvements are also generally recognized as the engine of economic growth – and unsustainable economic growth is one of the main drivers of environmental change.

For a solution to these problems, *efficiency is necessary, but not sufficient*. In fact, *efficiency alone makes things worse*. This is because process efficiency improvements are broadly equivalent to cost reductions, making the outputs of processes relatively more attractive and increasing their use – this effect has been referred to as the 'Jevons Paradox' (Polimeni and Polimeni 2006). Alternatively, cost reductions may release resources for increased use in other resource intensive activities. At the micro level, this is the well-known rebound effect (Energy Policy 2000). At the macro level, it is economic growth (Ayres and Warr 2009). In essence, economic growth ensures sufficient employment for workers that would otherwise be displaced by labour productivity and resource efficiency gains. In an economy that does not grow, continual increases over decades in efficiency and productivity would lead to mass unemployment (and likely social unrest), simply because fewer workers are needed to produce the constant economic output. At typical rates of productivity growth, half the workforce could be unemployed over a half-century period. However, increases in consumption and the associated economic activity provide the demand to re-employ displaced labour (Jackson 2009).

This occurs in all three of the scenarios, but varies by the extent that productivity and efficiencies were increased and how people are assumed to be employed. In both the business as usual and high resource efficiency scenarios, sufficient labour employment in traditional sectors was provided by increased demand associated with higher per capita consumption rates. Consequently, the final improvements in environmental indicators for the high resource efficiency scenario are not as large as might be anticipated from the range of efficiency measures that were imposed. This effect is shown in Figure 7.5 and Figure 7.9, where the difference between environmental outcomes is substantial, depending on whether the unemployment tension was resolved or not. In effect, economic growth substantially offsets the environmental gains.

In the system innovation scenario, however, the response is different to the efficiency gains and additional structural changes that are implemented. In this scenario, displaced workers are assumed to be absorbed into those services which are not associated with the physical productive sectors of the economy. Consequently, the feedback process driving per capita consumption is diminished compared with the other scenarios. This leads to lower physical activity in the economy and considerably improved environmental indicators.

This system innovation approach could be applied across nations in the Asia-Pacific region, though it is anticipated that thoughtful design of policy, institutions, and governance would be required. It is beyond the scope of this modelling study to explore this in detail. However, some key aspects are evident. Firstly, for efficiency to make a positive contribution to the solution of environmental problems, there need to be policies in place that focus on the problems and constrain their growth. The role of efficiency, then, is to maximize the benefits from activity *within the constraints*. But, it only works if such constraints are in place. Constraints should be focused foremost on absolute measures – an example being a cap on carbon emissions – and not on relative indicators such as efficiency alone. Attention will also need to be given to investment and suitable infrastructure development to make the widespread structural changes that have been modelled (Jackson 2009). Importantly, social and labour policy is needed to ensure that gains from productivity and efficiency improvements result in a labour force transition to service pursuits that do not directly or indirectly support more physical activity in the economy. Establishing this transition equitably across sectors and demographics will be essential (NEF 2010) to avoid the potential for some sections of the labour force to inadvertently absorb productivity gains as unemployment. Specific details of policy development would be necessary for individual countries, in order to accommodate differences in the present level of economic development of each nation.

References

Ayres RU and Warr B (2009) *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Edward Elgar: Cheltenham.

Barker T, Köhler J and Villena M (2002) Costs of greenhouse gas abatement: meta-analysis of post-SRES mitigation scenarios. *Environmental Economics & Policy Studies* **5**(2): 135–166.

Bezemer DJ (2009) "*No One Saw This Coming": Understanding Financial Crisis Through Accounting Models*. Faculty of Economics, University of Groningen: Groningen, The Netherlands.

Blatt JM (1983) *Dynamic Economic Systems: A Post-Keynesian Approach*. M.E. Sharpe: Armonk, New York.

Blinder AS (1998) *Asking About Prices: A New Approach to Understanding Price Stickiness*. Russell Sage Foundation: New York.

Bonan GB (2008) Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science* **320**: 1444–1449.

Bowman DMJS, Balch JK, Artaxo P, Bond WJ, *et al.* (2009) Fire in the earth system. *Science* **324**: 481–484.

Energy Policy (2000) Special issue on the rebound effect. *Energy Policy* 28(6–7): 355–500.

Foran BD and Poldy F (2004) Modelling physical realities at the whole economy scale. In *Economics of Industrial Ecology: Materials, Structural Change, and Spatial Scales*. (Eds JCJM van den Bergh and MA Janssen) pp. 165–194. MIT Press: Cambridge, MA.

Galbraith, JK (1975) *Money: Whence It Came, Where It Went*. Houghton Mifflin: Boston.

Garnaut R (2008) *The Garnaut Climate Change Review*. Cambridge University Press: Melbourne.

Hirsch RL (2007) 'Peaking of world oil production: recent forecasts.' US National Energy Technology Laboratory Report. US Department of Energy: Pittsburgh.

Hirsch RL, Bezdek R and Wendling R (2005) 'Peaking of world oil production: impacts, mitigation, and risk management.' US Department of Energy: Pittsburgh.

IPCC (2007) 'Fourth Assessment Report of the Intergovernmental Panel on Climate Change'. Cambridge University Press: Cambridge.

Jackson T (2009) ‘Prosperity without growth? The transition to a sustainable economy’. Sustainable Development Commission: London.

Kavalov B and Peteves SD (2007) ‘The future of coal.’ European Commission by the Institute for Energy, Directorate-General, Joint Research Centre: Luxembourg.

Keen S (2010) Solving the paradox of monetary profits. *Economics E-Journal* **4**(31), http://dx.doi.org/10.5018/economics-ejournal.ja.2010-31.

Lee FS (1998) *Post Keynesian Price Theory*. Cambridge University Press: Cambridge, UK.

Lennox JA, Turner GM, Hoffman RB and McInnis BC (2005) Modelling Australian basic industries in the Australian Stocks and Flows Framework. *Journal of Industrial Ecology* **8**(4): 101–120.

Lotze-Campen H (2008) The role of modelling tools in Integrated Sustainability Assessment (ISA). *International Journal of Innovation and Sustainable Development* **3**(1/2): 70–92.

NEF (2010) ‘21 hours. Why a shorter working week can help us all flourish in the 21st century’. New Economics Foundation: London.

Poldy F, Foran B and Conroy J (2000) ‘Future Options to 2050: Australian Stocks and Flows Framework; Report to Department of Immigration and Multicultural Affairs; 00/04.’ CSIRO Wildlife and Ecology: Canberra.

Polimeni JM and Polimeni RI (2006) Jevons’ paradox and the myth of technological innovation. *Ecological Complexity* **3**(4): 344–353.

Stern N (2006) *Stern Review on the Economics of Climate Change*. Cambridge University Press: Cambridge, UK.

Turner GM, Hoffman R, McInnis BC, Poldy F and Foran B (2011) A tool for strategic biophysical assessment of a national economy – The Australian Stocks and Flows Framework. *Environmental Modelling & Software.* In press; DOI: 10.1016/j.envsoft.2011.03.007.

Turner GM and Poldy F (2001) ‘Let’s get physical: creating a stocks and flows view of the Australian economy.’ In *MODSIM 2001 Congress*. Australian National University: Canberra.

United Nations Population Division (2008) ‘World population prospects.’ United Nations: New York.

Zittel W and Schindler J (2007) ‘Coal: resources and future production.’ Energy Watch Group: Ottobrunn: Germany.

Chapter 8: **Policy instruments to support resource efficiency**

Sonja Heyenga

Main messages

- The Asia-Pacific region is at the forefront in terms of policies for resource efficiency, sustainable consumption and production, and 'greening' economic growth.
- Achieving sustainable consumption and production involves increasing resource efficiency and promoting sustainable lifestyles, which requires cooperation among different stakeholders and sectors. It has the potential to make an important contribution towards poverty alleviation and the transition to low-carbon and green economies; and to maintain ecosystems and the services they provide.
- A number of countries in the Asia-Pacific region have incorporated 'Green Growth' policies and initiatives into their development strategies and stimulus plans, recognizing the competitive advantage that may accrue from investing in the effective and efficient use of natural resources through new technologies, infrastructures, and service delivery.
- Recent reviews of material and energy efficiency policies in developed and developing countries in Asia and the Pacific have shown that the definition of national quantitative targets is important to show ambition, create commitment, and send clear policy signals. Setting material and energy efficiency targets can form the basis for monitoring national policy outcomes and tracking progress.
- Governments now have a wide choice of different instruments to build a sound policy framework for resource efficiency. Over the past two decades, policy instruments have gradually evolved from traditional command-and-control regulations to economic instruments, information-based measures, and voluntary initiatives. An optimal mix of policy instruments will frequently include all four of these approaches.
- Material efficiency can be defined as the amount of a material needed to produce a particular product or service. Material efficiency can be improved either by reducing the amount of the material contained in the final product or by reducing the amount of material that enters the production process but ends up in the waste stream. Numerous countries in the Asia-Pacific region have implemented national policies to promote material efficiency.
- Energy efficiency targets are now in place for a number of countries in the region. Policy interventions range from phasing out inefficient appliances, to subsidizing the installation of more efficient technologies in homes and business premises, to the promotion of renewable energy sources.
- Water security is a rapidly growing issue in the Asia-Pacific region. A growing population, rapid urbanization and economic development have put heavy pressure on freshwater

resources in the region. Water efficiency is seen as one of the best options to confront water shortages in the Asia-Pacific region. Because the quality and quantity of water resources are positively correlated, it is important to simultaneously consider both issues when improving efficiency in the water sector.

- The dataset and indicators presented in this report will eventually enable policy makers to design integrated resource efficiency policies, to set targets and monitor progress with regard to the effectiveness and efficiency of natural resource use to contribute to economic development, rising standards of living, and poverty reduction. The quality and quantity of data available varies from country to country, and ongoing effort will be required strengthen data collection to ensure that policy makers have sufficient information on which to base decisions.

Overall strategies to ensure efficient and equitable use and distribution of resources

Achieving sustainable consumption and production (SCP) has become a priority and challenge at global, regional, and national levels since it was identified as a key environment-development issue by the UN Conference on Environment and Development in 1992. SCP is about increasing resource efficiency and promoting sustainable lifestyles, which requires cooperation among different stakeholders and sectors. It has the potential to make an important contribution towards poverty alleviation and the transition towards low-carbon and green economies. The Marrakech Process is a dynamic and multi-stakeholder platform that supports: (1) the implementation of projects and programmes on SCP at the regional and national levels; and (2) the elaboration of a 10-year Global Framework for Action on SCP to be submitted to the 18th and 19th Sessions of the UN Commission on Sustainable Development (CSD18 and CSD19) in 2010 and 2011. The Framework is being developed through a consultative process comprising international expert meetings, regional consultations, which have included four in Asia-Pacific, and national roundtables, including China and India, for this region. A Marrakech Process regional workshop in Manila in September 2009 and the subsequent Regional Implementation Meeting preparing for the 18th Session of the CSD, identified a number of priority SCP programmes of critical interest to the Asian region to be included in the future 10-Year Framework. SCP is a component of 'Green Growth' (see below), adopted by the Asia-Pacific region, which focuses on eco-tax reform, development of sustainable infrastructure, demand-side management, greening the market and business, and eco-efficiency indicators. The Marrakech Process, which started in 2003, has therefore been an important catalyst for subsequent SCP and resource efficiency initiatives and activities around the world, including Asia and the Pacific.

The recent Global Financial Crisis had a significant impact on the economies of the Asia-Pacific region. In its wake, there was a high degree of consensus among governments that the overriding priority was to re-invigorate economic growth. For the most part, this took the form of mechanisms to 'kick-start' the economy through activities designed to stimulate consumption and restore consumer confidence.

However, many experts believe that the Global Financial Crisis presented an opportunity to change the current economic model and introduce reforms to achieve a greening of the economy (e.g. Kuhndt *et al.* 2007; ESCAP 2008b; Rankine *et al.* 2009). Rather than postponing environmental actions, the recession can be seen as a springboard to both restore growth and to move towards a more resource-efficient and green economy. Past experience has shown that periods of economic recovery are often ideal times for implementing structural reform. According to the OECD (2009, page 8) the crisis '*provides both an opportunity and an incentive to improve efficiency in the use of energy and materials, and for the development of new green industries and businesses*'. For instance, policies that may be expensive, inefficient, or environmentally harmful can be reformed or removed in order to achieve both economic and environmental gains.

In response to the financial crisis, UNEP called for a *Global Green New Deal (GGND)* in early 2009 to revive the global economy and boost employment while simultaneously accelerating the fight against climate change, environmental degradation, and poverty. UNEP recommended that a significant portion of the estimated US$3.1 trillion in national economic stimulus packages be invested in five critical areas, including energy efficiency in buildings, sustainable transport technologies, renewable energy technologies, natural infrastructure, and sustainable agriculture (UNEP 2009a). Since then, several countries in Asia, particularly China and the Republic of Korea, have pioneered an economic and employment recovery based in part on significant green investments (UNEP 2010). The GGND is part of UNEP's Green Economy Initiative (GEI), which aims to put forward convincing evidence for a transition to a green economy, dominated by investment in, and consumption of, environmentally enhancing goods and services (see Box 8.1).

Box 8.1. The Green Economy Initiative (GEI)

The UNEP-led Green Economy Initiative (GEI) assists governments in shaping and focusing policies, investments, and spending towards a range of green sectors, such as clean technologies, renewable energies, water services, transport, waste management, green buildings, sustainable agriculture, and forests. UNEP launched the GEI in October 2008 to put forward strong and convincing evidence that would support a global plan for a transition to a green economy.

UNEP defines a green economy as one that results in *improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities* (UNEP 2011a). In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient, and socially inclusive. The concept of a 'green economy' does not *replace* sustainable development, but there is now a growing recognition that the greening the economy is fundamental to achieving sustainability.

The GEI has three main components:

1. **Policy analysis**: robust and practical economic policy analysis to inform decision making underpins the GEI. Key examples include:

- **UNEP's green economy report *Towards a Green Economy***, launched in February 2011, aims to provide timely and practical guidance to policy makers on what reforms are needed to unlock the productive and employment potential of a green economy.

- The report calls for an investment of 2% of global GDP in 10 key sectors to kick-start a transition towards a low-carbon, resource efficient economy.

- **The 'Economics of Ecosystems and Biodiversity' (TEEB) study** is a major international initiative to draw attention to the global economic benefits of biodiversity and highlight the growing costs of biodiversity loss and ecosystem degradation. See: http://www.teebweb.org/

- **The *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*** is the first comprehensive and authoritative overview of the complexity and policy relevance of global environmental challenges and employment. It draws conclusions and recommendations for policy makers, business and industry, workers, and trade unions in the context of the transition towards a low-carbon economy.

2. **Advisory services** to governments on ways to move towards a green economy.

3. **Partnerships** with a wide range of research, non-governmental organizations, business and UN partners.

GEI is one of the nine UN-wide Joint Crisis Initiatives (JCI) launched by the UN System's Chief Executives Board in response to the 2008 economic and financial crisis, which includes more than 20 UN agencies including the Bretton Woods Institutions. UNEP's work on the green economy has raised the visibility of this concept, particularly through its call in 2008 for a Global Green New Deal (GGND), which was designed as a timely and appropriate policy response to the economic crisis. The GGND recommended a package of public investments and complementary policy and pricing reforms aimed at kick-starting a transition to a green economy while reinvigorating economies and jobs and addressing persistent poverty.

For more information see http://www.unep.org/greeneconomy

Sources: TEEB 2011; UNEP 2009a; UNEP 2011a; UNEP 2011b

Green Growth is another strategy to promote environmentally sustainable economic growth that was adopted at the 2005 Ministerial Conference on Environment and Development in Asia and the Pacific, held in Seoul. The Conference delegates endorsed Green Growth as a policy focus and a powerful strategy to promote win-win approaches to reconciling the conflict between poverty reduction and environmental sustainability (ESCAP 2006). Green Growth seeks to achieve fundamental changes in the way societies produce and consume through the introduction of conceptual and systemic changes. A critical success factor of Green Growth is improving the eco-efficiency of both production and consumption.

A number of countries in the Asia-Pacific region have recognized the opportunity for greening their economies and incorporating Green Growth into their development strategies and stimulus plans. The Republic of Korea and China, in particular, have allocated large green investments through their stimulus packages (Figure 8.1).

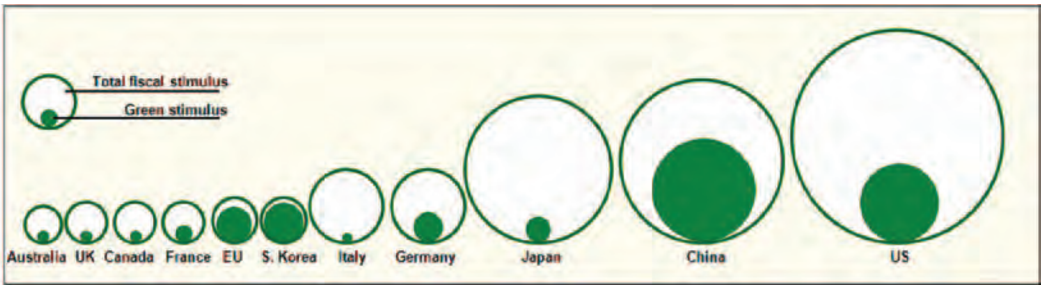


FIGURE 8.1.
Green stimulus packages (Source: after Deutsches Institut fuer Entwicklung, cited in Von Weizsäcker 2009)

The Chinese government announced an economic stimulus plan with a significant 'green focus' to help fight the effects of the recent financial crisis. Overall, $586 billion (or roughly 8% of the country's annual GDP) was to be spent over a 2-year period until the end of 2010 in 10 major areas, including electricity, health, water, and rural infrastructure (UNEP 2009a). Projects that support the growth of a green economy form a significant part of the stimulus package and have been estimated to reach US$221 billion. For instance, more than US$50 billion has been allocated for direct energy efficiency projects (World Resources Institute 2008).

Green growth has also become the new paradigm for economic development in the Republic of Korea. In 2009, the government announced the National Strategy for Green Growth which covers the years to 2050. To implement the strategy government announced the Five-Year Plan for Green Growth in July 2009, under which it would spend around 2% of the country's annual gross GDP on green growth and sustainability for the next 5 years (2009–2013), committing US$84 billion to green growth technologies. Investment in nine key green projects include: (1) a green car and cleaner energy programme; (2) green homes, offices, and schools; and (3) building green transportation. Through this initiative, the Republic of Korea is one of the first countries in the world to articulate a new national vision for sustainable economic development. Measures to move towards a resource efficient economy will also contribute to of new green employment opportunities. The Republic of Korea's stimulus package is forecast to create around 956,000 new jobs over the next 5 years in green technology and industry. As of August 2009, green investments accounted for nearly 80% of the Republic of Korea's total stimulus package (UNEP 2009a).

