UNEP

International Resource Panel

Decoupling Natural Resource Use and Environmental Impacts from Economic Growth

United Nations Environment Programme

Acknowledgements

Editor: International Resource Panel

Working Group on Decoupling

Lead authors: Marina Fischer-Kowalski, Institute of Social Ecology Vienna, Alpen-Adria University, Austria, with the support of the Lebensministerium, Austria and Mark Swilling, Sustainability Institute, School of Public Leadership, University of Stellenbosch, South Africa

Contributing authors: Ernst Ulrich von Weizsäcker (Chairperson of the Decoupling Working Group), Yong Ren, Yuichi Moriguchi, Wendy Crane, Fridolin Krausmann, Nina Eisenmenger, Stefan Giljum, Peter Hennicke, Rene Kemp, Paty Romero Lankao, Anna Bella Siriban Manalang

Jeff McNeely provided editorial support for the full report and summary brochure.

The report went through several rounds of peer-review coordinated in an efficient and constructive way by Jeff McNeely together with the International Resource Panel Secretariat. Valuable comments were received from several anonymous reviewers in this process. The preparation of this report also benefited from discussions with many colleagues at various meetings.

Special thanks go to Ernst Ulrich von Weizsäcker and Ashok Khosla as Co-Chairs of the International Resource Panel, the members of the International Resource Panel and its Steering Committee for their dedication and commitment.

Janet Salem, UNEP, provided valuable input and comments; the International Resource Panel's Secretariat coordinated the preparation of this report. Jaap van Woerden and Stefan Schwarzer of UNEP/DEWA/GRID–Geneva provided scientific data support in developing the figures.

The main responsibility for errors remains with the authors.

ISBN: 978-92-807-3167-5
Job Number: DTI/1388/PA

The full report should be referenced as follows:

UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A.

Copyright © United Nations Environment Programme, 2011

This publication may be reproduced in whole or in part and in any form for educational or nonprofit 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 for any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme.

Design/layout: L'IV Com Sàrl, Le Mont-sur-Lausanne, Switzerland.

Cover photos ©: Oleg Romanciuk/Dreamstime and Don Hammond/Design Pics/Corbis.

Disclaimer
The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Environment Programme concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does citing of trade names or commercial processes constitute endorsement.

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on FSC-certified paper, using eco-friendly practices. Our distribution policy aims to reduce UNEP's carbon footprint.

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on FSC-certified paper, using eco-friendly practices. Our distribution policy aims to reduce UNEP's carbon footprint.

UNEP

International Resource Panel

Decoupling Natural Resource Use and Environmental Impacts from Economic Growth

Contents

List of figures and tables v

Abbreviations and acronyms vii

Units viii

Preface ix

Foreword xi

Executive summary xiii

Objective and scope xvii

1 Introduction 1
1.1 Why decoupling?
1.2 Defining decoupling 4
1.2.1 Roots of the decoupling concept 4

2 Global long-term trends in the use of natural resources and in undesirable environmental impacts 7
2.1 Note on methodology 7
2.2 The global dynamics of material resource use 10
2.2.1 Conclusion 17
2.3 Assessing the dynamics of global environmental impacts 18
2.3.1 Strategies to reduce impacts 18
2.3.2 The Environmental Kuznets Curve 19
2.3.3 Empirical studies of impacts 20
2.3.4 Conclusion 25
2.4 Scenarios for future global materials use 26
2.4.1 Scenario 1: Business as usual 28
2.4.2 Scenario 2: Moderate contraction and convergence 29
2.4.3 Scenario 3: Tough contraction and convergence 29

3 Decoupling and the need for system innovations 33
3.1 Rethinking growth 33
3.2 Innovation and decoupling 35
3.3 Cities as spaces for innovation and decoupling 42
3.4 Experiences and lessons from the country case studies 45
3.4.1 Recognizing resource depletion and negative impacts 46
3.4.2 Policy responses 48
3.4.3 Decoupling 50