Japan has also implemented a policy package with a green focus to tackle the global financial crisis. Investments of nearly US$19 billion (1.6 trillion Yen) have been allocated to support the country's strategy of establishing a 'low carbon recycling-oriented society' (Government of Japan 2009). This will include the development of innovative technologies in the fields of solar power, fuel-efficient vehicles, and energy-efficient equipment. The government also wants to turn Japan into a resource-rich country by developing 'urban mines' and establishing systems for recycling products that contain rare metals and other resources (Government of Japan 2009). In Japan, employment in environmental industries is expected to double to 2.8 million people by 2020 (OECD 2009).

The Australian Government has initiated an A$42 billion economic stimulus plan to support economic growth. The plan provides investment to improve the energy efficiency and sustainability of Australia's buildings and infrastructure. The A$3.2 billion *Energy Efficient Homes Package*, which includes ceiling insulation and solar hot water system installations, was intended to help millions of Australian households reduce their energy use (Australian Government 2009a); however, there were implementation problems and the programme was abandoned. A further A$4.5 billion has been earmarked for the *Clean Energy Initiative*, which supports research, development, and demonstration of low-emission energy technologies.

Many eminent economists now contend that the current model of economic growth has reached its limits. For instance, Jackson (2009) argued that the current model of economic success is fundamentally flawed because it is based on ever-increasing production and consumption of goods and services. Instead of going back to the old ways, the financial and economic crisis offered a unique opportunity to also ensure the ecological sustainability of the planet. Daly (2005, 2008) is another economist who believes that the growth economy is failing. He claims that the global economy is now so large that society can no longer pretend it operates within a limitless ecosystem. Therefore, a new way of thinking is required to develop an economy that operates within the finite biosphere. In the 1970s, Daly (1973, 1977) put forward the concept of a steady-state economy, which seeks to sustain a constant, sufficient stock of real wealth and people for a long time (see Box 8.2 below).

Box 8.2. The steady-state economy

John Stuart Mill developed the idea of the steady-state economy in the mid 19th century, believing that after a period of economic growth, the economy would reach a stationary state, characterized by constant population and stocks of capital. Daly reintroduced the concept of a steady-state economy in the 1970s as a viable alternative to the growth economy and as a way to deal with the fundamental conflict between economic growth and ecological sustainability.

Daly (1977) defined a steady-state economy as an economy with constant population and constant stock of capital, maintained by a low rate of throughput that is within the regenerative and assimilative capacities of the ecosystems. In other words, a steady-state economy is stable in size and undergoes neither growth nor recession. Alternatively, a steady-state economy may be defined in terms of a constant flow of throughput at a sustainable, low level, with population and capital stock free to adjust to whatever size can be maintained by the constant throughput beginning with depletion and ending with pollution.

In a speech to the UK's Sustainable Development Commission in 2008, Daly outlined a number of policy ideas for the transition to a steady-state society. These included a cap-auction-trade system for the depletion of basic resources: a shift away from taxing income and toward taxing resource depletion and pollution, limits on income inequality, more flexible work days, and the adoption of a system of tariffs that would allow countries that implement sustainable policies to remain competitive in the global economy.

(Sources: Daly 1973, 1977, 2008; Mishra and Sarangi 2010)

Targets, monitoring and benchmarking

When developing national resource efficiency policies, governments should include provisions for measuring baselines, quantifying problems, setting targets, and monitoring progress towards achieving them through benchmarking (ADB and IGES 2008, p. 49). Quantitative targets and indicators are useful in determining the level of change required, while also allowing for comparisons between companies or different government initiatives. At the same time, targets are useful at the national level to orient action by governments (OECD 1998). Furthermore, indicators can help in measuring the progress of specific actions to improve resource efficiency against predefined targets.

Recent reviews of energy efficiency policies in developed and developing countries have shown that the definition of national quantitative targets is important to show ambition, create commitment, and send clear policy signals. For example, the World Energy Council (2008) found that quantitative targets for improved energy efficiency avoided disjointed actions and provided a long-lasting context for energy efficiency policies. Setting energy efficiency targets can form the basis for monitoring national policy outcomes and tracking progress.

Resource efficiency targets must be sufficiently clear for key actors, such as specific government agencies, industry, and consumers to understand and act on. They should integrate different environmental policy fields and provide verifiable interim results for material flow indicators and targets (Bahn-Walkowiak *et al.* 2008). A recent evaluation showed that several countries in the Asia-Pacific region have now adopted national energy efficiency programmes with quantitative targets. Yearly monitoring is usually a requirement (World Energy Council 2008).

Several countries in the Asia-Pacific region have initiatives to measure resource efficiency across the national economy. Table 8.1 presents national targets for achieving material, energy, and water efficiency in these countries. For example, Japan has set ambitious resource productivity, recycling, and waste reduction targets to be achieved via various 3R strategies and measures. The targets undergo yearly performance measurement and are supervised. China has also set a number of targets for achieving resource efficiency, including resource efficiency targets in the 11th Five-year Plan. For instance, by the year 2020, the Chinese government wants to reduce energy consumption per unit of GDP by 20% compared with 2005 levels (ESCAP 2007). China and Singapore are the only countries in the Asia-Pacific region that have set targets in all three key areas of resource efficiency. Overall, targets for achieving energy efficiency are more commonly used than material or water efficiency targets.

Table 8.1. Targets for achieving resource efficiency			
Country	**Material efficiency**	**Energy efficiency**	**Water efficiency**
Australia		• 20% of energy to be generated from renewable sources by 2020	
China	• Increase GDP generated by per tonne of 15 main resources consumed including energy, iron ore, non-ferrous metals and non-metals by about 25% over 2003 by 2010 • Increase the comprehensive use rate of solid industrial wastes from 55.8% in 2005 to 60% in 2010 • The proportion of reused copper, aluminium and lead in production output reaching 35%, 25% and 30%, respectively, by 2010 • Increase the amount recycled of major renewable resources by more than 65% by 2010 compared with the 2003 level • Limit the storage and treatment of industrial solid wastes to approximately 4,500 million tonnes • Constrain the growth rate of municipal garbage to approximately 5% by 2010	• Reduce energy consumption per unit of GDP by 20% by 2010 compared with the 2005 level	• Reduce water consumption per unit of industrial value-added by 30% by 2010 compared with the 2005 level • Improve the effective utilization coefficient of agricultural irrigation water from 0.45 in 2005 to 0.50 in 2010
India		• Energy savings of 10,000 MW by 2012	• Increase water use efficiency by 20% (pilot studies to be undertaken by 2013)
Japan	• 60% improvement in resource productivity by 2015 • 40–50% improvement in cyclical use rate • 60% reduction of final waste disposal amount	• Improve energy efficiency by at least 30% by 2030	
New Zealand		• 90% of electricity generated from renewable sources by 2025 • Non-transport energy savings of 30 PJ by 2025	
Philippines	• Waste conversion rate of at least 25% by 2006	• Average annual energy saving of 23 million barrels of fuel oil equivalent	
The Republic of Korea	• Increase recycling by 53% by 2011	• 46% reduction in energy intensity by 2030 • Energy consumption to be reduced by 42 m tonnes of oil equivalent by 2030	

Table 8.1. Targets for achieving resource efficiency			
Country	**Material efficiency**	**Energy efficiency**	**Water efficiency**
Singapore	• 60% of household waste to be recycled by 2012 • Recycling rate of 70% by 2030	• 35% improvement in energy efficiency from 2005 levels by 2030	• Reduce domestic water consumption to 140 L per person per day by 2030
Thailand		• Reduce energy consumption by 13% in 2008 and 20% in 2009	• Reduce water use by 10% between 2008 and 2010
Viet Nam		• Reduce total energy consumption by 3–5% (2006–2010) and then by 5–8% (2011–2015)	

(Sources: MEWR 2002; ESCAP 2007; UN-Water 2008; Government of India 2009; MWR 2009; New Zealand Government 2009a; Korea Environment Institute 2010)

Policy instruments

'Comprehensive policies comprising both regulatory and market-based tools are needed to achieve greater resource productivity.'(Ministry of the Environment (Japan) 2008a)

Once goals and targets for resource efficiency have been set, governments need to assess what policy tools and instruments are available to achieve them and how these can be effectively implemented. Several recent reports discuss policy instruments that may be used to promote resource efficiency (GTZ *et al.* 2006; ADB and IGES 2008). Governments now have a wide choice of different instruments with which to build a sound policy framework for resource efficiency. Over the past two decades, policy instruments have gradually evolved from traditional command-and-control regulations to economic instruments, information-based measures, and voluntary initiatives (UNEP 2007). An optimal mix of policy instruments will frequently include all four of these approaches (ADB and IGES 2008).

Due to the complexity of environmental problems, the use of multiple policy instruments is now the norm rather than the exception in natural resource management (Bennear and Stavins 2007). It is unusual for a single policy instrument to operate in isolation. In most situations, a mix of instruments is used to tackle a specific environmental problem. According to the OECD (2007) there are many advantages for using a mix of policy instruments, including: (1) accounting for the multi-aspect nature of environmental problems; (2) enhancing the effectiveness of one instrument with the help of another and vice versa; and (3) reducing administrative costs and improving enforcement possibilities.

The challenge for policy makers is to select an appropriate combination of policy instruments to meet specific environmental objectives while also having a positive economic and social impact (GTZ *et al.* 2006). Policy instruments should be combined in a way that provides a balanced and sound approach to promoting resource efficiency while being tailored to the unique context of local or national conditions. They must also be mutually reinforcing and without perverse incentives (DEFRA 2002).

There are a number of important requirements for applying an environmentally efficient and economically effective instrument mix. First, it is important to have a good understanding of the environmental issue to be tackled. Furthermore, links with other policy areas, such as employment, housing, and transport, need to be clearly understood. In addition, interactions between the different instruments within the mix need to be recognized (OECD 2006).

To achieve greater resource efficiency, policy makers try to shift companies' or householders' actions from a current wasteful practice to a one that conserves resources. This usually calls for a twofold policy approach, which includes both measures aiming to phase out the undesirable product and behaviour and measures to increase the market for more sustainable products (Bengtsson *et al.* 2010). Figure 8.2 illustrates this need for multiple policies to simultaneously increase the market share of 'front-runners' and decrease the share of 'laggards'.

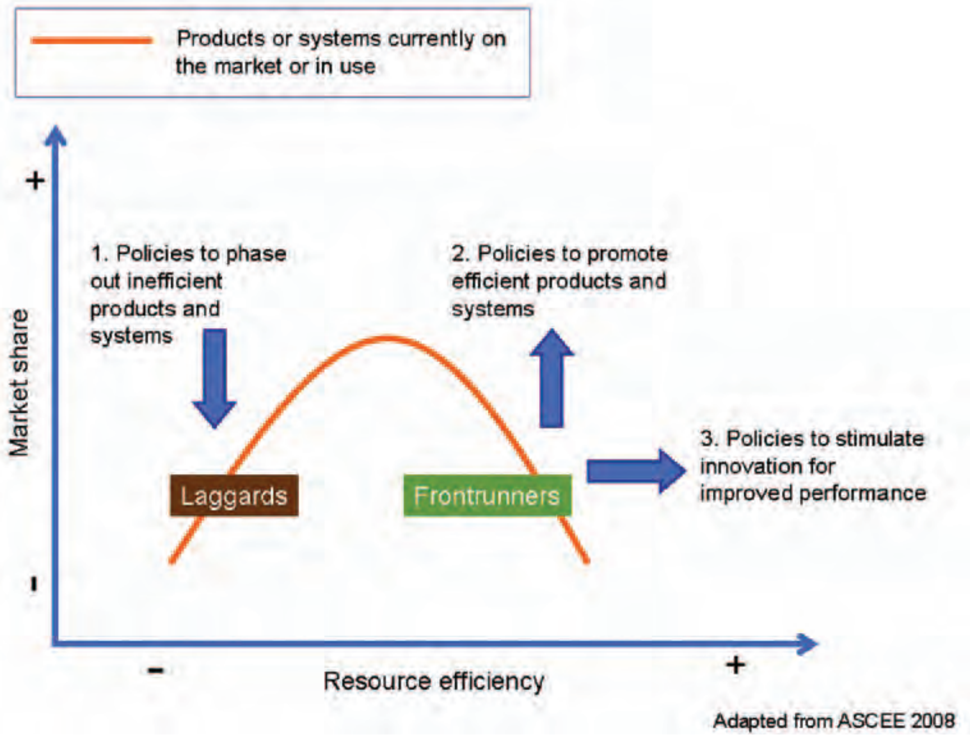


FIGURE 8.2. *Three types of policy interventions aiming at improving the resource efficiency of products and systems. (Source: Bengtsson* et al. *2010)*

In addition to shifting from less desirable products or behaviours – laggards – to better ones – front-runners – there is a need for policies to stimulate innovation, both for individual products and at the system level. For example, in addition to improving the fuel efficiency of automobiles, there is also a need to support the development of new energy sources for vehicles, to facilitate the dissemination of social innovations such as car sharing, to improve public transportation systems as viable alternatives to cars, and to reduce mobility needs through better city planning (Bengtsson *et al.* 2010).

This section presents four generic groups of policy instruments that can be used to promote resource efficiency. It is important to note that it is usually difficult to categorize a policy measure as being purely 'regulatory', 'economic', 'information-based', or 'voluntary'. Instead, there is often overlap. For instance, many information-based measures are often also voluntary in nature. Similarly, voluntary initiatives are often subsidized to ensure that participation is free of charge (DEFRA 2002).

Regulatory instruments

Traditional regulatory instruments set legal standards in relation to environmental performance, pressures, or outcomes (Ekins and Tomei 2007). They are often referred to as command-and-control instruments (CCIs) in the economic literature and have traditionally been favored by governments to carry out environmental policy. Regulatory instruments are policy mechanisms that are non-voluntary in nature and that compel resource use change by the threat of penalties for non-compliance. Penalties are set by legislation and used to influence the behaviour of resource users by encouraging them to avoid punishment for non-compliance.

Traditional regulatory instruments have several benefits, which explain their widespread use in environmental policy making. For governments, the setting of standards is inexpensive and the goals for policy achievement are clear (Bengtsson *et al.* 2010). They also impose minimum performance requirements and mandate compliance.

On the other hand, traditional regulatory instruments are often seen as inflexible, costly to enforce, and provide incentives only to avoid penalties rather than to improve outcomes. Also, industry is reluctant to submit to regulation, arguing that uniform regulation ignores the unique situation of each company and so imposes excessive costs due to ineffective allocation of the burden of compliance. This resistance can even make some regulation impossible to implement (Hotta 2004).

The shortcomings of traditional regulatory instruments and the difficulties of implementing them effectively do not imply that they should be avoided or replaced. Rather, it is important to develop more dynamic and flexible policy approaches. This can be achieved by combining regulatory instruments with other kinds of policy tools and by introducing regulatory instruments sequentially (Bengtsson *et al.* 2010).

Recent years have seen a trend in the development and implementation of more innovative and flexible regulatory instruments to promote resource efficiency. These typically include not only standards on emissions or technologies[1] and environmental liability, but also extended producer responsibility via product take-back, environmental control, enforcement through permits and inspection by authorities, and other measures to mobilize public action to change the patterns of production and consumption in order to improve resource efficiency.

Many countries in the Asia-Pacific region have introduced regulatory instruments to promote resource efficiency. These include: (1) laws and regulations to promote energy efficiency and renewable energy (see for example New Zealand's *Energy Efficiency and Conservation Act 2000*, Japan's *Energy Conservation Law 1997* and 2008 and its Top Runner standard programme outlined in Box 8.3, China's *Energy Conservation Law 1998* and *2008*, India's *Energy Conservation Act 2001*); (2) laws and regulations to promote resource efficiency and sustainable production and consumption (see for example Japan's 3Rs (reduce, reuse, and recycle) laws, China's *Circular Economy Law 2008* outlined in Box 8.4 and *Cleaner Production Law 2002*); and (3) laws to promote low carbon and green growth

1 Technical/emissions standards refer to required technical equipment or maximum levels of emissions from specific sources of pollution and can thus promote technological innovation.

(such as the Republic of Korea's *Framework Act on Low Carbon and Green Growth 2009* explained in Box 8.5).

These new regulatory instruments typically define various stakeholders' responsibilities (including those of governments at all levels, businesses and consumers), and combine the traditional command-and-control and legal liability approach with economic instruments, information disclosure, and governmental procurement measures.

Box 8.3. Japan's Top Runner standard programme

Japan's 'Top Runner' programme was introduced in 1998 as part of the country's Energy Conservation Law to improve energy efficiency in energy-using products. The programme is a regulatory approach administered by the Japanese Ministry of Economy, Trade and Industry (METI) and does not provide any kinds of government incentives. One of the most important characteristics of the Top Runner programme lies in its focus on the supply side of product markets. Stringent energy efficiency standards have been established for 21 product categories, including passenger vehicles, air conditioners, refrigerators, and television sets. Instead of setting a minimum energy performance standard, the current highest energy efficiency rate of a product in each category is taken as the standard (the 'Top Runner'). This standard represents the target value of energy efficiency that has to be reached by all products belonging to the category within a certain time period. Since the introduction of the Top Runner programme, each product category has achieved significant energy efficiency improvements. For example, the energy efficiency of air conditioners improved by 67.8% between 1997 and 2004. Energy efficiency improvements for other product categories include: electric refrigerators: 55.2% (1998–2004); gasoline passenger vehicles: 22.8% (1995–2005); vending machines: 37.3% (2000–2005); computers: 99.1% (1997–2005). Overall, the Top Runner programme is expected to achieve 0.35 exajoules (EJ) of energy savings between 1998 and 2010.

(Sources: Geller *et al.* 2006; ECCJ 2008)

Box 8.4. China's Circular Economy Law 2008

The Law specifies responsibilities for:

- government at all levels:
  - formulate the national and local plans
  - support research, science and technology
  - green consumption (green procurement)
- industries/businesses:
  - establish sound management systems and take measures of 3Rs
  - industry associations to develop sectoral 3Rs guidelines
- consumers/citizens:
  - resource conservation and sustainable consumption

Provides incentives:

- directs local governments to establish funds to support circular economy
- tax preferences to industries and activities that promote the conservation of energy, water, and materials
- financial institutions to give priority to loans and businesses promoting 3Rs
- develop pricing policies that encourage 3Rs

Legal liability:

- higher levels of government being authorized to punish individuals
- enterprises producing or selling prohibited equipment or products can be punished – ranging from fines up to 200,000 RMB to being ordered to shut down
- businesses that import prohibited materials or equipment may be fined from 100,000 up to 1 million RMB
- criminal punishment could also be imposed if an offense is committed

(Source: National People's Congress 2008, Xinhua News Agency 2008)

Box 8.5. The Republic of Korea's Framework Act on Low Carbon and Green Growth 2009

The National Assembly of the Republic of Korea passed the *Framework Act on Low Carbon and Green Growth 2009* in December 2009. President Lee Myung Bak signed and proclaimed the enactment of the law in January 2010, and the law came into force in April 2010. The law legally supports the Republic of Korea's national vision of low carbon and green growth. Major measures embodied in this law include:

- formulate and implement a National Green Growth Strategy
- establish a Green Growth Committee under the President's Office
- require measures to cultivate and support green economy and industries
- establish eco-friendly taxation and pricing system
- respond to climate change and develop an Energy Basic Plan with medium and long-term targets
- establish a cap-and-trade system for carbon emissions
- support companies that undertake investments in green industries
- educate and support public activities for practicing a green life.

To ensure the implementation and enforcement of the Act, the Republic of Korea also adopted the Enforcement Decree of the Framework Act on Law Carbon and Green Growth in January 2010.

(Source: Ministry of the Environment (Republic of Korea) 2010, Xinhua News Agency 2010)

Economic and market instruments

More recently, greater emphasis has been placed on the use of economic instruments to help correct market failures (UNEP 2007). Economic instruments work by encouraging certain behaviours through economic incentives. In contrast to regulatory instruments, which force all regulated entities to comply with the same standards, the incentives and disincentives provided through economic instruments can generate different behaviours depending on each actor's specific circumstances (Stavins 2000). This flexibility can often reduce the overall compliance costs quite significantly compared with uniform regulation.

The two most notable advantages of economic instruments over traditional regulation are their cost effectiveness and their ability to provide incentives for innovation and improvement beyond a certain level of performance (Stavins 2000). However, in order to generate the desired effects, economic instruments usually require sophisticated institutions to implement and enforce them, particularly in the case of charges and tradable permits. Charges and taxes need to be collected and monitoring is required to avoid "free-riding". Tradable permits are particularly challenging; to create a well-functioning market can require a fairly large administration, and the regulated entities usually need training in how to use the permit market effectively. Another drawback of economic instruments is that their effects on resource consumption are not as predictable as under a traditional regulatory approach (Bengtsson *et al.* 2010).

There are many different types of economic instruments, such as subsidies (including the removal of environmentally harmful subsidies), taxes (on emissions or products), rebates (on tax, purchase of environmentally friendly products), tradable permits, and deposit-refund schemes.

Subsidies

Subsidies can often be environmentally harmful because they distort prices and resource allocation decisions, influencing the amount of goods and services produced and consumed in an economy. For example, fuel tax rebates stimulate the use of fossil fuels and increase GHG emissions. Over a decade ago, Roodman (1998) estimated that governments worldwide could cut $650 billion of harmful subsidies each year. Myers and Kent (2004) put the estimate at over $1,000 billion annually. Even today, there are still numerous examples of subsidies that are paid for the consumption of electricity, coal, water, and other resources around the world. For example, Australia recently introduced the 'small business and general business tax break', which offers a tax deduction of up to 50% for small businesses to purchase new business vehicles, among other physical items (Australian Taxation Office 2009). The removal of subsidies that distort the economy and cause environmental damage is usually one of the most cost-effective means for achieving environmental protection and economic development simultaneously (Markandya 1998).

Some subsidies, on the other hand, can successfully generate environmental benefits. For instance, various countries in the Asia-Pacific region support the development of renewable energy sources. Australia's Renewable Energy Equity Fund (REEF) provides capital for small innovative renewable energy companies that are commercializing research and development in renewable energy technologies (DEWHA 2008). Similarly, New Zealand's Energy Efficiency and Conservation Authority offers funding for energy efficiency initiatives, including home insulation, solar water heating, and energy-saving technologies for businesses (EECA 2009). Also, Hong Kong introduced a tax incentives scheme in 2008 that offers a reduction in registration tax for buyers of environmentally friendly commercial vehicles (EPD 2009). Furthermore, the Chinese Government launched a financial subsidies fund to promote energy efficient lighting products in 2008. While bulk users will receive a subsidy of 30% on each highly efficient lighting product, residential users will receive a subsidy of 50% (Wei 2009).

Environmental taxes

There is a large body of research on the desirability of environmental taxes and the proper pricing of natural resources (e.g. Von Weizsäcker and Jesinghaus 1992; Daly 1994; Bernow *et al.* 1998; Hamilton 2000). Environmental taxes are levied on resource use or polluting environmental emissions. They represent an additional cost to producers, which acts as an incentive for greater efficiency, reducing intensity of resource use and environmental impact (explained in Box 8.6).

Environmental taxes are usually claimed to be advantageous because they can achieve environmental goals in a more efficient way than command-and-control type regulation. At the same time, they can generate revenue for essential environmental spending that is otherwise difficult to finance. They also provide continuous incentives for research in environmental technologies, especially when businesses perceive the tax to persist in the long term (GTZ *et al.* 2006). Another important strength of environmental taxes is that they may reduce demand for goods whose production or consumption involves multiple externalities. For example, a gasoline tax deters vehicle use and thereby minimizes local pollution and global climate impacts while also reducing externalities from traffic congestion and traffic accidents (Goulder and Parry 2008).

However, the introduction of environmental taxes often meets with resistance when taxation is seen simply as a way of increasing governmental revenue. Governments may be able to lower resistance by reducing other taxes or by recycling revenues to support environmental objectives. Supportive economic and political framework conditions are also required for the successful implementation of environmental taxes. This includes a system of monitoring, revenue collection, and enforcement, as well as measures to combat possible corruption.

The social equity aspects of environmental taxes are also important. Concerns have been raised that taxes that are based on the consumption of goods and services may weigh more heavily on the poor than on the wealthy. However, according to Von Weizsäcker and Jesinghaus (1992), environmental taxes can encourage environmentally conscious consumption patterns without causing significant negative social distribution effects, when introduced gradually and in ways that are revenue-neutral and easy to administer. For example, if energy prices are raised in proportion with measured average increases of energy productivity then '*the driven mile or industrial energy services would not become more expensive as prices rise*' (Von Weizsäcker 2009).

Several countries in the Asia-Pacific region, including China, Japan, the Republic of Korea, Thailand, and Viet Nam have made progress towards environmental tax reform (ETR). For example, the government of the Republic of Korea has increased the country's petroleum excise tax by 31% annually. The government of Viet Nam is currently developing an environmental tax to be levied on petroleum, oil, coal, plastic bags, and fertilizers. China recently adopted a new law on corporate income tax that grants preferential tax treatment for investment in energy-saving and environmentally friendly projects and equipment. In addition, the country's consumption tax was revised in 2006, putting a higher tax burden on larger, energy-inefficient vehicles (Zhou 2010).

Box 8.6. Environmental tax reform

Environmental tax reform (ETR) (also known as 'eco-tax reform' or 'green tax and budget reform') entails a reconsideration of the present tax system. It seeks to use the revenues from environmental taxes to reduce the tax burden on beneficial economic activities, such as investment or employment. It thereby shifts the tax burden towards the 'bads' (such as pollution, waste, and resource depletion) and away from the 'goods' (such as employment, income, and investment). The goal of ETR is a zero net increase in the tax burden, but a positive impact on employment and polluting behaviour through the market.

Von Weizsäcker *et al.* (1997, p. 204) proposed a 'revenue-neutral, slowly progressing long-term tax shift' in their seminal report to the Club of Rome 'Factor 4: Doubling wealth – halving resource use' so that resource prices reflect externalities. Revenue neutrality could be achieved by reducing other taxes, such as income taxes or corporation taxes, to ensure that the overall tax burden does not increase, but is merely redirected to more resource efficient activities. Advantages of ETR include: (1) changing perverse incentive structures; (2) reducing undesirable taxes; and (3) achieving environmental deregulation.

Bernow *et al.* (1998) developed a general outline of a nearly revenue-neutral ETR package, with the aim of reducing pollution, creating jobs, boosting wages, and increasing the progressiveness of the tax structure. Key components of this ETR package include:

- levying taxes on polluting or resource depleting activities
- rebating this revenue to the taxpayers by reducing payroll taxes
- phasing the tax shift in gradually and predictably over a number of years
- providing transitional assistance for communities, workers, and industries that are strongly affected by the tax
- investigating the implications for international competitiveness of those industries that are most affected by the tax.

Today, many consider ETR to be a powerful policy tool that creates the potential for a 'double dividend' – an environmental improvement coupled with an economic benefit. It can lead to enhanced economic growth, greater employment, more efficient resource use, and a cleaner environment.

(Sources: Von Weizsäcker and Jesinghaus 1992; Daly 1994; Bernow *et al.* 1998; Bosquet 2000; Ekins and Tomei 2007; ESCAP 2008a)

Information-based measures

Information-based measures have become more popular in recent years, partly because of the lower costs of dissemination brought by information technology. These policy instruments provide information about the environmental performance of certain products, services or systems in a standardized manner so that consumers and investors can make more informed decisions (Jordan *et* *al.* 2003). Approaches such as public information campaigns, eco-labelling schemes, research and development, and public disclosure of a company's environmental performance are used to generate knowledge about the adoption of resource-conserving practices. Information-based measures may be mandatory or voluntary.

One of the advantages of information-based measures is their low implementation costs compared with the complex administration needed for regulatory instruments (Bengtsson *et al.* 2010). In addition, they can raise public awareness about more sustainable consumption patterns and provide incentives to companies for reducing their environmental burden in order to avoid competitive disadvantage (Jordan *et al.* 2003). Information-based measures can also enhance the effectiveness of economic instruments, such as environmental taxes, especially if they convey information on private benefits (OECD 2007). Conversely, the effectiveness of information-based measures largely depends upon the reactions of the information recipients (Karl and Orwat 1999). Approaches such as eco-labelling can be ineffective in markets where consumers have low awareness levels for environmental issues, or where the amount of discretionary spending is low.

One of the most common types of information-based measures is the use of eco-labelling schemes. These schemes display information about the environmental performance of a product or service so that consumers can make informed choices when purchasing. Several countries in the Asia-Pacific region have recognized the importance of eco-labels and have introduced programmes to help create market preference for resource efficient products and equipment. For example, Thailand's Green Label Scheme has been developed to conserve resources, reduce pollution, and improve waste management. Environmental certification is awarded to products, such as refrigerators, computers, air-conditioners, and building materials, which are shown to have the least detrimental impacts on the environment. Participation in the scheme is voluntary and in March 2009 nearly 191 products from 36 companies had been awarded the certificate (TEI 2009). Another example is Singapore's Energy Smart Building Labelling Programme, which seeks to promote energy efficiency and conservation in the building sector by according recognition to energy efficient buildings. This eco-label awards office buildings, hotels, and retail malls that perform in the top 25% in terms of energy efficiency within their cohort. An official ceremony is held annually to honor the award winners (NEA 2009).

Some of the strengths of eco-labelling schemes include raising environmental awareness, rewarding environmentally ambitious companies with public recognition, and serving as a benchmarking and information tool to help 'green' the corporate image of manufacturers. On the downside, the increasing number of eco-labelling schemes may lead to consumer confusion. Furthermore, there may be a lack of expertise and technologies to develop appropriate certification procedures in some countries (GTZ *et al.* 2006).

Education is another important information-based measure and is critical to the decision-making process (UNEP 2007). Several countries in the Asia-Pacific region have introduced educational programmes to enhance knowledge in the population about resource efficient behaviour. For example, the government of the Northern Territory in Australia introduced the 'Re-thinking Waste-in-Schools Education Program' in 2007 to promote awareness of resource efficiency issues within school communities (Northern Territory Government 2007). In India, the Bureau of Energy Efficiency has prepared an educational curriculum on energy efficiency and conservation for school education in 10 states across the country. The objective of this programme is to create awareness among children and their parents on energy issues. The school education programme also covers other activities, including an annual painting competition on energy conservation, to educate children about energy efficiency (BEE 2008).

Name : Yeerina Debnath **Prize** : First **Std.** : Vth **School** : St. Augustine Day School, Kolkata

FIGURE 8.3. *Painting by Ms Yeerina Debnath, 1st Prize winner of National Painting Competition on Energy Conservation 2008, organized by Ministry of Power and Bureau of Energy Efficiency, New Delhi (India) (Source: BEE 2008)*

Due to their drawbacks and limitations, information-based instruments do not function as complete substitutes for other types of policy instruments. Instead, they function as additional or supplementary measures that provide further incentives for resource efficiency and pollution abatement (Karl and Orwat 1999; Bengtsson *et al.* 2010).

Voluntary initiatives

Voluntary initiatives do not enforce participation; rather they seek to bring about the desired change by directly influencing decisions on resource efficiency. Voluntary initiatives include partnership projects, voluntary codes of practice, voluntary environmental management standards or audits, and voluntary agreements. Voluntary agreements aim to promote environmental improvements through the development of clear voluntary goals (Bengtsson *et al.* 2010). The OECD (1999) defines voluntary agreements as schemes where firms make commitments to improve their environmental performance beyond legal requirements.

One example is the Republic of Korea's 'Voluntary Agreement System for Energy Conservation and Reduction of Greenhouse Gas Emissions'. Businesses can enter a voluntary agreement with the government and establish energy saving and GHG emission reduction targets that are effective for 5 years. Businesses that take part in this initiative are expected to introduce production systems with high energy efficiency. The Korean Government provides incentives for participation in the form of financial assistance, tax incentives, training, and technical support (Price 2005). In addition, participating businesses are showcased through the media to enhance their image (KEMCO 2009).

Voluntary initiatives also play a role in stimulating industrial energy efficiency improvements in Japan. The Japanese Iron and Steel Federation (JISF) has established the 'Voluntary Action Program for Environmental Protection by Steelmakers', which focuses on measures to reduce energy consumption and to recycle waste materials. Through this initiative, the Japanese steel industry is committed to reduce its energy use 10% below 1990 levels by 2010 (Geller *et al.* 2006).

In China, voluntary initiatives with industry are an important focus of the country's energy conservation efforts. Of greatest significance is the Top-1000 programme, which has the aim of saving 100 million tonnes of coal equivalent by 2010 (Andrews-Speed 2009) (see Box 8.7).

Box 8.7. China's Top-1000 programme

The Top-1000 Energy-Consuming Enterprises programme is one of China's key initiatives for achieving its ambitious goal of reducing the country's energy consumption per unit of GDP by 20% between 2005 and 2010. It is a voluntary agreement between the government and 1008 of China's highest energy-consuming enterprises and was launched in April 2006. Included in the Top-1000 programme are large-scale enterprises in nine major energy-consuming sectors, including iron and steel, petroleum and petrochemicals, chemicals, and electric power generation. Together, these enterprises account for approximately one-third of China's energy consumption.

The overall goal of the programme is to significantly improve the energy efficiency of all participating enterprises. Enterprises that have signed up to the programme were expected to realize joint savings of 100 million tonnes of coal equivalent (Mtce) between 2006 and 2010. This overall programme target has been broken down to the provincial level. All participating enterprises have signed energy conservation agreements with local governments and are expected to formulate energy conservation plans and efficiency goals, establish reporting and audit systems, and conduct training. They are also required to report their energy consumption by fuel on a quarterly basis.

Due to data confidentiality issues, it has been difficult to undertake a detailed analysis of the reported progress of the Top-1000 programme. According to China's National Development and Reform Commission, participating industrial enterprises have so far invested over $7.3 billion in technology innovation and implemented over 8000 energy-saving projects. It has also been reported that the Top-1000 programme saved 20 Mtce in 2006 and 38 Mtce in 2007, which indicated that it was well on track to achieve its overall target in 2010.

(Sources: NDRC 2008; Price *et al.* 2010; Zhou *et al.* 2010)

Opinions differ concerning the effectiveness of voluntary initiatives to achieve environmental outcomes. On the one hand, voluntary initiatives are more flexible than traditional regulatory instruments. Geller *et al.* (2006) found that voluntary agreements between governments and the private sector can be effective, especially in situations where regulatory instruments are difficult to enact or enforce. In Europe, for example, voluntary agreements have led to significant reductions in industrial energy use in a number of countries.

On the other hand, evaluations of experience with voluntary agreements show that results have been varied, with some programmes appearing to just achieve business-as-usual savings or to have weak targets (Price 2005). For instance, a review of the use of voluntary approaches in environmental policy found that in many cases voluntary initiatives did not contribute to environmental improvements significantly different from what would have happened anyway (OECD 2003). Agreements that are completely voluntary in nature have less government pressure for participation, along with fewer incentives and no penalties. As a result, most programmes that fall within this category show lower participation rates and weaker results (Price 2005).

In contrast, voluntary initiatives usually work well when people also have another incentive to change their behaviour. It is believed that voluntary initiatives are likely to be more effective if there is a threat of command-and-control regulation being put into use (Bengtsson *et al.* 2010). For instance, Price (2005) found that initiatives that combine voluntary efforts with a mix of incentives and penalties have higher participation rates and are generally more successful at meeting their predetermined targets.

Management standards, such as the ISO 14000 series, can also be understood as a voluntary initiative. Although such standards are not policy tools in a strict sense, they can be used by policy makers, for example, by requiring that all major suppliers to governmental agencies be certified. In addition, ISO 14000 environmental management systems require the certificate holder to identify key indicators of environmental impacts, to set targets, and to follow up achievements (Bengtsson *et al.* 2010).

Firm-based environmental standards are also emerging as an important influence on the environmental performance of industry in the Asia-Pacific region. These standards uniformly apply to all plants worldwide and are not tied to the local regulatory requirements of the place where they are located. This typically means that a plant is required to go beyond compliance with local and national standards in order to meet firm-based global environmental standards (Angel and Rock 2005). Economic globalization is the key underlying driver for firm-based environmental standards. There is also growing external pressure on firms and industries around environmental issues and firms face the risk of damage to brand reputation (Angel and Rock 2005). Today, firms are challenged with managing complex global production networks at multiple sites of production with different regulatory expectations and with a need to respond to a variety of end-market regulations (Angel *et al.* 2007). As a consequence, firms are adopting their own global environmental standards as a necessary way to operate their global production networks (see Box 8.8).

Box 8.8. Firm-based environmental standards in Thailand's cement industry

The cement industry is a very energy-intensive and pollution-intensive industry, responsible for large amounts of GHG emissions and air pollution. Several of the larger multinational cement firms have moved to establish a set of firm-based global environmental standards, which include uniform approaches to managing and reporting energy use and pollution emission.

The case study cement firm in Thailand operates six cement plants with a total production capacity of about 12 million tonnes of cement per year. In 1999, a European-based building conglomerate acquired the largest ownership stake in the firm. The European-based conglomerate operates 129 cement plants in more than 30 countries around the globe and maintains various forms of firm-based global environmental standards. These range from standardized management and reporting practices to performance standards for energy use and emissions.