4 Decoupling, trade and development dynamics 55
4.1 Trade and the distribution of resources and environmental burdens 55
4.1.1 The dynamics of global trade in economic (monetary) and physical terms 55
4.1.2 The economic structure of global trade 56
4.1.3 The physical structure of global trade 58
4.1.4 Indirect resource flows embodied in trade 60
4.1.5 Trade, decoupling and development 62
4.2 Decoupling, development and inequality 64
4.2.1 Africa as a special case? 66
4.3 Decoupling and the rebound effect 67
4.4 Prices and resource productivity 69

5 Conclusions and major policy challenges 71
5.1 Conclusions 71
5.2 Major policy challenges 74

Country case studies 76

6 Germany 77
6.1 Recognizing limits 77
6.2 National Strategy for Sustainable Development 78
6.3 A feasible vision? The '2000 Watt/cap society' 79
6.4 The key to sustainable energy: efficiency increase by a Factor x 80
6.5 Integrating material and energy efficiency strategies 81
6.6 Decoupling – empirical evidence and strategic actions 82
6.7 Impulse programme for material efficiency (2005–2009) 83
6.8 Research on integrated strategies (Ecological Industrial Policy) 84
6.9 Institutional context for decoupling: selected problems 86
6.10 Conclusion and outlook 86

7 South Africa 87
7.1 Recognizing limits 88
7.2 Climate change 92
7.3 Oil resources 93
7.4 Energy 94
7.5 Water and sanitation 95
7.6 Solid waste 96
7.7 Soils 98
7.8 Biodiversity 99
7.9 Policy responses 100
7.9.1 Macroeconomic policy versus Section 24(b) of the Constitution 100
7.9.2 National Framework for Sustainable Development 100
7.9.3 Growing influence of sustainability thinking 101
7.10 Decoupling – opportunities for action 102
7.10.1 Decoupling opportunities 102
7.11 Conclusion 103

8 China 105
8.1 Recognizing limits 106
8.2 Policy responses 106
8.3 Towards an 'ecological civilization' 107
8.4 The circular economy 107
8.5 Environmental economic instruments 108
8.6 Decoupling – evidence and strategic actions 110
8.7 Decoupling trends in China 112
8.8 Actions towards decoupling 115
8.9 One world, one dream – the Green Olympics 116
8.10 Conclusion 116

9 Japan 119
9.1 Recognizing limits 120
9.1.1 Limits of resources – lessons learned from oil crises 120
9.1.2 Limits at the end-of-pipe 120
9.2 Policy responses 121
9.2.1 Towards a sound material cycle society 121
9.2.2 The Fundamental Law and Plan 123
9.3 Contribution to international initiatives 124
9.4 Japan's strategy for a sustainable society 124
9.5 Decoupling – evidence and innovation 125
9.5.1 Voluntary actions by industries 125
9.5.2 Actions by local authorities 126
9.5.3 A Japanese approach to decoupling: the Top Runner Programme 126
9.6 Lessons from the use of resource productivity indicator 128
9.7 Conclusion 129