The conglomerate uses a standardized set of economic and environmental performance metrics that all plants must report on. Other standards relate to GHG emissions and the use of alternative fuels. The conglomerate as a whole has a stated target of reducing CO_2 emissions by 20% from the firm's baseline emissions in 1990 by the year 2010. All plants are required to follow a prescribed methodology to calculate and report CO_2 emissions, to develop a plan for reducing emissions, and to increase the use of waste materials as a source of fuel.

The introduction of firm-based global environmental standards had significant impacts upon the Thai cement plant. For instance, the standards led to the introduction of computer-based, real-time monitoring of emissions, along with specific protocols for calculating and reporting air emissions and GHG emissions. The conglomerate helped the Thai plant to prepare a plan to reduce CO_2 emissions, which resulted in a 12% reduction in carbon-emissions intensity by 2005. Furthermore, the Thai firm was able to benchmark their own environmental performance because it had access to standardized performance information for other plants operated by the conglomerate. In addition, the firm introduced a standardized alternative fuels and raw materials programme, which resulted in a dramatic increase in the use of alternative fuels and raw materials. Finally, the Thai plant has been able to bid on intra-firm contracts to provide technical assistance to other plants within the firm network. In 2002, the Thai plant earned over $10 million through providing technical assistance to other plants operated by the conglomerate.

Overall, the implementation of firm-based global environmental standards has proven to be a successful approach to performance-based continuous improvement. Intra-firm benchmarking served as a platform for firm-wide learning, creating an intra-firm marketplace for technical assistance. Statistics provided by the firm in 2010 indicate that their efforts have successfully reduced GHG emissions and energy usage. The cement firm in Thailand has developed into one of the highest energy efficient cement plants worldwide due to the firm-based environmental standards of its global production network.

(Sources: Angel and Rock 2005; The Siam Cement Group 2010)

National policies to promote resource efficiency

Material efficiency

Material efficiency can be defined as the amount of a material needed to produce a particular product. Material efficiency can be improved either by reducing the amount of the material contained in the final product (called 'lightweighting') or by reducing the amount of material that enters the production process but ends up in the waste stream. Numerous countries in the Asia-Pacific region have implemented national policies to promote material efficiency (see Table 8.2). Japan, China, and the Republic of Korea, in particular, have introduced comprehensive policies and legislation to reduce waste and resource consumption and to increase recycling.

Japan is considered to be a leader in the field of resource efficiency and dematerialization (Bahn-Walkowiak *et al.* 2008). In the early 1990s, Japan began to introduce specific laws to promote the wiser use of resources and minimize the environmental impacts of consumption. These laws include the *Law for the Promotion of Utilisation of Recycled Resources 1991* and the *Containers and Packaging Recycling Law 1995*. In 2000, the Japanese government made the strategic decision to create a sound material-cycle society, which involves reducing the consumption of natural resources and environmental loads. The *Fundamental Law for Establishing a Sound Material-Cycle Society 2000* is a framework law that introduced the basic principles for a sustainable Japan. According to this law, a recycling oriented society is one that minimizes the environmental impacts of human activities while streamlining the use of natural resources by promoting waste reduction, reuse of recycled resources, and appropriate disposal (Yabar 2009).

The Fundamental Plan for Establishing a Sound Material-Cycle Society was adopted by the Japanese Cabinet in 2003 to implement measures that would lead to more sustainable patterns of production and consumption. The plan also sets quantitative national targets on resource productivity, cyclical use rate and final waste disposal amount. The plan was reviewed after 5 years and the Second Fundamental Plan for Establishing a Sound Material-Cycle Society was approved in 2008. The second fundamental plan has set the following targets for the fiscal years 2000–2015 (Ministry of the Environment (Japan) 2008b):

- resource productivity (GDP/direct material input): 60% improvement
- cyclical use rate (total used and recycled material input/material input): 40–50% improvement
- amount of final disposal: 60% reduction

A number of specific product laws have also been enacted to supplement the *Fundamental Law for Establishing a Sound Material-Cycle Society 2000*. These include laws on containers and packaging, home appliances, construction materials, food wastes, vehicles, and green procurement (see Figure 8.4).

Since the introduction of this legislative framework, Japan has made substantial progress in achieving greater recycling rates, while reducing final disposal amounts and dioxin emissions. For instance, after the introduction of these product-oriented recycling Acts, the amount of waste for final disposal in 2005 was 44% lower than in the year 2000.

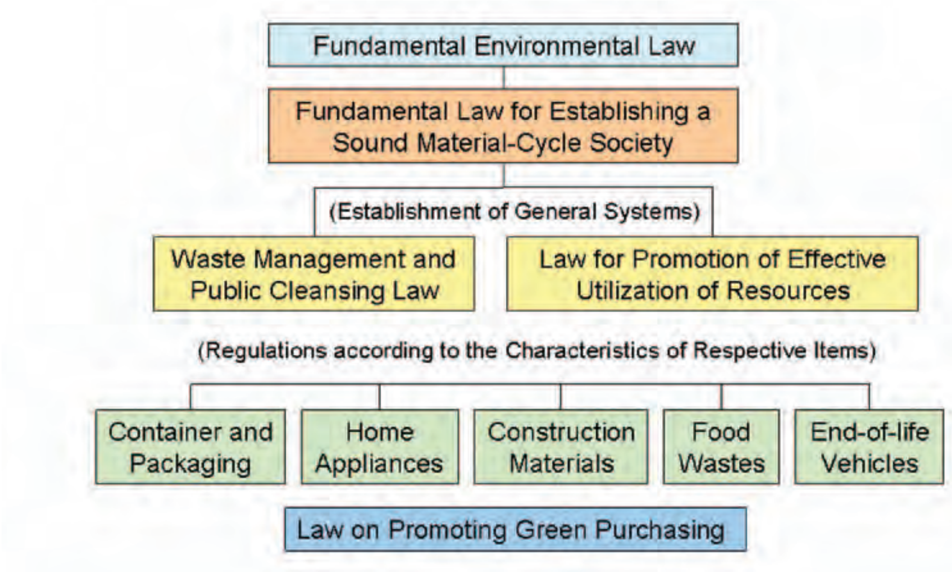


FIGURE 8.4. *Legislative framework to establish a sound material–cycle society in Japan (after Ministry of the Environment (Japan) 2008b)*

Japan is also actively promoting the 'reduce, reuse and recycle' (3R) concept through close cooperation with international organizations and policy dialogue with governments from other countries. Japan introduced the 3R initiative officially at the G8 summit held in 2004 in the United States. Japan has also helped other countries by engaging in policy dialogue and considering their needs through frameworks such as the Tripartite Environment Ministers Meetings between China, Japan and the Republic of Korea (Takiguchi and Takemoto 2008). Japan also strives to promote the establishment of sound material-cycle societies internationally by disseminating state-of-the-art mechanisms and technologies.

Material efficiency has also developed into an important issue for the Chinese Government, which introduced the circular economy concept to deal with environmental degradation and resource scarcity associated with rapid economic development. China recently introduced a framework law that provides a policy basis for the development of a circular economy. The *Circular Economy Law (2008)* requires low energy consumption, low emissions of pollutants, and minimal waste discharge, using the 3R principles. The law recognizes that the development of a circular economy is an important strategy for the economic and social development of China. Industrial enterprises are required to reduce resource consumption and recycle waste materials. China's government also allocates funds to businesses to encourage innovation in recycling technologies. Furthermore, the central government provides tax breaks to enterprises using energy-efficient technologies and equipment. The *Circular Economy Law* also includes provisions about the use of hazardous materials and energy inefficient technologies, through which companies can be fined from 50,000 to 200,000 RMB (approximately US$7,500 to US$30,000). Enforcement of the *Circular Economy Law* requires the enactment of supporting regulations. Some of these have been enacted while others are still being drafted. Another important future step outlined in the law is the development of a Circular Economy Development Plan, which will outline the major tasks and measures necessary to achieving a circular economy. In addition, it will define indicators for rates of waste reuse and recycling.

The Republic of Korea is another country that has implemented a number of national policies to increase material efficiency in the Asia-Pacific region. The *Act on the Promotion of Saving and Recycling of Resources (1992)* seeks to contribute to the preservation of the environment and sound development of the national economy by facilitating the use of recycled resources and by reducing the generation of wastes and facilitating recycling. It also includes product design provisions for vehicles and electrical goods. Producers of these goods are required to consider ways to use less material, adopt recyclable materials, curb the use of hazardous substances, reduce product weight, and make products easier to dismantle (KLRI 1997).

The government of the Republic of Korea also introduced a mandatory 'extended producer responsibility' (EPR) system through amendments to the *Act on the Promotion of Saving and Recycling of Resources* in 2003. The EPR system applies to a specified list of products and packaging materials and imposes continuing accountability on producers over the entire life cycle of their products. Under the EPR system, the government of the Republic of Korea sets mandatory take-back and recycling requirements for each product and producers pay fees to join organizations that handle all of the collection and recycling obligations. Producers that do not meet their obligations are penalized (Walls 2006). Other policy initiatives by the government of the Republic of Korea to promote material efficiency include volume-based waste collection (see Box 8.9), regulations for promoting recycling of construction waste, and an NGO campaign to reduce food waste (Yoshida *et al.* 2007).

Box 8.9. The Republic of Korea's volume-based waste fee system

The government of the Republic of Korea introduced a volume-based waste fee system in 1995 in order to reduce waste generation at the source and maximize waste recycling. Households and small commercial operators are required to purchase designated bags to throw away their garbage and a waste collection fee is charged in proportion to the amount thrown away. This way, the public has an incentive to generate less waste to minimize costs. The cost for waste treatment is recovered from the sale of the designated bags. The average price for a 20 L garbage bag was US$0.38 in 2004.

To avoid the illegal dumping or burning of waste, a fine of up to US$1,000 is imposed on the violator. The government has also introduced a reward system for reporting illegal dumping activities. Anyone who reports such an activity is paid as much as 80% of the fine charged to the violator. These measures have successfully reduced illegal dumping in urban areas. However, burning of waste by rural residents and dumping in public gardens and rivers are problematic and the government of the Republic of Korea is currently devising new strategies to monitor and prevent these activities.

After 10 years of implementation, the system has proven to be very successful in reducing the generation of municipal solid waste and increasing the recycling rate. Between 1994 and 2004, municipal solid waste generation decreased by nearly 14%. In the same time period, the national recycling rate increased from 15.4% to 49.2%.

(Source: Ministry of the Environment (Republic of Korea) 2006)

Table 8.2. Examples of national policies, laws and regulations to promote material efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
Australia	National Waste Policy (2010) • Aims to avoid the generation of waste, to reduce the amount of waste for disposal and to manage waste as a resource
China	*Circular Economy Law (2008)* • Promotes the development of a circular economy, improving resource utilization efficiency, protection and improving the environment and realizing sustainable development • Refers to the reduction, reuse, and recycling of resources during production, circulation and consumption
	Environmental industrial park policy • Established about 30 pilot eco-industrial parks
	Solid Waste Act (1995), amended in 2004. • Establishes a legal framework for product take-back and recycling
	Regulation on the Management of Electronic Waste ('China WEEE') (draft, scheduled to enter into effect in 2011) • Regulates the mandatory recycling and treatment of waste electrical and electronic appliances (televisions, refrigerators, washing machines, air conditioner and computers) • Intends to promote the circular use of resources
	Law Promoting Cleaner Production (2002) • One objective is to raise the efficiency of using resources
	Opinions of the State Council on Accelerating Development of Circular Economy (2005) • Proposed the objective, targets, major works, and guidance for development of a circular economy in China
India	Municipal Solid Waste Rules (2000) • Obliges municipalities to segregate organic from household waste to treat by composting, etc.
	National Environmental Policy (2006) • One key objective is the efficient use of environmental resources by reducing use per unit of economic output • Proposes actions for recycling and reuse of waste
	Plastic Manufacture and Usage Rules (2003) • Development of plastic recycling – amount recycled: 1.7 million tonnes (2004–05)
Japan	*Fundamental Law and Plan for Establishing a Sound Material-Cycle Society (2000 and 2003; amended 2008)* • Framework law and implementation programme to move the country toward a recycling-based approach in product design, manufacture, use and disposal • Established targets to be achieved by 2015 for resource productivity, cyclical use rate, and the amount of final disposal
	Individual product laws have set up targeted recycling regimes for • containers and packaging • home appliances • food waste • construction materials • end-of-life vehicles

Table 8.2. Examples of national policies, laws and regulations to promote material efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
Japan	*Law on Promoting Green Purchasing (2002)* *Law for Promotion of Effective Utilisation of Resources (2006)* (deals with battery take-back, labeling and reuse) *Waste Management and Public Cleansing Law (2003)*
Malaysia	*Solid Waste and Public Cleansing Management Act (2007)* • Aims to improve the collection, recycling and disposal of solid waste • Prescribed recycling and separation of recyclables
	National Strategic Plan for Solid Waste Management (2005) • Comprehensive efforts to promote the reduction, reuse and collection of solid waste
New Zealand	*Waste Minimisation Act (2008)* • Encourages waste minimization and a decrease in waste disposal • Requires product stewardship schemes for priority products • Puts a levy on all waste disposed of in landfills • Introduces a waste minimization fund to provide financial assistance for projects that increase resource efficiency
	New Zealand Waste Strategy (2002) • Zero waste concept is the long-term goal • One major goal of this strategy is to increase economic benefit by using material resources efficiently • Contains 30 aspirational targets for improved waste management, minimization and resource efficiency
Pakistan	National Environmental Policy (2005) • Encourages the reduction, recycling, and reuse of municipal and industrial solid and liquid wastes
Philippines	National 3R policies • Set the goal of achieving a waste conversion rate of at least 25% by 2006
	Ecological Solid Waste Management Act (2000) • Mandates management for 'zero waste' as a national policy • Requires local government to recycle 25% of waste collected
The Republic of Korea	*Waste Management Act (1995)* • Volume-based waste collection • Extended producer responsibility for electronic appliances and vehicles with mandatory targets for product recovery and recycling
	Act on the Promotion of Construction Waste Recycling (2003) • Construction work contracted by a public agency must use more than a certain level of recycled aggregate
	Act on the Promotion of Saving and Recycling of Resources (1992), amended in 2003 • Promotes the efficient use of resources, waste prevention, and resource reutilization towards improving environmental conservation • Amendments to the Act introduced mandatory EPR scheme

Table 8.2. Examples of national policies, laws and regulations to promote material efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
The Republic of Korea	Second Comprehensive National Waste Management Plan (2002–2011) • National framework for the promotion of waste reduction policies • Includes waste reduction and recycling targets (e.g. increase recycling by 53% by 2011)
Singapore	Green Plan 2012 • Has a 'zero landfill' objective • Includes a national recycling programme for households launched in 2001 with target of 60% recycling by 2012 • The recycling rate in 2009 was 57%, up 16% from 2000
	Sustainable Development Blueprint (2009) • Aims to attain a recycling rate of 70% by 2030
Viet Nam	National 3R Strategy • Sets 3R targets for 2020
	Environmental Protection Law (2005) • Includes 14 provisions to promote 3R and other related activities

(Sources: MEWR 2002; MEF 2009; MEWR 2009; New Zealand Government 2009b; National Environment Agency (Singapore Government) 2011)

Energy efficiency

Governments should exploit energy efficiency as their energy resource of first choice because it is the least expensive and most readily scalable option to support sustainable economic growth, enhance national security, and reduce further damage to the climate system (Expert Group on Energy Efficiency 2007)

According to the World Energy Council (2008), energy efficiency includes all changes that result in decreasing the amount of energy used to produce one unit of economic output (e.g. the energy used per unit of GDP). Energy efficiency is associated with economic efficiency and includes technological, organizational, and behavioural changes.

The introduction of energy efficiency policies brings multiple benefits to national economies. First, it prepares economies for the increasing cost of energy and limits the macroeconomic impacts of oil price fluctuations. Second, it increases competitiveness by reducing energy costs. Third, it enhances economic development and reduces energy shortages (World Energy Council 2008). In most economies of the Asia-Pacific region, energy efficiency improvements can defer the need for huge investment to expand the energy supply and meet demand growth. Importantly, improving energy efficiency has been recognized worldwide as one of the most important means to reduce GHG emissions. For instance, the IPCC (2007) clearly demonstrated that energy efficiency policies play a critical part in cost-effective strategies for reducing CO_2 emissions.

The 2007 Darwin Declaration is one of the latest cooperative efforts by countries in the Asia-Pacific region to promote the use of cleaner energy and to improve energy efficiency and conservation. It requires countries in the Asia-Pacific region individually to set energy efficiency goals and design future plans to enhance the overall energy efficiency of their economies. It also maintains that energy working groups (EWG) of the Asia-Pacific region should collaborate with the International Energy Agency (IEA) to develop energy efficiency indicators and identify best practices to be followed by others (APEC 2007).

In 2007, the Asia-Pacific Economic Cooperation (APEC) Peer Review on Energy Efficiency (PREE) was formed to promote information sharing among APEC members on energy efficiency performance and on policies and measures for improving energy efficiency. Participation in PREE is voluntary. Countries that choose to participate are encouraged to undergo a voluntary peer review of their energy efficiency efforts. So far, New Zealand and Viet Nam have been the first two countries in the Asia-Pacific region to be assessed by a team of energy efficiency experts (APEC 2009a, 2009b). In the case of New Zealand, the review team was impressed with the level of attention and resources allocated to energy efficiency policies and programmes by the New Zealand Government. A few recommendations were made to apply slight corrections to the existing policy regime (APEC 2009a).

The review of Viet Nam's energy efficiency efforts found that the country had strengthened its policy framework on energy efficiency improvements since 2006. Efforts to enhance institutional capacity were achieved through the creation of Viet Nam's Energy Efficiency and Conservation Office. This agency is tasked to formulate, develop and implement energy efficiency and conservation policies and programmes. However, the review team identified a gap between the planning and the implementation of energy efficiency improvement programmes, mainly due to a lack of information and data for an effective monitoring and evaluation system. The review team made several recommendations to enhance the efforts of the Vietnamese government in achieving greater energy efficiency (APEC 2009b).

Energy efficiency improvements have been lauded by almost all countries of the Asia-Pacific region as one of the quickest and most cost-effective pathways to achieve sustainable energy development. Energy efficiency measures are aimed at lowering energy intensities in particular sectors or the economy as a whole. In the context of increasing energy prices and growing import dependency, energy efficiency measures are considered strategically important and are being vigorously undertaken by almost all economies in the Asia-Pacific region at both government and business levels.