References 130

About the International Resource Panel 151

Working Group on Decoupling 152

List of figures and tables

Figure 1 Two aspects of 'decoupling' xiii
Figure 2 Global material extraction in billion tons, 1900–2005 xiv
Figure 1.1 Stylized representation of resource decoupling and impact decoupling 5
Figure 2.1 Global material extraction in billion tons, 1900–2005 11
Figure 2.2 Global metabolic rates 1900–2005, and income 12
Figure 2.3 Gross Domestic Production and Domestic Material Consumption in OECD countries, 1980–2000 12
Figure 2.4 Composite resource price index (at constant prices, 1900–2000) 13
Figure 2.5 Commodity price indices 13
Figure 2.6 The global interrelation between resource use and income (175 countries in the year 2000) 14
Figure 2.7 Average metabolic rates (resource use in tons/capita) by development status and population density 17
Figure 2.8 Environmental risk transition framework 19
Figure 2.9 Global growth of cereals production and fertilizer consumption 21
Figure 2.10 World conventional oil discoveries and production 22
Figure 2.11 Global extraction of industrial minerals and ores 1980 and 2006, by type of country 23
Figure 2.12 Ore grades of mines in Australia, 1840–2005 23
Figure 2.13 Ore grades of gold mines, 1830–2010 24
Figure 2.14 Ore grades of nickel and copper mines, 1885–2010 24
Figure 2.15 Resource use according to three different scenarios up to 2050 30
Figure 3.1 The different guises of development 34
Figure 3.2 Resource productivity, labour productivity and energy productivity in EU-15 37
Figure 3.3 Price dynamics of wages, materials and electricity 37
Figure 3.4 Conceptual model of innovations 39
Figure 3.5 System innovation 40
Figure 3.6. The relation between urbanization level (%) and Gross National Income (GNI) 43
Figure 4.1. Composition of exports (in monetary units) by world regions, 2006 57
Figure 4.2. Raw material extraction and trade by country type 58
Figure 4.3. Physical and monetary trade balances of three country types, 1962 to 2005 59
Figure 4.4. Physical trade balances, year 2005 60
Figure 4.5. Virtual water trade balances and flows of agricultural products, 1997–2001 61
Figure 4.6. Material intensity of the world economy: Domestic extraction of materials per unit of GDP by world region 64
Figure 4.7. Eco-friendly spending, total amount and percentage of total fiscal stimulus package 66
Figure 4.8. CO_2 emissions from fossil fuel consumption 70
Figure 6.1. Resource productivity and GDP growth 82
Figure 6.2. Structure of the project MaRess 85
Figure 7.1. Real GDP growth 1983–2004 88

Figure 7.2. GDP and employment change 1983–2004 (non-agricultural sectors) 89
Figure 7.3. Final consumption expenditure by households 89
Figure 7.4. Percentage of household saving and debt 1970–2006 90
Figure 7.5 Domestic extraction 91
Figure 7.6 Material efficiency 1980–2000 91
Figure 7.7 Primary material exports 1980–2000 92
Figure 7.8 Solid waste disposal in millions of tons in Cape Town, 2002–2027 97
Figure 8.1 The process of economic development in China since 1978 105
Figure 8.2 Scenarios for economic growth and its pressures on environment and resources 111
Figure 8.3 Three stages of economic growth and pressures on environment and resources 112
Figure 8.4 Trends of energy, GDP and population and the decoupling index of primary energy consumption to GDP growth 113
Figure 8.5 Trends of fresh water consumption, GDP and population and the decoupling index of fresh water consumption to GDP growth 113
Figure 8.6 Trends of industrial waste water and solid waste discharge and GDP and the decoupling index of industrial waste water and solid waste discharge to GDP 114
Figure 8.7 Trends of COD discharge, SO_2 emission and GDP and the decoupling index of SO_2 emission and COD discharge to GDP 114
Figure 9.1 Scheme of a sound material cycle society (SMC) 122
Figure 9.2 Trends of material flow indicators 123
Figure 9.3 Legislative framework for sound material cycle policy 124
Figure 9.4 Framework of Japan's strategy for a sustainable society 125
Figure 9.5 Waste management efforts in Shibushi City 126

Table 2.1 Metabolic scales and rates, overview of scenario analysis 31
Table 7.1 Comparative carbon emissions 2004 93
Table 7.2 Past and projected consumption of transportation fuels (million litres/year) 94
Table 7.3 Energy intensities 95
Table 7.4 Historical water consumption (1996) and projected water demand (2030) by sector 95
Table 7.5 Key threats to South Africa's ecosystems 99
Table 9.1 Top Runner Programme achievements 127