At government level, the promotion of energy efficiency is typically undertaken through energy conservation policies and financial incentives. Major legislation on energy efficiency exists in China (the *Energy Conservation Law* last amended in 2007), India (the *Energy Conservation Act 2001*), Japan (the *Energy Conservation Law*, last amended in 2008), New Zealand (the *Energy Efficiency and Conservation Act* 2000), and Thailand (the *Energy Conservation Promotion Act*, last amended in 2007). These laws are generally comprehensive and involve many sectors from industry to households (ESCAP 2008a). The range of policy measures adopted through such legislation includes: mandatory stipulations to use clean energy technologies and phase out programmes for obsolete energy-intensive equipment (China); energy conservation standards and labelling requirements for industrial equipment and energy audits for energy intensive factories (India); economic incentives for the efficient use of energy and the development of clean energy technologies (Japan); mandatory energy performance standards and mandatory disclosure of data in relation to energy efficiency (New Zealand); and regulatory frameworks for energy efficiency and conservation investment in factories across different sectors under public–private partnership audit programmes (Thailand).

Over the past decade, India has put great effort into improving its energy efficiency. This began with the *Energy Conservation Act 2001* mentioned above, followed by the creation of the Bureau of Energy Efficiency (BEE) in 2002. The BEE is a separate entity that oversees energy efficiency improvements in the country. It has recently developed the Action Plan for Energy Efficiency. Furthermore, a number of initiatives have been introduced to promote energy efficiency in India. These include:

- the Bachat Lamp Yojana Scheme – voluntary effort to replace incandescent bulbs in households with energy efficient and high-quality compact fluorescent lamps
- the Standards and Labelling Scheme – minimum energy performance standards for appliances and equipment. It includes mandatory labelling, awareness raising campaigns to educate consumers and others
- the Energy Conservation Building Code – sets minimum energy performance standards for new commercial buildings
- the Agricultural and Municipal Demand Side Management Programme – replacement of inefficient pumps, street lighting
- promoting energy efficiency in small and medium-sized enterprises

In 2009, the BEE was asked to prepare the implementation plan for the National Mission on Enhanced Energy Efficiency (NMEEE) as part of the country's Action Plan on Climate Change. NMEEE represents one of eight long-term, integrated strategies for achieving key goals in the context of climate change. NMEEE introduces four new initiatives to enhance energy efficiency in India:

- a market-based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded ('Perform Achieve and Trade' scheme)
- accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable ('Market Transformation for Energy Efficiency' MTEE)
- creation of mechanisms that help finance demand side management programmes in all sectors by capturing future energy savings ('Energy Efficiency Financing Platform' EEFP)
- developing fiscal instruments to promote energy efficiency ('Framework for Energy Efficient Economic Development' FEEED)

Box 8.10. Energy efficiency in Indian industries

The industry sector in India accounts for about 45% of total commercial energy consumption in the country (96.21 million tonnes of oil equivalent (Mtoe)). It is one of the largest contributors to CO_2 emissions after the power sector. A broad analysis of industrial energy-use patterns shows that about 60% of industrial energy consumption is accounted for by seven sectors namely: (1) cement; (2) pulp and paper; (3) fertilizer; (4) iron and steel; (5) textiles; (6) aluminum; and (7) chlor-alkali. Most of the plants in these sectors are large units, few of them operating under the public sector. These sectors have been included as 'designated consumers' by the Bureau of Energy Efficiency (BEE) under the *Energy Conservation Act 2001* (nearly 750 such consumers are identified by BEE). Although detailed baseline energy consumption data for industrial consumers is not available from a single source, it has been found from several individual studies that significant potential exists for energy efficiency improvements in industry. Various energy sector studies also show that there are wide variations in specific energy consumption (energy required to produce one unit of the product) within the same industrial sub-sector using comparable technology. Though some units exhibit energy efficiency levels that are at the global frontier, a large number of units operate at much lower energy efficiencies. This indicates that there is substantial scope for energy efficiency improvements within an industrial sector.

For example, the specific thermal energy consumption for modern cement plants is as low as 663 kcal/ kg (2,775 kJ/kg) clinker and for old plants is as high as 900 kcal/kg (3,768 kJ/kg) clinker. Similarly, the specific power consumption of some of the modern cement plants is around 65 kWh/ tonne cement, whereas this figure is close to 90 kWh/tonne cement for old plants. India's National Action Plan on Climate Change estimates that various schemes and programmes initiated by the Government of India would result in an energy saving of 10,000 MW in various sectors of the Indian economy by the end of 11th Five-Year Plan in 2012.

Source: Mishra and Sarangi 2010

Singapore has developed a national plan to promote energy efficiency. The Energy Efficient Singapore strategy focuses on promoting the adoption of energy efficient technologies and measures by removing market barriers to energy efficiency. At the same time, the strategy seeks to build capacity and develop the local knowledge base and expertise in energy management. Raising awareness among the public and businesses is used to stimulate energy efficient behavior and practices (Government of Singapore 2009).

Australia has no specific energy efficiency law. However, governments at the national and state level have implemented a number of energy efficiency policies. The National Framework for Energy Efficiency was introduced in 2004 with the aim of implementing a number of energy efficiency packages. Stage 1 of the initiative primarily focused on removing the barriers to the uptake of energy efficiency in areas such as building, industry, and appliances and equipment (MCE 2004). Stage 2 of the initiative commenced in 2008 and includes five new energy efficiency measures:

- expanding and enhancing the Minimum Energy Performance Standards (MEPS) programme for electrical appliances and equipment such as white goods, home entertainment units, water heaters, air conditioners, and computers
- introducing a heating, ventilation, and air conditioning high efficiency system strategy
- phasing-out incandescent lighting in the residential sector
- providing government leadership to stimulate energy efficiency in buildings through green leases
- developing measures for a national hot water strategy to improve the energy efficiency of water heaters.

The Republic of Korea has also introduced a number of policies and strategies to increase energy efficiency. According to President Lee Myung-bak, the vision for the country is one of 'green growth as a means of national development'. The National Basic Energy Plan (2008–2030) calls for increased energy efficiency and sets an energy efficiency target in terms of reduced energy intensity and reduced energy consumption. For 2030, the target is a 46% reduction in energy intensity (from the current level of 0.341 tonnes of oil equivalent (Toe)/US$1,000 to 0.185 Toe/US$1,000). Energy consumption is targeted to be reduced by 42 million Toe within the same time period. The country's Green Energy Industry Development Plan seeks to improve energy efficiency and promote energy conservation. Furthermore, the government provides support for research and development in green technologies.

Table 8.3 provides an overview of national policies that have been implemented in countries of the Asia-Pacific region to promote energy efficiency.

Table 8.3. Examples of national policies, laws and regulations to promote energy efficiency in selected countries in Asia and the Pacific

Country	Policy detail
Australia	National Framework for Energy Efficiency (Stage 1 in 2004; Stage 2 in 2008) • Stage 1: Addressing the barriers to the uptake of energy efficiency • Stage 2: Implementing energy efficiency measures
	National Strategy on Energy Efficiency (2009) • Provides for a nationally consistent and coordinated approach to energy efficiency by transitioning Australia into a low carbon economy and by reducing barriers to the uptake of energy efficiency
	Energy Efficiency Opportunities Act (2006) • Encourages large energy-using businesses (those using more than 0.5 PJ of energy per year) to improve their energy efficiency by identifying, evaluating and publicly reporting on cost effective energy savings opportunities
China	11th Five-Year Plan (2006-2010) • Target to reduce energy consumption per unit of GDP by 50–60% from 2000 levels by the year 2020
	Energy Conservation Law (1998), amended in 2008 • Seeks to encourage the rational use of energy and promote improvements in energy conservation technologies • Includes energy efficiency labelling scheme and establishment of energy conservation audit facilities in local governments

Table 8.3. Examples of national policies, laws and regulations to promote energy efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
China	National Climate Change Programme (2007) • Proposes a range of measures to improve energy efficiency and energy conservation • Includes energy efficiency objective of reducing energy consumption per unit of GDP by 20% by 2010
	Procurement Policy for Energy Efficient Products (2004) • Requires government agencies to give priority to products that are certified as energy-efficient in the procurement process
India	*Energy Conservation Act (2001)* • Legal mandate for the implementation of energy efficiency measures • Programmes are anticipated to result in a saving of 10,000 MW by the end of 2012
	National Mission for Enhanced Energy Efficiency (2008) • As part of the National Action Plan on Climate Change, this national mission proposes four new initiatives (1) market-based mechanism for trading in certified energy savings, (2) accelerating the shift to energy efficient appliances in designated sectors (3) demand side management programmes and (4) developing fiscal instruments to promote energy efficiency
	National Energy Efficiency Plan (approved August 2009) • Will set up energy efficiency targets for industry by December 2010
	Other initiatives for improved energy efficiency • Energy Conservation Building Code (2007) • Mandatory energy audits of large industrial consumers (2007) • Enhancing efficiency of power plants • Introduction of mandatory energy labelling programme for appliances (2006) • Electricity from renewable sources such as wind power and hydro (National Hydro Energy Policy) • Clean Air Initiative • 'Bachat Lamp Yojana' programme to promote energy saving devices
Indonesia	National Energy Policy (2006) • Framework policy that seeks to increase energy efficiency and promote renewable sources of energy
	Government Regulation on Energy Efficiency (draft only)
Japan	*Energy Conservation Law (1979)* last amended in 2008 • Provides the legal framework for improvements in energy efficiency and conservation • Regulatory measures include: a. Businesses need to report energy use, employ an energy manager and prepare energy conservation targets b. Transport service providers need to prepare energy conservation plans c. Manufacturers need to enhance energy consumption efficiency of products d. Building sector needs to implement energy conservation measures e. Energy conservation labelling programme for air-conditioners, televisions and refrigerators

Table 8.3. Examples of national policies, laws and regulations to promote energy efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
Japan	Energy and Environment Policy • Includes measures for improved energy resource use efficiency and diversification of energy resources
	National Plan for Promoting Energy Efficiency and Conservation • Aims to improve energy efficiency by at least 30% from 2003 levels by 2030
Kazakhstan	*Law on Energy Saving (1997)* • Focuses on the economic and organizational requirements for the efficient use of fuel and power generation and for environmental protection • Contains provisions for the development of energy efficient equipment, products and advanced technologies
Malaysia	The Ninth Malaysia Plan: 9MP (2006–2010) • Includes energy efficiency objectives such as: • a) intensifying energy efficiency initiatives in industry, transport, and commercial sectors • b) promoting greater use of renewable energy for power generation and by industry
New Zealand	*Energy Efficiency and Conservation Act (2000)* • Legislative basis for promoting energy efficiency and renewable energy in the country • Provides for establishment of mandatory energy performance standards and mandatory disclosure of data in relation to energy efficiency
	Energy Efficiency and Conservation Strategy (2007) • Detailed action plan for increasing the uptake of energy efficiency, conservation and renewable energy programmes across the economy and to make doing so part of the normal behaviour of New Zealanders • Programmes in this strategy seek to achieve a number of targets (e.g. 90% of electricity generated from renewable sources by 2025) • Programmes are expected to achieve 30 PJ of savings in non-transport energy per year by 2025 and 20 PJ of energy savings in the transport sector by 2015
Pakistan	National Environmental Policy (2005) • Promotes energy efficiency and renewable sources of energy • Gives preferential status and tax incentives to energy efficient domestic products and imports
Philippines	National Energy Efficiency and Conservation Program (2004) • Seeks to achieve the efficient use of energy to minimize environmental impact • Target to achieve an average annual energy savings of 23 million barrels of fuel oil equivalent and 5,086 Gg CO_2 emissions avoidance

Table 8.3. Examples of national policies, laws and regulations to promote energy efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
Singapore	Energy Efficient Singapore Strategy (2009) • Promotes the adoption of energy efficient technologies and measures by addressing market barriers to energy efficiency • Builds capacity to drive and sustain energy efficiency efforts and to develop the local knowledge base and expertise in energy management • Raises awareness among the public and businesses so as to stimulate energy efficient behaviour and practices • Promotes research and development to enhance Singapore's capability in energy efficient technologies
	Sustainable Development Blueprint (2009) • Aims to achieve a 35% improvement in energy efficiency from 2005 levels by 2030
The Republic of Korea	National Basic Energy Plan (2008–2030) • Calls for increased energy efficiency • Energy intensity target: 46% reduction by 2030 from current levels • Energy consumption target: reduction of 42 million Toe by 2030 from current levels
	Rational Energy Utilization Act (revised in 2003) • Emphasizes the efficient use of energy and reduction of greenhouse gas emissions
Thailand	National Energy Strategy (2005) • Key component of the strategy was the efficient use of energy to reduce energy consumption by 13% in 2008 and 20% in 2009
	Energy Conservation Promotion Act (1992), revised 2007 • Promotes the use of energy efficient materials and equipment by setting energy efficient standards
	National Energy Policy and Development Plan (2006) • Seeks to promote energy efficiency by setting standards for energy-intensive appliances and labelling of products
Viet Nam	National Energy Efficiency Program (2006–2015) • Seeks to coordinate efforts for improving energy efficiency, reducing energy losses and implementing extensive measures for conservation of energy • Target to reduce total energy consumption by 3–5% (2006–2010) and then by 5–8% (2011–2015)
	Law of Energy Conservation and Efficiency Use (draft only)

(Sources: MCE 2004; ESCAP 2007; New Zealand Government 2007; ESCAP 2008a; Government of India 2008; ECCJ 2009; MEF 2009; MEWR 2009; APEC 2009b)

Water efficiency

Water security is a rapidly growing issue in the Asia-Pacific region brought on by increasing demand for water, drought, and depletion and contamination of surface and groundwater (ADB 2003, UNEP 2008a, UNEP 2008b, UNEP 2009b, UNEP 2011c). Demographic growth, urbanization and economic development are putting unprecedented pressure on renewable, but finite, water resources and will continue to do so (UNESCO 2009, FAOWATER 2010a). Poor access to water and sanitation, the impact of water-related diseases, degraded ecosystems, and inefficient irrigation practices continue to dampen economic development in many nations of the Asia-Pacific region (E-Network 2010). Globally, there have been concerted efforts to remedy the shortage of water by providing financial and technical assistance for water desalination, treatment of wastewater, and improved management and conservation techniques (Alsharhan and Wood 2003). Water efficiency is seen as one of the best options to deal with water shortages in the region.

Water use efficiency is the reduction in water use per unit of any given activity while water quality is maintained or enhanced (Billi *et al.* 2004). It seeks to minimize human impacts on the quantity and quality of water resources while meeting socio-economic demands for water (ESCAP 2007). Because the quality and quantity of water resources are positively correlated, it is important to consider both issues simultaneously when improving efficiency in the water sector.

The achievement of economic efficiency occurs when water prices truly reflect the social costs of developing supplies, when the resource is used efficiently and rationally, and the contribution of water to production is correctly valued. In these circumstances, the forces of supply and demand to use the resources efficiently need to be supported by incentives and technological change. Optimization of water use occurs through consideration of: (1) economic efficiency – maximum economic benefit for society; (2) institutional efficiency – capacity of existing institutions; (3) social efficiency – fulfillment of the needs of the user community; (4) environmental efficiency – ecosystem function and natural resource conservation; and (5) technological efficiency – ways of extracting more valuable products from the same resource (Billi *et al.* 2004). These non-exclusive definitions of water use efficiency can be achieved simultaneously.

Economic efficiency in resource use is supported by the development of demand-side management policies, such as cost-recovery, environmental taxes, and water use permits tradeable on special markets (Billi *et al.* 2004). An important issue is establishing a dynamic balance between interventions in water supply and demand, taking into account the variability of supply in time and space, the changes in demand and the limits and opportunities of technology.

Water resource policies

Water policies are aimed at increasing water use efficiency, by reducing wasted water and managing water demand. Major inefficiencies of water use arise from *unaccounted-for-water*, which includes unmeasured water put to beneficial use (unmetered use) as well as water losses from the system. Examples of water losses include: illegal connections, reservoir seepage and leakage, reservoir overflow, leaks, evaporation, and malfunctioning distribution system controls (Californian Government Department of Water Resources 2010). Water policies also direct water demand management, determining the efficient allocation of water to meet growing demand for consumption.

Water resource policies are implemented through laws, regulations, subsidies, pricing, incentives, institutional arrangements, and major programmes and initiatives (Mayers *et al.* 2009). Although policies are primarily developed by governments, often institutions and non-governmental and private sectors assist in the development and implementation of water policies. Water resource policies can be scrutinized for effectiveness, efficiency, equity, and sustainability, particularly because the impacts of policy may be negative and positive, and are often implemented by various means such as compulsion, persuasion, or incentives (Mayers *et al.* 2009). Although it is beyond the scope of this chapter to evaluate individual water resource policies for countries and subregions, there is a generalized need for policies that tackle water security, improve water governance, and ensure greater investment in the delivery of water services into the future (E-Network 2010). International efforts for solving water problems and better enabling water policies include various United Nations initiatives such as the Millennium Development Goals, which aim to improve access to clean water and sanitation, the World Water Forum, the World Water Council, the Asia-Pacific Water Forum and the Network of Asian River Basin Organizations (NARBO) (Water Resources in Japan 2008).

Neighbouring countries often share responsibilities for water resource management, such as for the Mekong, Brahmaputra, and Ganges basins. Transboundary water treaties, multilateral agreements and international water laws are aimed at conflict resolution and provide directions for the possible improvement in cooperation over international water resources (Ma *et al.* 2008). The main challenges to harmonious transboundary water resource management are dealing with water shortages, pollution, and uncoordinated utilization by riparian states. To gain optimal utilization and effective protection of transboundary waters, IWRM techniques have been promoted (Transboundary Water Cooperation 2006). Transboundary water cooperation targets poverty reduction, natural resources protection, and crises and conflict prevention and resolution. For example, The Asian Development Bank is supporting IWRM-based developments in Viet Nam's Vu Gia-Thu Bon river basin: one of five target basins to benefit from long-term integrated river basin investment programmes (ADB 2010). In the Pacific Islands, integrated water resource management (IWRM)[2] has been adopted to guide water policy and legislation (SOPAC 2009).

Agricultural water use policies

The Asia-Pacific region is the world's largest consumer of water. The majority of water is withdrawn for use in agriculture, although increasingly water is allocated to industry and for domestic use. Water reform in the agricultural sector will require improved water management that achieves high water productivity, while sustaining communities, increasing food security, and maintaining rural incomes (FAOWATER 2010b).

To increase water efficiencies and water productivity, harmonization of regional trade agreements and adoption of good practices in product coverage, rules of origin, customs procedures, intellectual property protection, foreign direct investment, anti-dumping and dispute resolution, government procurement, competition, and technical barriers to trade is necessary (Rae 2007). Implementation of World Trade Organization procedures, safeguarding agricultural agreements by facilitating trade and meeting various international standards will contribute to the harmonization of regional rules and the rules of the multilateral system (Rae 2007).