Abbreviations and acronyms

3R	Reduce, reuse and recycle
A	Annum
ASGI-SA	Accelerated and Shared Growth Initiative for South Africa
BAU	Business as usual
BMU	German Ministry for the Environment, Nature Conservation and Nuclear Safety
Cap	Capita
CCICED	China Council for International Cooperation on Environment and Development
CCS	Carbon capture and storage
CHP	Combined Heat Power
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
DE	Domestic Extraction
DEMEA	Deutsche Materialeffizienzagentur (German Material Efficiency Agency)
DI	Decoupling Index
DMC	Domestic Material Consumption
DMI	Direct Material Input
ECLAC	UN Economic Commission for Latin America and the Caribbean
EFA	Effizienzargentur (Efficiency Agency of North Rhine-Westfalia)
EIA	Environmental Impact Assessment
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom
EU-27	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom
FGD	Flue-gas desulphurization
G8	Group of Eight
GDP	Gross Domestic Product
GPI	Genuine Progress Indicator
ICLEI	International Council for Local Environmental Initiatives
IECP	Integrated Energy and Climate Programme
IPCC	Intergovernmental Panel on Climate Change
IRP	International Resource Panel
LCA	Life cycle assessment
LED	Local Economic Development
LTMS	Long Term Mitigation Scenario
MEPS	Minimum Efficiency Performance Standards
MFA	Material flow accounting
MLP	Multi-level perspective
MSW	Municipal solid waste
MTB	Monetary trade balance
NFSD	National Framework for Sustainable Development
NIC	Newly Industrialized Countries
NIPF	National Industrial Policy Framework

NO_x	Mono-nitrogen oxides NO and NO_2
NSSD	National Strategy for Sustainable Development
OECD	Organisation for Economic Co-operation and Development
PTB	Physical trade balance
RNE	German Council for Sustainable Development
SEPA	State Environmental Protection Administration (now the Ministry for Environmental Protection)
SMC	Sound Material Cycle Society
SME	Small to medium sized enterprise
SO_2	Sulfur dioxide
SOIS	Sustainability Oriented Innovation System
SO_x	Sulfur oxides
SRES	Special Report on Emissions Scenarios
TCE	Ton of coal equivalent
TPER	Total Primary Energy Requirement
TPES	Total Primary Energy Supply
UK-SDC	United Kingdom's Sustainable Development Commission
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
WTO	World Trade Organization
Yr	Year

Units

g	grams
kg	kilograms (10^3 grams)
Mg	megagrams (10^6 grams)
Tg	teragrams (10^9 grams)
T	ton (10^6 grams)
Mt	megaton (10^6 tons)
Gt	gigaton (10^9 tons)
J	joules
W	watts (J/s)
GJ	gigajoules (10^9 joules)
MW	megawatt (10^6 watts)
m^3	cubic meter (10^3 liters)
Gm^3	giga cubic meters (10^9 cubic meters)

Preface

Decoupling human well-being from resource consumption is at the heart of the International Resource Panel's (IRP) mandate. It is also at the heart of the Green Economy Initiative of UNEP that has just produced an impressive report on the Green Economy (February 2011).

The conceptual framework for decoupling and understanding of the instrumentalities for achieving it are still in an infant stage. The IRP plans to carry out a series of investigations on decoupling, each of which will result in a report. The reports will aim to support the Green Economy Initiative and also to stimulate appropriate policies and action at global, national and local levels.

This first report is simply an attempt to scope the challenges. The report presents basic facts and figures on natural resource flows worldwide. Four country studies embedded in the report show that consumption of natural resources is still rising rapidly. Drawing on these data, the report attempts to outline the issues that now need to be addressed to decouple these material and energy flows from social and economic progress.

Even in the two countries which arguably have made the most explicit efforts towards decoupling, Japan and Germany, and where at first glance domestic resource consumption shows stabilization or even a modest decline, deeper analysis shows that many goods contain parts that have been produced abroad using major amounts of energy, water and minerals. Thus some of the advanced countries are managing the problem of high resource intensity by "exporting" it elsewhere. The Report observes that trade – not surprisingly – is generally enhancing energy use and resource flows and thus, overall, impeding rather than promoting decoupling.

Two case studies from developing countries, China, and South Africa, show a steady increase of resource flows, probably indicative of the trends in all emerging economies. However, in the case of China there appears to be some success in the national effort to achieve *relative* decoupling through modernization of the economy and explicit policies to reduce resource intensity. Absolute reduction of energy and resource consumption cannot yet be expected to be part of the policies of developing countries.

On a worldwide scale, resource consumption is steeply on the rise (see Figure 2.1), and resource consumption is still a reliable companion of economic prosperity (see Figure 2.6). All such empirical facts and figures show that the world's climate and geological environment are subject to ever increasing pressures, which are pushing the limits of sustainability. This should make citizens and policy makers impatient to reverse the dangerous trends and improve the situation.

The report's Introduction lists some of the challenges that will be addressed in future reports of the IRP. Among the positive prospects are technologies that deliver more and better services using much less energy, water, or minerals; policies and appropriate market signals that make the transition to a clean and low resource intensity economy attractive and profitable; and the special role of urban areas in forging innovations towards a sustainable economy. Such opportunities for effective decoupling offer not only lifelines for the survival of human civilization but also serve as preconditions for reducing poverty and social inequalities.

New reports in the decoupling agenda pipeline include ones on technologies and policies, and on how cities can accelerate or be impacted by decoupling interventions. We hope that the growing interest in Green Economy issues, particularly among policy-makers, will be well served by this work.

We are very grateful to the team coordinated by professors Marina Fischer-Kowalski and Mark Swilling for having collected the relevant data and presenting a rounded picture of resource intensities and the attempts to reduce them. We thank the authors of the four case studies on national decoupling policies, which give strong inputs and support to the conclusions of the report. We hope that other such case studies will be triggered by the publication and circulation of this report, particularly by national institutions.

We also wish to thank Jeff McNeely, member of the IRP, for serving as Peer Review Coordinator for the report, and the (anonymous) peer reviewers who have gone to the trouble of reading and commenting the draft report; their suggestions have certainly improved its quality. Finally, we would like to thank the Paris Office of UNEP, notably Ms. Janet Salem, for excellent support work throughout the preparation of the report.

Dr. Ernst Ulrich von Weizsäcker, Emmendingen, Germany
Dr. Ashok Khosla, New Delhi, India
Co-Chairs, International Resource Panel (IRP)

31 March 2011

Foreword

A transition to a low carbon resource efficient Green Economy has become one of the leitmotifs of international efforts to evolve sustainable development in a rapidly changing 21st century.

Next year in Brazil, governments will meet again 20 years after the Rio Earth Summit of 1992 amid a landscape of persistent and emerging challenges and against a backdrop of recent and on-going crises that in part are being triggered by the way society manages or more precisely mismanages natural resources.

A Green Economy, in the context of sustainable development and poverty eradication, is one of the two central themes of Rio+20. It underlines that it is in the interests of all nations – developed and developing and state or market-led – to begin reducing humanity's planetary impact in ways that reflect national circumstances.

This new report by UNEP's International Resource Panel is an important part of this overall discourse and direction. It brings empirical evidence to bear on the levels of natural resources being consumed by humanity and the likely consumption levels if past trends are mirrored into the future.

Indeed, it suggests that such unsustainable levels of consumption could triple resource use by 2050 and it brings forward the powerful and urgent concept of 'decoupling' as a key action in order to catalyze a dramatically different path.

Decoupling at its simplest is reducing the amount of resources such as water or fossil fuels used to produce economic growth and delinking economic development from environmental deterioration. For it is clear in a world of nearly seven billion people, climbing to around nine billion in 40 years time that growth is needed to lift people out of poverty and to generate employment for the soon to be two billion people either unemployed or underemployed.

But this must be growth that prizes far more efficient resource management over mining the very assets that underpin livelihoods and our economic opportunities in the first place.

Overall the analysis suggests that over the coming decades the level of resources used by each and every person may need to fall to between five and six tons. Some developing countries are still below this level whereas others, such as India are now on average at 4 tons per capita and in some developed economies, Canada for example, the figure is around 25 tons.

The report points out that technological and systematic innovation, combined with rapid urbanization, offer an historic opportunity to turn decoupling from theory into reality on the ground. The report spotlights the countries of China, German, Japan and South Africa where governments are making headway with conscious efforts to stimulate decoupling.

It underlines too how the complexities of the modern world, with globalized trade and exporting economies demand the kind of sophisticated analysis provided by the Panel if decoupling is to be fully understood and – more importantly – realized.

The sharp spikes in commodity prices have served to remind the international community of the risks we all run if a transition to a Green Economy is unfulfilled and postponed into an indefinite future. The evidence from preparations on the road to Rio+20 is that governments, the private sector and civil society realize this and are looking for the options that can scale-up and accelerate such a transition.