2 Integrated management means that all the different uses of water resources are considered together. Water allocations and management decisions consider the effects of each use on the others and are able to take account of overall social and economic goals, for sustainable development.

Providing quality urban water resources

Water resource strategies are dominated by demand or supply management, in some cases by public acceptance (e.g. Australia), and are dependent on the system of governance, existing infrastructure and national wealth. Many cities and rural areas of the Asia-Pacific region are without effective sewerage systems, and with minimal pollution restraints on industry, water courses are often polluted. In these countries, water of uncertain quality is used for household and industrial water supplies, thereby contributing to poor human health, exposure to water-related diseases and high mortality rates from gastrointestinal diseases and waterborne vectors (World Health Organization 2006; FAOWATER 2010a). Many countries in the Asia-Pacific region are unable to provide adequate water efficiently or effectively, and are often dependent on international aid to provide cities and towns with access to reliable potable water supplies.

Urban water supply has become a critical issue for the rapidly expanding cities in the developing world and in regions where reduced precipitation has affected available water supplies. For example, the combination of population growth and declining water availability from prolonged drought has led to severe water restrictions in many of Australia's towns and cities. As a consequence, the federal government has initiated water reform policies and is investing in new water supplies, improving the management and delivery of urban water services, and allowing for greater innovation and more efficient water use (NWC 2009). Direct and indirect water reuse schemes, where the level of treatment of reused water is based on the degree of human contact with the water, has been undertaken in response to water shortages in many countries, such as Singapore, China, and Australia (PUB 2008; Water for Good 2009; WateReuse Association 2010). Successful water reuse initiatives now supply treated wastewater and stormwater for potable and non-potable use in some parts of Asia and in Australia (Po *et al.* 2003).

Box 8.11, below, provides an example of how one Australian community manages its water supply.

Box 8.11. Protecting water supplies in Mount Gambier, South Australia

In the rural City of Mount Gambier, South Australia, urban stormwater is directed via 400 bores into an unconfined aquifer that that flows into Blue Lake (Figure 8.5). The lake is the source of drinking water for the city and surrounding areas. Street cleaning regimes, passive stormwater retention basins and gross pollutant traps are used to manage pollutants, and maintain the quality of the untreated stormwater flowing directly into the township's water supply. There is an ongoing public education campaign, with emphasis on maintaining water quality through vigilance. The community has accepted their source of drinking water without protest for the last 120 years, unlike other communities who protest the inclusion of wastewater into potable supplies.

FIGURE 8.5. *Blue Lake, Mount Gambier, South Australia is the regional water supply and has been augmented by stormwater for the last 120 years. Constant vigilance by authorities and the community protects water quality and water supply.*

Source: Mount Gambier Tourism (2010)

There is enormous potential for increasing water use efficiency in many sectors and industries across the Asia-Pacific region. Effective policy and legal frameworks are necessary to develop, implement, and enforce rules and regulations for controlling water use. Several countries in Asia and the Pacific are engaging in reform, focusing on principles of integrated water resources management. (See Box 8.12 and Box 8.13 for more detailed examples.)

Box 8.12. Water efficiency policies in Australia

Australia is one of the driest continents on Earth and water shortages and the longer-term security of water supply are serious concerns for the country, despite the flood events of early 2011. Water scarcity in some regions of Australia is becoming increasingly acute, which has lead to a rapid implementation of policy actions in recent years.

The National Water Initiative (NWI) 2004 is a joint commitment by Australia's federal and state governments to make the country's water use more efficient and sustainable. The objectives of the NWI are to: (1) improve water security; (2) ensure ecosystem health; (3) encourage the expansion of water markets and trading; and (4) encourage water conservation through efforts such as using stormwater and recycled water. A central aim of the NWI is to implement policies that promote water use efficiency and innovation in both urban and rural areas. According to a recent review of progress in water reform, significant advances have been made in increasing the productivity and efficiency of water use in Australia. For example, several jurisdictions across the country have undertaken pricing reforms to provide incentives for individuals and businesses to conserve water (National Water Commission 2009).

The Australian Government introduced the mandatory Water Efficiency Labelling and Standards Scheme (WELS) in 2006 to help reduce domestic water consumption. The scheme covers a range of products, including shower heads, tap equipment, washing machines, dishwashers, and toilets. Industry must register these products and provide water efficiency information and star-ratings to consumers. It is projected that the WELS scheme will reduce domestic water consumption by 5% or 87,200 ML each year by 2021.

In 2008, Water for the Future (WftF) was launched as a national framework initiative to further advance the NWI. The Australian Government is investing A$12.9 billion over 10 years to deal with four key priority areas: (1) taking action on climate change; (2) using water wisely; (3) securing water supplies; and (4) supporting healthy rivers. WftF includes a range of investment programmes to promote water use efficiency. For instance, the On-Farm Irrigation Efficiency Program was launched in October 2009 and will provide financial assistance to irrigators to modernize their on-farm irrigation infrastructure. Another example is the Water Efficiency Opportunities Program, which was recently implemented to support and encourage water efficiency in Australia's commercial and industrial sectors. It provides best practice guides on water efficiency, checklists to self-assess water efficiency opportunities and step-by-step instructions for businesses considering options for wastewater reuse.

Source: (Australian Government 2009b; DEWHA 2009; National Water Commission 2009)

Box 8.13. Water management in Singapore

Singapore is a small but highly urbanized country that suffers from water scarcity due to limited natural freshwater sources. The country has an annual water consumption of about 500 GL. In 2008, per capita consumption was 165 L per day.

Since 1932, Singapore has depended on the southern Malaysian state of Johor to meet its water needs. However, in recent years, the government of Singapore has moved in the direction of reducing its reliance on outside sources and strengthening its own internal water supply capacities. The government has been very active in diversifying its water supply through major infrastructure projects, including the construction of desalination and wastewater reclamation plants.

Conservation is the other important cornerstone of Singapore's water management policy. Mandatory water-saving devices, water audits, and nation-wide education programmes are among the policy measures used to achieve conservation. Under the Singapore Green Plan, Singapore aims to lower per capita domestic water consumption to 155 L per day by 2012. Pricing has been used as a tool for managing water consumption. The government raised water tariffs for domestic consumers gradually between 1997 and 2000, bringing them into line with those for non-domestic users. A water conservation tax is charged when the water consumption of domestic users exceeds 40 m^3 (40kL) per month. These adjustments have resulted in a clear reduction in usage.

Singapore's most recent policy initiative to achieve greater water efficiency is the Sustainable Development Blueprint (2009). This strategy seeks to further reduce domestic water consumption, to 140 L per person per day by 2030. As part of this strategy, the government of Singapore recently introduced a mandatory water use efficiency labelling scheme. It applies to a range of water fittings, appliances, and products, including shower and basin taps, dual flush cisterns, and urinals.

(Sources: MEWR 2002; Kog 2004; Tortajada 2006; PUB 2010)

Table 8.4. Examples of national policies, laws and regulations to promote water efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
Australia	Water for the Future (2008) • A 10-year, A$12.9 billion strategic programme that seeks to use water wisely, take action on climate change, secure water supplies and support healthy rivers • Includes a range of programmes that promote water efficiency, including: (1) water efficiency opportunities for industry; (2) on-farm irrigation efficiency programme; and (3) funding for the development and uptake of smart technologies and practices in water use across Australia
	Water Efficiency Labelling and Standards Act (2005) • Requires certain water-using products to be labeled for water efficiency • Is expected to reduce domestic water use by 5% by 2021
	National Water Initiative (2004) • Seeks to increase the efficiency of water use in urban and rural areas • Includes provisions for managing urban water demand, preparing water plans, expanding the trade in water and improving pricing for water storage and delivery
Cambodia	*Law on Water Resources Management (2007)* • Water resources shall be managed and developed based on integrated water resource management (IWRM) • Incentives may be awarded to research and development initiatives that increase water use efficiency • Financial penalties are imposed on person breaching the provisions of the law (e.g. using water without securing a license)
China	*Water Law (2002)* • To rationally develop, use, conserve and protect water resources and to bring about sustainable utilization of water resources • Water use efficiency and conservation are a priority topic under the law
	11th Five-Year Plan (2006–2010) • Seeks to initiate a water saving society • By 2010, water use efficiency shall be improved significantly and water consumption per unit of industrial value added shall be decreased by 30% compared with 2005
India	National Environmental Policy (2006) • Proposes actions to enhance and conserve water resources by promoting efficient water use techniques, introducing rainwater harvesting and improving productivity per unit of water consumed through mandatory water audits
	National Water Policy (2002) • Seeks to achieve water use efficiency and foster an awareness of water being a scarce resource
	National Water Mission (2008) • As part of the National Action Plan on Climate Change, this national mission seeks to conserve water, minimize wastage and ensure more equitable distribution of water resources • One of the five identified goals of this mission is to increase water use efficiency by 20%

Table 8.4. Examples of national policies, laws and regulations to promote water efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
Indonesia	*Water Resources Law No. 7/2004* • Proposes the establishment of IWRM framework
	Government Regulation on Water Resources Management No. 42/2008 • Details procedures to procure water resource licenses
	Government Regulation on Water Resources Council No. 12/2008 • Establishes the Water Resources Council as the umbrella organization for the management of water resources in the country
Japan	National Comprehensive Water Resources Plan (Water Plan 21) (1999) • Developed basic targets for the period 2010–2015 including the sustainable use of water and the conservation of water resources
Kazakhstan	National Integrated Water Resources Management and Water Efficiency Plan (2005) • To improve water efficiency (WE) in the domestic sector through the application of water tariffs and a public awareness campaign • To improve WE in industrial sector through monitoring water consumption, providing training for water inspectors and adopting polluter pays principles into policy • To improve irrigation infrastructure and farm application methods
Malaysia	National Study for the Effective Implementation of IWRM in Malaysia – Ministry of Natural Resources and the Environment (2006)
New Zealand	New Start for Fresh Water Strategy (2009) • Proposes a new direction for water management • Acknowledges that New Zealand is approaching water resource limits
	National Policy Statement for Freshwater Management (currently being developed) • The efficient use of freshwater is recognized as being of national significance under the proposed policy statement
	Water efficiency labelling scheme (2010)
Pakistan	National Water Policy (draft) • Aims to achieve efficient management and conservation of water resources
Singapore	Singapore Green Plan 2012 (2002) • Seeks to conserve water through mandatory water-saving devices, water pricing, water audits, and education programmes • Sets targets to lower per capita domestic water consumption to 155 L per day by 2012
	Sustainable Development Blueprint (2009) • Sets targets to reduce domestic water consumption to 140 L per person per day by 2030
Thailand	National Water Law (draft) • Aims to reduce water usage by 10% between 2008 and 2012
	National Water Policy (2000) • Provides for the sharing of water resources

Table 8.4. Examples of national policies, laws and regulations to promote water efficiency in selected countries in Asia and the Pacific	
Country	**Policy detail**
The Republic of Korea	• *Law on Low Carbon and Green Growth (2009)* • Taking action on climate change, secure water supplies, and conserve water resources • Promoting efficient techniques for preventing water pollution • Restoration of the ecological function of streams and conservation of water
Viet Nam	National Strategy on Water Resources to 2020 (2006) • Seeks to strengthen the protection, exploitation, use and development of water resources

(Sources: MEWR 2002; ESCAP 2007; UN-Water 2008; Government of India 2009; MWR 2009; New Zealand Government 2009a; Korea Environment Institute 2010)

References

ADB (2003) 'Water for all: the water policy of the Asian Development Bank'. Asian Development Bank (ADB): Manila, Philippines.

ADB (Asian Development Bank) (2010) 'Water for all. 1st stakeholders' workshop of Vu Gia-Thu Bon river basin'. Retrieved 23 March 2010, from www.adb.org/water.

ADB and IGES (2008) 'Towards resource-efficient economies in Asia and the Pacific'. Asian Development Bank and Institute for Global Environmental Strategies: Manila, Philippines.

Alsharhan AS and Wood WW (Eds) (2003) *Water Resources Perspectives: Evaluation, Management and Policy: Developments in Water Science*. Elsevier: Amsterdam.

Andrews-Speed P (2009) China's ongoing energy efficiency drive: origins, progress and prospects. *Energy Policy* **37**(4): 1331–1344.

Angel DP, Hamilton T and Huber MT (2007) Global environmental standards for industry. *Annual Review of Environment and Resources* **32**: 295–316.

Angel DP and Rock M (2005) Global standards and the environmental performance of industry. *Environment and Planning A* **37**: 1903–1918.

APEC (2007) 'Darwin declaration on: achieving energy security and sustainable development through efficiency, conservation and diversity'. Asia-Pacific Economic Cooperation: Singapore.

APEC (2009a) 'Peer review on energy efficiency in New Zealand'. Asia-Pacific Economic Cooperation: Singapore.

APEC (2009b) 'Peer review on energy efficiency in Vietnam'. Asia-Pacific Economic Cooperation: Singapore.

Australian Government (2009a) 'Nation building: economic stimulus plan, Commonwealth Coordinator-General's progress report (3 February 2009–30 June 2009)'. Department of the Prime Minister and Cabinet: Canberra.

Australian Government (2009b) 'Water Efficiency Labelling and Standards (WELS) Scheme.' Retrieved 15 November 2009, from http://www.waterrating.gov.au.

Australian Taxation Office (2009) 'Small business and general business tax break overview.' Retrieved 13 September 2009, from www.ato.gov.au.

Bahn-Walkowiak B, Bleischwitz R, Bringezu S, Bunse M *et al.* (2008) *Resource Efficiency: Japan and Europe at the Forefront*. Federal Environment Agency: Berlin.

BEE (2008) 'National level painting competition on energy conservation 2008.' Retrieved from http://www.bee-india.nic.in/NCEC2008/PaintingCompetition2008_Winners.pdf.

Bengtsson M, Hotta Y, Hayashi S and Akenji L (2010) 'Policy tools for sustainable materials management: applications in Asia'. IGES Working Paper. Institute for Global Environmental Strategies: Hayama, Japan.

Bennear LS and Stavins RN (2007) Second-best theory and the use of multiple policy instruments. *Environmental and Resource Economics* **37**(1): 111–129.

Bernow S, Costanza R, Daly H and DeGennaro R (1998) Ecological tax reform. *Bioscience* **48**(3): 193–196.

Billi A, Cannitano G *et al.* (2004) The Economics of water efficiency: a review of theories, measurement issues and integrated models. *OPTIONS mediterraneennes* **Series B No 57**: 227–262.

Bosquet B (2000) Environmental tax reform: does it work? A survey of the empirical evidence. *Ecological Economics* **34**: 19–32.

Californian Government Department of Water Resources (2010) 'Water use efficiency'. Retrieved 23 March 2010, from www.water.ca.gov/wateruseefficiency/leak/.

Daly HE (1973) *Toward a Steady-State Economy*. W.H. Freeman and Company: San Francisco.

Daly HE (1977) *Steady-State Economics*. W.H. Freeman and Company: San Francisco.

Daly HE (1994) Fostering environmentally sustainable development: four parting suggestions for the World Bank. *Ecological Economics* **10**: 183–187.

Daly HE (2005) Economics in a full world. *Scientific American* **293**(3): 100–107.

Daly HE (2008) 'A steady-state economy'. Sustainable Development Commission: United Kingdom.

DEFRA (2002) 'Types of environmental policy instruments'. Department for Environment, Food and Rural Affairs: United Kingdom.

DEWHA (2008) 'Renewable Energy Equity Fund (REEF).' Retrieved 26 March 2010, from http://www.environment.gov.au/settlements/renewable/reef/index.html

DEWHA (2009) 'Water for the future achievements.' Retrieved 26 March 2010, from http://www.environment.gov.au/water.

E-Network (2010) Strategic planning of water resources. 'World Water Forum: concept note.' Retrieved 23 March 2010, from www.spmwater-asiapacific.net/modules/xfsection/article.php?articleid=8.

ECCJ (2008) 'Top Runner Program revised edition (January 2008).' Retrieved 26 March 2010, from http://www.eccj.or.jp/top_runner/index_contents_e.html

ECCJ (2009) 'Stock-take of existing policies and measures on energy efficiency and conservation.' Retrieved 26 March 2010, from http://www.asiaeec-col.eccj.or.jp/st-takes/index.html

EECA (2009) 'Inspiring energy efficiency – advancing renewable energy.' Retrieved 16 September 2009, from http://www.eeca.govt.nz/.

Ekins P and Tomei J (2007) Stimulating eco-efficiency in Asia and the Pacific: the role of public policy. *Second Green Growth Policy Dialogue: The Role of Public Policy in Providing Sustainable Consumption Choices: The Resource-Saving Society and Green Growth*. ESCAP, United Nations.

EPD (2009) 'Tax incentives for environment-friendly commercial vehicles.' Retrieved 26 March 2010, from http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/environment_friendly_commercial_vehicles.html

ESCAP (2006) *The Role of Public Policy in Providing Sustainable Consumption Choices: Resource Saving Society and Green Growth*. The Second Green Growth Policy Dialogue, Beijing, China.

ESCAP (2007) 'Eco-efficiency: a practical path to sustainable development'. Economic and Social Commission for Asia and the Pacific: Bangkok.

ESCAP (2008a) 'Energy security and sustainable development in Asia and the Pacific'. Economic and Social Commission for Asia and the Pacific (ESCAP): Bangkok.

ESCAP (2008b) 'Greening growth in Asia and the Pacific'. Follow-up to the World Summit on Sustainable Development. Economic and Social Commission on Asia and the Pacific: Bangkok.

Expert Group on Energy Efficiency (2007) 'Realizing the potential of energy efficiency: targets, policies, and measures for G8 countries'. United Nations Foundation: Washington DC.

FAOWATER (2010a) 'Natural Resources and Environment Department. Water scarcity.' Retrieved 22 March 2010, from www.fao.org/nr/water/topics_scarcity.html.

FAOWATER (2010b) 'Natural Resources and Environment Department. Water management and irrigation systems.' Retrieved 23 March 2010, from www.fao.org/nr/water/topics_irrig_watermng.html.

Geller H, Harrington P, Rosenfeld AH, Tanishima S and Unander F (2006) Policies for increasing energy efficiency: thirty years of experience in OECD countries. *Energy Policy* **34**: 556–573.

Goulder LH and Parry IWH (2008) Instrument choice in environmental policy. *Review of Environmental Economics and Policy* **2**(2): 152–174.

Government of India (2008) 'National action plan on climate change.' Retrieved 26 March 2010, from http://moef.nic.in/modules/public-information/reports/.