Decoupling represents a strategic approach for moving forward a global Green Economy – one that "results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities".

I would like to thank the International Resource Panel under the leadership of Ashok Khosla and Ernst Ulrich von Weizsäcker as co-chairs for its pioneering work presented in this report. It not only inspires current generations but also protects the interest of future ones.

Achim Steiner
UN Under-Secretary General and Executive Director, UNEP

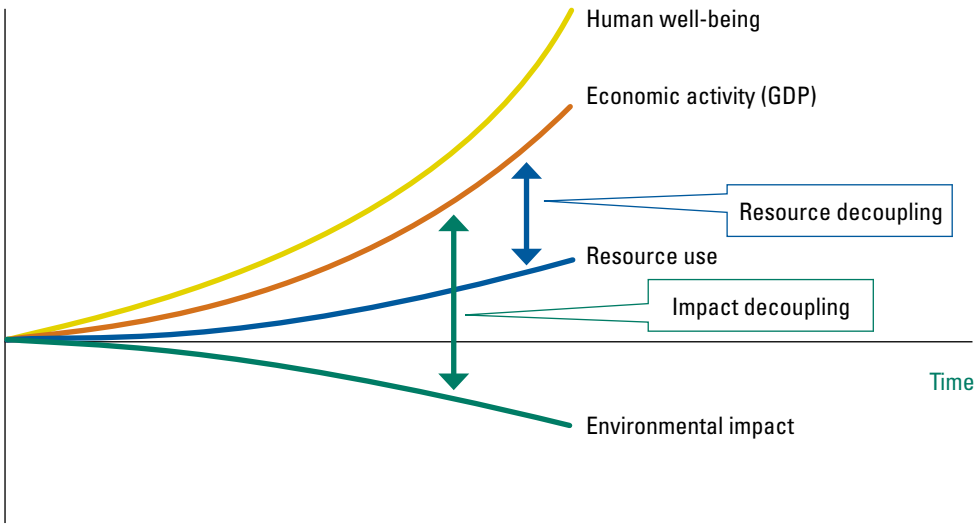
Nairobi, Kenya, March 2011

Executive summary

The 20th century was a time of remarkable progress for human civilization. Driven by scientific and technological advances, the extraction of construction materials grew by a factor of 34, ores and minerals by a factor of 27, fossil fuels by a factor of 12, and biomass by a factor of 3.6 (Figure 2). This expansion of consumption was not equitably distributed, and it had profound environmental impacts. Over-exploitation, climate change, pollution, land-use change, and loss of biodiversity rose toward to top of the list of major international concerns. One result was that 'sustainability' became an over-arching global social, environmental and economic imperative among governments, international organizations, and the private sector. Leaders increasingly understood that making progress towards a more sustainable economy requires an absolute reduction in resource use at a global level, while human well-being demands that economic activities should expand and environmental impacts diminish.

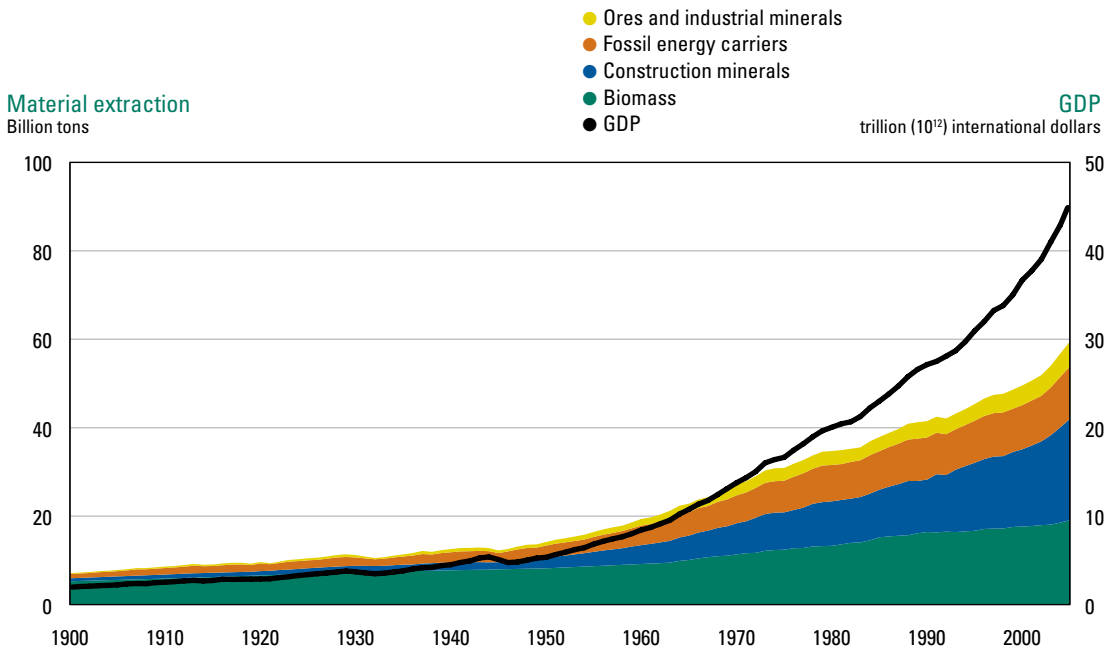
UNEP's International Resource Panel (IRP) has applied the concept of 'decoupling' to this challenge. While the term has been applied to everything from electronics to physical cosmology to linear algebra, in the sense used here decoupling means using less resources per unit of economic output and reducing the environmental impact of any resources that are used or economic activities that are undertaken. Figure 1 captures the essence of the two key aspects of decoupling as applied to sustainable development, namely resource decoupling and impact decoupling.

Figure 1. Two aspects of 'decoupling'



The report focuses on the extraction of four categories of primary raw materials – construction minerals, ores and industrial minerals, fossil fuels, and biomass – which together are estimated to be harvested at a rate of 47 to 59 billion metric tons (47–59 Gt) per year (2005 data), with continued increases into the future a clear tendency (see Figure 2). The steady increase in the use of these raw materials has been accompanied, or perhaps prompted, by continuously declining prices of most of these categories of resources. Declining prices may be interpreted as reflecting increasing supply, but are more likely to reflect more efficient means of extraction and structurally weak market positions for certain resource-rich resource-exporting developing countries. On the other hand, many critical resources are becoming more expensive to extract, with petroleum in the Arctic and in the open sea being outstanding examples. More recently, at least some of these resources are showing greater price volatility, which may support a more rapid transition based on the decoupling of growth rates from rates of resource use and negative environmental impacts.

Figure 2. Global material extraction in billion tons, 1900–2005



Source: Krausmann *et al.,* 2009

Decoupling will require significant changes in government policies, corporate behaviour, and consumption patterns by the public. These changes will not be easy, and this paper will not attempt to chart the course toward their achievement or fully explore all of the challenges the concept poses. Rather, it will seek to build understanding of the critical concept of decoupling, which provides the foundation for the work of the International Resource Panel (IRP).

This report is envisaged as the first in a short series, with the subsequent reports from the Decoupling Working Group of the IRP seeking to respond to the most significant challenges that are identified here (Chapter 5). Other work of the IRP will apply the

concept of decoupling to greenhouse gas (GHG) mitigation technologies, metal flows and recycling, land and soil, and water.

Having reviewed the trends in the use of natural resources and accompanying undesirable environmental impacts in the first section of Chapter 2, the last section of that chapter considers possible future implications by presenting three brief scenarios: (1) business as usual (leading to a tripling of global annual resource extraction by 2050); (2) moderate contraction and convergence (requiring industrialized countries to reduce their per capita resource consumption by half the rate for the year 2000); and (3) tough contraction and convergence (aimed at keeping global resource extraction at its current levels). None of these scenarios will lead to actual global reductions in resource use, but all indicate that substantial reductions in the resource requirements of economic activities will be necessary if the growing world population can expect to live under conditions of sustainable resource management.