Government of India (2009) 'National water mission under national action plan on climate change.' Retrieved 26 March 2010, from http://wrmin.nic.in/writereaddata/linkimages/MissionDocument 8395131900.pdf

Government of Japan (2009) 'Summary of the policy package to address economic crisis'. Provisional translation by the Cabinet Office, Government of Japan.

Government of Singapore (2009) 'Energy efficiency in Singapore.' Retrieved 26 March 2010, from http://www.e2singapore.gov.sg

GTZ, CSCP and Wuppertal Institute (2006) 'Policy instruments for resource efficiency: towards sustainable consumption and production'. German Technical Cooperation, Centre on Sustainable Consumption and Production and the Wuppertal Institute: Eschborn, Germany.

Hamilton C, Schlegelmilch K, Hoerner A and Milne A (2000) 'Environmental tax reform: using the tax system to protect the environment and promote employment'. Tela Series. Australian Conservation Foundation: Melbourne.

Hotta Y (2004) 'The transnational politics of ecological modernization, An analysis of the formation of transnational authority in global environmental and industrial governance, with special reference to the Zero Emissions Initiative in Japan'. University of Sussex: Sussex, UK.

IPCC (2007) 'Climate change 2007: mitigation of climate change'. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge.

Jackson T (2009) Beyond the growth economy. *Journal of Industrial Ecology* **13**(4): 487–490.

Jordan A, Wurzel RKW and Zito A (2003) *'New' Instruments of Environmental Governance?: National Experiences and Prospects*. London, Frank Cass.

Karl H and Orwat C (1999) Economic aspects of environmental labeling. In *The International Yearbook of Environmental and Resource Economics 1999/2000*. (Eds H Folmer and T Tietenberg) pp. 107–170. Edward Elgar: Cheltenham.

KEMCO (2009) 'Voluntary agreement.' Retrieved 26 March 2010, from http://www.kemco.or.kr/new %5Feng/main/main.asp

KLRI (1997) Act on the promotion of saving and recycling of resources. Korea Legislation Research Institute: Seoul.

Kog YC (2004) *Water Security in Southeast Asia*. Paper presented at 'Water: A Catalyst for Peace' conference, 6–8 October 2004, Zaragoza, Spain.

Korea Environment Institute (2010) 'Korea Environment Institute.' Retrieved 14 January 2011, from http://www.kei.re.kr/.

Kuhndt M, Herrndorf M and Fernandez A (2007) *Activating Policy Instruments for Resource Efficiency in the Asia-Pacific Region*. Paper presented at 'Greening the Business and Making Environment a Business Opportunity' conference, 5–7 June 2007, Bangkok, Thailand.

Ma J, Hipel KW *et al.* (2008) Transboundary water policies: assessment, comparison and enhancement. *Water Resources Management* **22**: 1069–1087.

Markandya A (1998) The cost of environmental regulation in Asia: command and control versus market-based instruments. *Asian Development Review* **16**(1): 1–30.

Mayers J, Batchelor C *et al.* (2009) 'Water ecosystem services and poverty under climate change: key issues and research priorities'. International Institute for Environment and Development: London.

MCE (2004) 'Statement on National Framework for Energy Efficiency. Overview Plan of Stage One Measures 2005–2007'. Ministerial Council on Energy: Canberra.

MEF (2009) 'India State of Environment Report 2009'. Ministry of Environment & Forests, Government of India: New Delhi.

MEWR (2002) 'The Singapore Green Plan 2012'. Ministry of the Environment and Water Resources: Singapore.

MEWR (2009) 'A lively and liveable Singapore: strategies for sustainable growth'. Ministry of the Environment and Water Resources: Singapore.

Ministry of the Environment (Japan) (2008a) 'Results of the G8 environment ministers meeting 2008'. Ministry of the Environment (Japan): Tokyo.

Ministry of the Environment (Japan) (2008b) 'The second fundamental plan for establishing a sound material-cycle society'. Ministry of the Environment (Japan): Tokyo.

Ministry of the Environment (Republic of Korea) (2006) 'Volume-based waste fee system in Korea'. Korea Environmental Policy Bulletin. Ministry of the Environment: Seoul.

Ministry of the Environment (Republic of Korea) (2010) Framework Act on Low Carbon, Green Growth. Ministry of the Environment: Seoul. Retrieved from http://eng.me.go.kr/board.do?method=view&docSeq=8744&bbsCode=law_law_law&currentPage=1&searchType=&searchText=&categoryCode=00

Mishra A and Sarangi GK (2010) Efficiency and equity in energy use and distribution in the Asia-Pacific region: key policy initiatives (draft). The Energy and Resources Institute: New Delhi.

Moglia M, Alexander KS *et al.* (2008) Regional and country scale water resource assessment; Informing investments in future water supply in the Asia Pacific Region – a decision support tool. Water for a Healthy Country National Research Flagship: CSIRO.

MWR (2009) 'Conserving and protecting water resources.' Retrieved from www.mwr.gov.cn.

Myers N and Kent J (2004) *The New Consumers: The Influence of Affluence on the Environment*. Island Press: Washington DC.

National Environment Agency (Singapore Government) (2011) waste Statistics and Overall Recycling. Retrieved from http://app2.nea.gov.sg/topics_wastestats.aspx.

National People's Congress (2008) Standing Committee of the 11th National People's Congress (NPC): Beijing, China. http://www.npc.gov.cn/npc/xinwen/2008-08/29/content_1538671.htm

National Water Commission (2009) 'Australian water reform 2009: second biennial assessment of progress in implementation of the National Water Initiative'. National Water Commission: Canberra.

NDRC (2008). NDRC No. 58 Public Communique. National Development and Reform Commission, Beijing, China. Retrieved from http://hzs.ndrc.gov.cn/jnxd/t20080903_234934.htm

NEA (2009) 'Energy smart building labelling programme.' Retrieved from http://www.e2singapore.gov.sg/buildings/energysmart-building-label.html

New Zealand Government (2007) 'New Zealand energy efficiency and conservation strategy: making it happen'. New Zealand Government: Wellington.

New Zealand Government (2009a) 'Backgrounder on "New start for fresh water" Cabinet paper.' Retrieved from http://www.mfe.govt.nz/issues/water/freshwater/new-start-fresh-water.html

New Zealand Government (2009b) 'Why waste minimisation is important, New Zealand Ministry for the Environment.' Retrieved from http://www.mfe.govt.nz/issues/waste/index.html

Normile D (2010) Restoration or devastation? A massive South Korean project to dam and dredge four major rivers has provoked bitter opposition from scientists and environmentalists. *Science* **327**: 1568–1570.

Northern Territory Government (2007) 'Re-thinking waste-in-schools challenge'. Department of Natural Resources, Environment, The Arts and Sport: Northern Territory, Australia.

NWC (2009) 'Australian water reform 2009.' Retrieved 23 March 2010, from www.nwc.gov.au/www/html/2466-chapter-11---urban-water.asp?intSiteID=1.

OECD (1998) 'Eco-efficiency'. Organisation for Economic Co-operation and Development: Paris.

OECD (1999) 'Involving international business: voluntary agreements and competitiveness'. OECD Round Table on Sustainable Development. Organisation for Economic Co-operation and Development: Paris.

OECD (2003) 'Voluntary approaches for environmental policy: effectiveness, efficiency and usage in policy mixes'. Organisation for Economic Co-operation and Development: Paris.

OECD (2006) 'The political economy of environmentally related taxes'. Organisation for Economic Co-operation and Development: Paris.

OECD (2007) 'Instrument mixes for environmental policy'. Organisation for Economic Co-operation and Development: Paris.

OECD (2009) 'Green growth: overcoming the crisis and beyond'. Organisation for Economic Co-operation and Development: Paris.

Po M, Kaercher JD *et al.* (2003) Literature review of factors influencing public perceptions of water reuse. CSIRO Land and Water Technical Report 54/03, December 2003. CSIRO: Perth.

Price L (2005) Voluntary agreements for energy efficiency or GHG emissions reduction in industry: an assessment of programs around the world. *Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry*. Lawrence Berkeley National Laboratory, University of California.

Price L, Wang X and Yun J (2010) The challenge of reducing energy consumption of the Top-1000 largest industrial enterprises in China. *Energy Policy* **38**(11): 6485–6498.

Public Utilities Board (PUB) (2008) 'Singapore's National Water Agency, NEWATER.' Retrieved 23 March 2010, from www.pub.gov.sg/NEWater/Pages/default.aspx.

PUB (2010) *Guidebook On Water Efficiency Labelling Scheme*. Public Utilities Board: Singapore.

Rae AN (2007) Regional agricultural trade liberalization: priorities for policy makers and future research needs. In *Agricultural Trade: Planting the Seeds of regional Liberalization in Asia – a Study by the Asia-Pacific Research and Training Network on Trade*. Volume 60. pp. 295–309. United Nations: New York.

Rankine H, Watkins M and Kasemsawasdi W (2009) Innovative socio-economic policy for improving environmental performance: payments for ecosystem services. United Nations Economic and Social Commission for Asia and the Pacific (ESCAP): Bangkok.

Roodman DM (1998) *The Natural Wealth of Nations: Harnessing the Market for the Environment*. W.W. Norton and Company: New York.

SOPAC (2009) 'Pacific Islands Applied Geoscience Commission: water sanitation and hygiene.' Retrieved 23 March 2010, from www.pacificwater.org/pages.cfm/resource-center/water-tools/iwrm-toolboxes-1/water-resources-policy-legislation.html.

Stavins RN (2000) Market-Based Environmental Policies. In *Public Policies for Environmental Protection.* (Eds PR Portney and RN Stavins) pp. 31–76. Resources for the Future: Washington DC.

Takiguchi H and Takemoto K (2008) Japanese 3R policies based on material flow analysis. *Journal of Industrial Ecology* **12**(5–6): 792–798.

TEEB (2011) 'The Economics of Ecosystems and Biodiversity.' Retrieved 15 February 2011, from www.teebweb.org.

TEI (2009) ‘Thai green label scheme.’ Retrieved 26 March 2010, from http://www.tei.or.th/greenlabel/

The Siam Cement Group (2010) ‘Sustainable development: environmental performance indicator.’ Retrieved 23 July 2010, from http://www.siamcement.com/en/05sustainability_development/02_environmental_performance_indicators.html.

Tortajada C (2006) Water management in Singapore. *Water Resources Development* **22**(2): 227–240.

Transboundary Water Cooperation (2006) Special 136 A BMZ Position Paper. Federal Ministry for Economic Cooperation and Development: Bonn.

UN-Water (2008) ‘Status report on IWRM and water efficiency plans for CSD16’. United Nations: New York.

UNEP (2007) ‘GEO4: Global Environment Outlook – environment for development’. United Nations Environment Programme: Nairobi.

UNEP (2008a) Freshwater under threat: South Asia. United Nations Environment Programme: Nairobi, Kenya.

UNEP (2008b) Freshwater under threat: Northeast Asia. United Nations Environment Programme: Nairobi, Kenya.

UNEP (2009a) ‘Green Economy Fact Sheet’. United Nations Environment Programme: Nairobi.

UNEP (2009b) Freshwater under threat: South East Asia. United Nations Environment Programme: Nairobi, Kenya.

UNEP (2010) *A Global Green New Deal: Rethinking the Economic Recovery*. Cambridge University Press: Cambridge, UK.

UNEP (2011a) *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - A Synthesis for Policy Makers*. United Nations Environment Programme, Nairobi, Kenya.

UNEP (2011b) ‘Green Economy.’ Retrieved 15 February 2011, from http://www.unep.org/greeneconomy/AboutGEI/tabid/1370/Default.aspx

UNEP (2011c) Freshwater under threat: Pacific Islands. United Nations Environment Programme: Nairobi, Kenya.

UNESCO (2009) ‘The United Nations World Water Development Report 3: Water in a changing world’. UNESCO and Earthscan: Paris and London.

Von Weizsäcker E (2009) Managing the transition to resource-efficient and low-carbon industries. *International Conference on Green Industry in Asia*. Manila, Philippines.

Von Weizsäcker E and Jesinghaus J (1992) *Ecological Tax Reform. A Policy Proposal for Sustainable Development*. Zed Books Ltd: London.

Von Weizsäcker E, Lovins AB and Lovins LH (1997) *Factor Four: Doubling Wealth, Halving Resource Use*. Earthscan: London.

Walls M (2006) 'Extended producer responsibility and product design: economic theory and selected case studies'. Organisation for Economic Co-operation and Development: Paris.

Water for Good (2009) 'Water for Good ensures South Australia's water future to 2050'. South Australian Government: Adelaide.

Water Resources in Japan (2008) 'Responding to international water resource problems.' Retrieved 23 March 2010, from http://www.mlit.go.jp/tochimizushigen/mizsei/water_resources/contents/responding_to_international.html.

WateReuse Association (2010) 'WateReuse: creating new sources of high quality water. San Diego moves forward with potable reuse pilot study.' Retrieved 23 March 2010, from www.watereuse.org/node/852.

Wei H (2009) Practice and experience of promoting efficient lighting in China. *International Conference on Green Industry in Asia*. Manila, Philippines.

World Energy Council (2008) *Energy Efficiency Policies around the World: Review and Evaluation*. World Energy Council: London.

World Health Organization (2006) WHOStat database. World Health Organization: Geneva. Retrieved 18 February 2010, from http://www.who.int/whosis/whostat/en/index.html

World Resources Institute (2008) 'A "Green lining" in China's economic stimulus plan.' Retrieved 26 March 2010, from http://www.wri.org/stories/2008/11/green-lining-chinas-economic-stimulus-plan

Xinhua News Agency (2008) 'Law on circular economy adopted.' 30 August 2008. Retrieved 17 May 2010, from http://china.org.cn/business/news/2008-08/30/content_16360177.htm.

Xinhua News Agency (2010) 'S. Korea authorizes "low carbon, green growth" law.' 13 January 2010. Retrieved 17 May 2010, from http://news.xinhuanet.com/english/2010-01/13/content_12804133.htm.

Yabar H, Hara K, Uwasu M, Yamaguchi Y, Zhang H and Morioka T (2009) Integrated resource management towards a sustainable Asia: policy and strategy evolution in Japan and China. *International Journal of Environmental Technology and Management* **11**(4): 239–256.

Yoshida H, Shimamura K and Aizawa H (2007) 3R strategies for the establishment of an international sound material-cycle society. *Journal of Material Cycles and Waste Management* **9**(2): 101–111.

Zhou N, Levine MD and Price L (2010) Overview of current energy-efficiency policies in China. *Energy Policy* **38**(11), 6439–6452.

Chapter 9: **Conclusions**

Heinz Schandl

Natural resources underpin economic activities and material standards of living. In a situation of increasing population, enhanced economic activity, and rising aspirations and material standards of living, measuring and modelling natural resource use and how it interacts with economic development provides important information for policy planning, in particular in rapidly developing economies. This Resource Efficiency: Economics and Outlook (REEO) report for Asia and the Pacific looks at the history, current condition, and future trajectories of natural resource use related to the domains of materials, energy, water, land, and waste and emissions. It analyses resource use and economic development within an integrated modelling framework and links the results to policy analysis.

The report concludes that:

- Increasing resource efficiency will be vital to the future development of the Asia-Pacific region, to ensure economic and social development in a world in which resources are becoming scarcer and more expensive, and the absorptive capacity of ecosystems is decreasing rapidly.
- Resource efficiency, however, will be a necessary but insufficient condition for sustainable development in Asia and the Pacific and will need to be complemented by systems innovation; that is, moving to new ways of providing essential provisions such as housing, mobility, energy and food.
- A business-as-usual approach would see resource use in the Asia-Pacific region increase by a factor of three to five in coming decades. This is related to economic development resulting in an industrial transformation that goes hand in hand with a large increase in natural resource use, waste, and emissions. The speed and scale of this transformation is unprecedented in human history. The challenge for public policy is to achieve a sustainability transition, enabled by resource efficiency and systems innovation, despite the inherent growth dynamic of the industrial transformation. What is required is a 'new industrial revolution' that provides food, housing, mobility, energy, and water with only about 20% or less of the per-capita resource use and emissions found in current systems.
- Resource use has become more global, driven by the increasingly global organization of business, finance, trade, and information flows, which have contributed to exponential growth in the amount of traded goods. Both imports and exports of materials and energy sources have grown at faster rates than the domestic extraction of those natural resources.
- Many markets for natural resources have also become global and resource prices are driven by international trends, including market monopolies and commodity speculation.
- Prices alone do not provide appropriate signals for enabling resource efficiency and systems innovation, because global resource markets are characterized by complex producer–consumer networks and complicated institutional and power relationships. It will require

transition to a green economy, new forms of governance, together with market incentives to improve current resource efficiency trends and to trigger systems innovation.

Most national economies globally have used resources more efficiently over time, allowing for relative decoupling between economic activity and resource use to occur. Very often though, efficiency gains have led to higher levels of overall consumption, offsetting previous gains, which is known as rebound. Because of already very high resource use globally, dematerialization – that is, an absolute reduction in resource use – needs to be achieved. This will require policies that actively deal with the rebound caused by efficiency gains. Measuring and monitoring of resource use has become an important imperative for integrative policy planning and for the evaluation of policies and programmes that have been implemented. This report presents comprehensive accounts for materials, energy, and other resources for Asia and the Pacific for the first time to underpin policies for sustainable resource use.

This report has used modelling and scenarios to help to envisage possible or likely futures and to assess the impact of a set of policies. The biophysical model assists in understanding the growth dynamic inherent in the Asia-Pacific region, not just from an economic point of view, but also from a biophysical perspective.

Asian and Pacific countries, as well as regional bodies such as the Association of Southeast Asian Nations (ASEAN), the South Asian Association for Regional Cooperation (SAARC), and the South Pacific Regional Environment Programme (SPREP) need to invest in knowledge gathering to support policy decisions and prioritization of resource-related environmental problems, assessment of current and new policy arrangements in regard to the sustainability of resource use, and policy integration to take into account the role of natural resources within the wider context of sustainable development.

The region and its countries must manage the environmental impacts of using natural resources, materials, and products by launching more initiatives to enable the sustainable use of natural resources, the prevention and recycling of waste, and the reduction of emissions, as well as an integrated product policy to reduce the environmental impacts of products.

The region may use more efficient technologies, introduce resource efficient buildings and infrastructure, allow for changes in consumption and use less of a given resource if there are cost-efficient and feasible means to do so. Additional policies need to be put in place to help avoid rebound, which would offset efficiency gains.

Materials

Summary

At the beginning of the 21st century, the Asia-Pacific region has become the single largest user of materials including biomass, fossil fuels, ores, industrial, and construction minerals. Total materials consumed in 2005 amounted to around 32 billion tonnes, or 8.6 tonnes per capita. Materials use in the Asia-Pacific region grew strongly between 1970 and 2005, but there is still huge potential for future growth. In coming decades, the Asia-Pacific region will be the most important driver of global resource use and related environmental impacts, including resource scarcity, pollution, and climate change.

In 2005, the Asia-Pacific region showed stark differences in domestic material consumption, ranging from very low material consumption in South Asia and South-East Asia of between 5 and 7 tonnes per capita, to moderate material consumption in the Pacific of around 10 tonnes per capita and Central Asia and North-East Asia of around 12 tonnes per capita, to Australia and New Zealand at above 45 tonnes per capita.

The region is diverse, with both large material exporters and importers. Overall, the Asia-Pacific region will become increasingly dependent on foreign materials to enable manufacturing growth and increasing material standards of living. While Australia and New Zealand, and to a much smaller extent also Central Asia, were net exporters of materials, all other subregions were either only marginally integrated into world markets or on a trajectory to become reliant on foreign resources, as the example of North-East Asia shows.

Continuing improvements in material efficiency seem to be an endogenous trend in economic development and, on a global scale, material efficiency has improved over the last century. Material efficiency in the Asia-Pacific region, however, was stagnant between 1970 and 1990. Since then, the region has decreased in material efficiency due to shifts in economic activity from very efficient production (e.g. Japan) to less efficient production (e.g. China). In 2000, this trend has reversed global resource efficiency for the first time in a century and the world today is using resources increasingly less efficiently.

Material use over the last three decades was mainly driven by rising wealth and per-capita incomes and, to a much lesser extent, by growing populations. Technology and innovation are usually viewed as mediating factors to mitigate growth in material use and emissions in the face of population and income growth. Overall, technological developments have not contributed significantly to mitigate the environmental impacts of production and consumption in the Asia-Pacific region. This was especially the case in the period from 1985 to 1995, and in the North-East Asia subregion. This suggests that in the rapid process of industrialization, low material use and emission technologies are increasingly being replaced by new technologies that use more resources, both in businesses and households.

The contribution of technology to reducing resource pressure has actually been very small over the last three decades. An assessment of the main drivers suggests that the assumption that technology and efficiency will help solve issues of overuse of resources is not supported. This indicates that technology is not a solution in its own right, and the focus should be on best available and appropriate environmental technologies.

Because of the speed and magnitude at which new infrastructure and productive capacity is established in the Asia-Pacific region, there is both a huge challenge and a great opportunity for innovation and new technologies and systems that will have lasting effects in decades to come. This will not happen spontaneously, but will require well-designed policies that take an integrated view of economic, social, and environmental imperatives.

Response

Increasing resource efficiency and promoting sustainable lifestyles is fundamental to achieving sustainable consumption and production, which requires cooperation among different stakeholders and sectors. Sustainable consumption and production and resource efficiency have the potential to make an important contribution towards poverty alleviation and the transition to low-carbon and green economies.

Numerous countries in the Asia-Pacific region have implemented national policies to promote material efficiency. A number of countries have incorporated ‘green growth’ into their development strategies and stimulus plans, recognizing the competitive advantage that may accrue from investing into the effective and efficient use of natural resources through new technologies, infrastructure, and methods of service delivery.

Countries will have to identify different policy responses catering for their very different respective positions within the global economy, depending on whether economic activity focuses on primary sectors, manufacturing, or the service sector and whether their economies either export or import materials as a result.

Improved material efficiency, cyclical resource use, and material efficient buildings and infrastructure, as well as substitution of materials will ease the dependency of regional development on foreign resources.

Materials efficiency is a combined effect of production and consumption activities, and depends on the infrastructure for energy, housing, and mobility that helps in mitigating high material growth as economies develop. Enabling improvements in materials efficiency needs to be a major objective of governments in the Asia-Pacific region. Existing programmes that enhance materials efficiency are manifold and include high-level policies for reducing, reusing and recycling materials, as well as sectoral and industrial policies. The region will have to invest in ‘technological leap-frogging’ to avoid the material intensive path of economic development that many of today’s industrialized countries have taken.

Governments now have a wide choice of different instruments to build a sound policy framework for resource efficiency. Policy instruments include traditional regulatory approaches, as well as economic instruments, information-based measures, and voluntary initiatives including environmental standards and certification schemes. Over the past two decades, policy instruments have gradually evolved from command-and-control regulations to economic instruments, the provision of information, and voluntary approaches. An optimal mix of policy instruments will frequently include all four of these approaches.

Credible and harmonized data is needed to underpin informed decision making and policy responses that may eventually enable material efficiency and dematerialization. There is therefore a need to establish institutional capacity for measuring, monitoring and analyzing material flows.

Energy use

Summary

The Asia-Pacific region, currently home to more than half of the world's population, has seen rapid growth in energy use since the 1980s, now contributing 20% of total global energy demand or 170.5 eJ annually. If population and per capita consumption continues growing at current rates, the Asia-Pacific region will use half of all energy sources by 2030. The region has been reasonably successful in meeting its increased energy demand from domestic energy production. This has been achieved by greatly expanding the proportion of coal, and decreasing the proportion of renewable energy in the energy mix. As a result, the region now has a major impact on global carbon emission trends. Between 1970 and 2005, CO_2 emissions in the Asia-Pacific region grew fourfold, and rose from 13 to 30% of global emissions.

The economic efficiency of energy use has declined, caused by some key production processes in economies dominated by building new infrastructure for the first time, which tends to be more primary resource intensive, rather than modernizing existing infrastructure. As a consequence, enhancing energy efficiency in the Asia-Pacific region may prove more difficult than for regions dominated by mature economies. Rising per-capita income has been the most important driver for energy consumption and new technologies have tended to increase energy consumption rather than to restrain it.

Response

Improvements in energy efficiency in large urban agglomerations across the region will depend on sustainable infrastructure, urban planning, and urban mix, as well as public transport systems and improved building standards. Key measures for mitigating exponential growth of energy consumption, GHG emissions, and air pollution in cities will include energy efficiency, fuel switching, heat and power recovery, renewable energy, feedstock change, product change, and changes in household lifestyles.

Renewable energy development in the region should consider three key concerns: to diversify the energy mix; to ensure energy security; and to meet the environmental challenges. Because of the high dependency of the region on traditional biomass for heating and cooking, and the lack of access to electricity, priority should be given to renewable decentralized energy solutions, which may become an effective alternative to electrification in remote rural areas.

The region should focus its energy strategies on its endowment of renewable energy resources that are largely untapped. Programmes and financial resources for covering the high initial and transaction costs need to be provided through government and intergovernmental funding schemes to boost renewable energy development in the region.

Asia and the Pacific has 40% of the world's hydro-electric technical potential, and 35% of annual solar and geo-thermal energy potential. Biomass and wind energy resource potential is also widely available in the region. Hydro potential in the region, if exploited properly, can contribute significantly to the energy mix of the region. China and India together constitute about 20% of the world's hydro resources. There is need to establish adequate financial resources and technical expertise to make use of these precious natural resources that have, to date, been unexploited, in an environmentally sustainable manner.

Priority should be given to renewable energy development by introducing a stream of market and policy mechanisms and instruments across countries in the region. Key policy initiatives may include setting renewable energy targets, promoting demand push measures such as fixing renewable portfolio standards, designing feed-in tariffs, giving fiscal and financial incentives such as direct capital investment subsidies or rebates, tax incentives and credits, sales tax and value added tax exemptions, direct production payments and tax credits, green certificates and net metering, and direct public investments or financing.

The region should strengthen existing fiscal and financial instruments for creating incentives for renewable energy development in the Asia-Pacific region. Tax incentives, while not prominent in China, are widely used in India to attract investment. Renewable energy funds in various forms are used in economies such as China, India, Australia, New Zealand, and the Philippines to support renewable energy development. Various forms of subsidies are also currently being implemented in several economies including China, India, Thailand, and the Republic of Korea.

Exploring off-grid based renewable energy solutions may be a cost-effective mechanism to electrify rural areas in Asia-Pacific developing economies. Existing experience of solar-based stand-alone home energy systems that are providing electricity to around 2 million households in the developing economies in the region – mostly in Bangladesh, Western China, Fiji, India, Indonesia, Mongolia, Nepal, Sri Lanka, and Viet Nam – should be extended to other countries by learning from what has worked. There are many more examples of success that could be adopted and further up-scaled.

Water

Summary

Water use in the Asia-Pacific region has been dominated by agriculture and the need for increased food and livestock production to service larger populations and changing lifestyles. Central Asia withdraws significantly more water per capita than other subregions, which can be explained by climatic factors and very low water efficiency in agriculture. Australia and New Zealand have the second highest levels of water withdrawal per capita, though significantly less than Central Asia. The Asia-Pacific region increased total water withdrawals over a 15 year period (1985–2000) by 329,160 GL, representing an approximate 25% increase. Central Asia has maintained its very high withdrawal, while all other subregions have increased withdrawals.

Water efficiency decreased in the Asia-Pacific region between 1985 and 2000. Future scenarios suggest that water use in developed nations in the region will decline, while water use in developing nations will further increase, leading to accumulated pressure on water resources. Many river basins will be under severe stress, complicated by strong competition for scant water resources between households, industry, and agriculture. The situation may well be exacerbated by climatic change. Globally, by 2025, agriculture is expected to increase requirements for water 1.3 times, industry 1.5 times, and households 1.8 times. As a result, many of the world's transboundary river basins will

be stressed or highly stressed, and the competition for water resources may cause ongoing tension between nations.

Many countries have been extracting water in an unsustainable manner by withdrawing more water per year than is available from renewable sources. The situation is more serious in Central Asia, particularly in Uzbekistan, Turkmenistan, and Tajikistan. In South Asia, Pakistan, India, and Sri Lanka have also seen a large surge in extraction. In North-East Asia, large volumes of withdrawals indicate that China has also been extracting water rapidly.

Response

A significant proportion of the population in the Asia-Pacific region will live in water-stressed river basins, which will heighten the need for policies supporting water use efficiency and water demand strategies to provide a basis for future economic growth and to provide water resources for burgeoning populations. Additionally, technologies and infrastructure supporting alternative water sources, recycled water, eco-city development, and dampened water demands while tackling industrial and urban pollution at point of source, may allow for water savings and protect the quality and quantity of water available for consumptive use.

Central Asia is particularly vulnerable to water stress in coming years and will need to manage water resources and improve water productivity. International assistance in developing effective integrated water resource management (IWRM) policies and transboundary agreements for riparian areas will be needed to ensure access to a sustainable water supply. Monitoring of groundwater levels, management of surface to groundwater connectivity, and provision of environmental flows will be necessary to support biodiversity outcomes and ensure sustainable water supplies into the future.

Water security is a rapidly growing issue in the Asia-Pacific region. Growing population, rapid urbanization, and economic development have put heavy pressure on freshwater resources in the region. Water efficiency is seen as one of the best options to remedy water shortages in the region. Because the quality and quantity of water resources are positively correlated, it is important to simultaneously deal with both issues when improving efficiency in the water sector.

Water reform in the agricultural sector will require improved water management that achieves high water productivity, while sustaining communities, increasing food security, and maintaining rural incomes.

To increase water efficiencies and water productivity, there needs to be harmonization of regional trade agreements and adoption of good practices in product coverage, rules of origin, customs procedures, intellectual property protection, foreign direct investment, anti-dumping and dispute resolution, and government procurement. Competition and technical barriers to trade will be a priority.

Implementation of WTO procedures, safeguarding agricultural agreements by facilitating trade, and meeting various international standards will contribute to the harmonization of regional rules and the rules of the multilateral system.

Demand or supply management will critically rely on public acceptance and will depend on the system of governance, existing infrastructure, and standard of living.

For many cities and rural areas of Asia and the Pacific, the effectiveness of sewerage systems combined with pollution standards for industry will help reduce the pollution of water courses. This will assist in mitigating poor human health, the exposure to water-related diseases and high mortality rates from gastrointestinal diseases and waterborne vectors.

Urban water supply will continue to be a critical issue for the rapidly expanding cities in the developing world and in regions where decreased precipitation has reduced available water supplies. Water reform policies and investment in alternative water supplies, improving the management and delivery of urban water services, and allowing for greater innovation and more efficient water use will be required. Direct and indirect water reuse schemes, where the level of treatment of reused water is based on the degree of human contact with the water, will help respond to water shortages in many countries. International funding needs to be available for many countries in the Asia-Pacific region to provide cities and towns with access to reliable potable water supplies. International cooperation will be highly desirable, given that competition for water resources will cause ongoing tension between nations.

Land use

Summary

The Asia-Pacific region is currently experiencing unprecedented production and consumption demands (driven by economic and population growth) that are outstripping the renewal capacity of the region's natural resources, resulting in dramatic land use changes. Regionally, Asia and the Pacific's transition from an agrarian socio-ecological regime into an industrialized one is still in the early phases and its effects on land use, while already substantial, will continue to evolve. Land use intensity in the Asia-Pacific region has increased over time, with less land now being used per unit of economic output, implying that the region as a whole has made improvements in land use efficiency.

Response

Given the increasing growth and impact of urban areas in Asia and the Pacific, both environmentally and economically, there is an urgent need to expand understanding and improve datasets on urban land use at both national and regional scales. Improved reporting and data collection on the various land use types and their GDP contribution is required to enable better understanding of land use efficiency at all scales.

Further observation and policy development is essential to ensure that national and regional land use efficiency is improved, and that future land use needs can be met.

The Asia-Pacific region's use of ecosystem management economics to guide land use activities has been wide and varied, with payments for ecosystem services receiving considerable attention as a way of obtaining desired ecosystem management outcomes. Careful consideration in the design and implementation of such schemes using ecosystem management economics is necessary to ensure that any instrument applied stimulates the desired outcomes and to limit negative externalities.

The development of carbon trading markets in the Asia-Pacific region has the potential to bring about major changes in land use and land use efficiency, and has already done so to some degree. As a result, these markets need to be carefully considered to understand the additional consequences (negative and/or positive) of ensuing land use change.

Emissions and waste

Summary

Greenhouse gas emissions have grown substantially since the 1990s, with greater acceleration since 2000, especially in China. Annual GHG emissions reached 16 billion tonnes of CO_2 equivalent in 2005, a growth of 60% in just 15 years. There is an indication, though, that a considerable proportion – about 20% – of greenhouse gas emissions are related to the Asia-Pacific region producing goods for consumers in the rest of the world. The economic intensity of GHG emissions has been stagnant in the Asia-Pacific region since 1990, while the rest of the world has improved their emission intensity substantially. Also sulfur dioxide emissions, a major cause of acidification, have grown. Urban air quality in many cities of the region is causing significant environmental impacts and health problems.

There has been considerable success in phasing out the new production and consumption of the first group of human-made ozone-depleting substances (ODS), in all countries including in the Asia-Pacific region, due to sound policy. Waste is an increasing problem, but many countries have started to deal with waste and recycling within an understanding of improved resource management, allowing for a reduction of overall resource use, the reuse of materials, and increased recycling.

Despite the great importance of emissions and waste flows to environmental quality and human health, the availability of internationally comparable data that links emissions and waste to those activities causing it is less than satisfactory.

Response

Many countries in Asia-Pacific have developed national policies on waste management, minimization, and recycling to tackle this serious and growing environmental issue and promote material efficiency.

Countries should continue to invest in establishing institutions and capacity for monitoring and data analysis. A credible and comprehensive database on waste and emissions would greatly support policy planning, and programmes that aim to reduce waste and emissions and also to monitor the success of the emission reduction, waste, and recycling policies many countries are implementing.

Future scenarios

Summary

Three scenarios were established for the REEO to show how resource use and emissions could develop under different policy scenarios: business-as-usual, which demonstrates marginal improvement in resource efficiency; a resource efficiency scenario that implements large-scale efficiency in material and energy use across all sectors; and a system innovation scenario that assumes transition to new industrial infrastructures for commercial and residential buildings, mobility, energy, and water, as well as food production and lifestyle changes.

The REEO modelling indicates that business-as-usual leads to continued growth of energy use, carbon dioxide emissions, and materials use, which may ultimately challenge the capacity of the Earth's resources and ecosystems.

Making use of all technological potential within existing systems, as assumed in the resource efficiency scenario, will not significantly reduce these impacts. The potential efficiency gains may be far reaching, but will not keep pace with a growing population and growing per-capita income. Resource efficiency may contribute to constraining the global environmental impact of rapid development and modernization in the Asia-Pacific region, but efficiency used in isolation will not avoid undesirable environmental consequences.

The structural change assumed in the system innovation scenario may eventually lead to sustainability, but requires substantial changes in economic behaviour and societal aspirations. It will require a new industrial revolution to establish the wellbeing of nations and people on a very different economic basis. Asia-Pacific economies need to invent and implement new industrial infrastructures that require less energy and materials, and allow for higher flexibility and lower risks in the face of global environmental change and resource scarcity. If the potential of these strategies for environmental savings is to be realized, it will be necessary to avoid rebound by moving to reduced labour force participation; that is, leisure-based lifestyles with lower consumption.

Response

Massive investment in infrastructure, skills, and institutional and governance capacity is required to achieve resource efficiency and transition to a new sustainable economic regime in keeping with system innovation and the capacity of global resources and ecosystems. The strategies will need to enable policies and programmes to be integrated across public policy domains, and identify trade-offs as well as synergies.

A final word

This focus on Asia and the Pacific is very timely because the region has become the most economically dynamic in the world and thus global sustainability will be decided in this region. The competitiveness of the Asia-Pacific region will depend on the speed and scale at which new industrial infrastructure that uses less materials and energy can be introduced to offset the unprecedented economic growth and improved standard of living. The alleviation of poverty will be closely linked to this overall economic success story. Tackling resource efficiency now will enable the region to continue on a path to prosperity for all.

The dataset and indicators presented in this report will eventually enable policy makers to design integrated resource efficiency policies, to set targets, and monitor progress with regard to the effectiveness and efficiency of natural resource use to contribute to economic development, rising standards of living, and poverty reduction. The quality and quantity of data available varies from country to country, and ongoing effort will be required to ensure that policy makers have sufficient information on which to base decisions.

The challenges for sustainable resource use in Asia and the Pacific may seem overwhelmingly large in the face of rapid development and transformation in the region, but also because of the likelihood of further growth occurring as human development needs are met. This report is a small step in the context of the policy cycle and decision-making process for instituting sustainable resource use in the region. It presents evidence of the resource use implications of development, thereby contributing to problem recognition and supporting agenda setting by countries and regional intergovernmental agencies. Decision making, policy formulation, and policy implementation will need to follow if the challenges are to be taken seriously and the window of opportunity for sustainability – social and economic development, enhanced human wellbeing, and environmental and resource integrity – is to be taken in Asia and the Pacific. The indicators proposed in this report may help to monitor progress and thereby evaluate policies that aim for sustainable development and the sustainable use of natural resources.

Index