Technological innovations have often led to greater resource consumption; however, innovations in resource extraction and use systems (Chapter 3) will be required to enable decoupling to take place in different settings, with a diversity of approaches being applied. Economic innovations will also be essential, perhaps even leading to a substantially revised progress indicator that complements GDP with environmental and social concerns. In this context, UNEP's Green Economy Initiative seeks to couple a revived world economy with reducing ecosystem degradation, water scarcity, and carbon dependence. The increasing trend of resource consumption has been driven in part by technological innovation, and such innovations that can instead support decoupling will be discussed in more detail in future reports of the Decoupling Working Group.

Drawing especially on case studies from South Africa, Germany, China, and Japan (full case studies are included in Chapters 6–9), Chapter 4 explores some of the ways that decoupling affects development. One major lesson learned is that the rising economic and environmental costs of resource depletion and negative environmental impacts have affected the economic growth and development trajectories of these countries, leading all of them to adopt policies that commit both governments and industries to reduce the amount of resources used for each unit of production (or increase resource decoupling) and reduce negative impacts on the environment (or implement impact decoupling). The case studies also show that concepts of resource efficiency, resource productivity, dematerialization, material flows and decoupling are used in somewhat different ways in these countries, indicating that these ideas can be expected to evolve in nationally-specific ways that reflect the unique circumstances of each country. This diversity in approaches to decoupling can be taken as a sign of the strength of the concept.

Chapter 4 discusses decoupling as applied to trade and the distribution of resources, making the key point that many imported resources are subsequently exported in a different form, such as manufactured goods, which may be interpreted as shifting at least part of the responsibility for consumption (and therefore decoupling) to the ultimate consumer. Trade is of growing concern, as internationally traded materials increased from 5.4 billion tons (5.4 Gt) in 1970 to 19 billion tons (19 Gt) in 2005, complicating the application of decoupling by obscuring responsibility for it. Decoupling potentially can also enhance equity among nations, drawing on the concept of 'metabolic rates' (resources used per capita) as an objective means of comparing resource consumption rates of different countries. Overcoming inequity needs particular attention. As an indicator of inequity in resource consumption, the richest 20% of the world's population were

responsible for 86% of consumption expenditure in 1998, while the poorest 20% had to settle for just 1.3% of such expenditure.

Chapter 4 also suggests that innovation towards decoupling may be developed especially in urban settings, where an increasing majority of the world's people will live in the coming years. It has already been demonstrated that more dense forms of living allow for lower consumption of many raw materials at the same levels of material comfort, suggesting fertile grounds for further decoupling. Decoupling may also experience a 'rebound effect', which requires addressing the concern that efficiency gains in resource use may paradoxically lead to greater resource use.

Some of the major challenges of decoupling that remain to be addressed include:

- How can the **understanding of global resource flows and their associated environmental impacts** be coupled to related challenges, such as climate change and the role that ecosystem services play?
- How can policymakers (and the general public) be convinced about the **absolute physical limits** to the quantity of non-renewable natural resources available for human use under current economic conditions?
- How can the **decoupling that has already started to happen** at least in some countries lead to rapid escalations in investments in innovations and technologies to accelerate decoupling more generally?
- How can **appropriate market signals be developed** to help resource productivity increases become a higher priority?
- How can **cities** best become the spaces where ingenuity, resources, and communities come together to generate practical decoupling in the ways cities produce and consume?
- How can decoupling come to be accepted as a necessary precondition for **reducing the levels of global inequality** and eventually help eradicate poverty?

This paper presents substantial evidence supporting the need for both resource decoupling and impact decoupling, and indicates some examples of where such decoupling is actually occurring. While different categories of resources have very different kinds of environmental impacts, progress toward decoupling has been made in construction minerals, ores and industrial minerals, fossil fuels, and biomass. But this progress to date has been indicative rather than decisive, and a far greater effort will be required to convince key audiences of the critical importance of decoupling. The future work of the International Resource Panel is designed to support such efforts, in hopes of leading to an effective transition to a Green Economy that enhances human welfare while sustaining environmental resources.

Objective and scope

The objective of this study is to provide a solid foundation for the concept of decoupling, clearly defining key terms and concepts and indicating its many applications to resource management. It assesses whether decoupling is already taking place, and identifies the driving factors, both technological and economic. This report aims to also provide some indications of the kinds of policy measures and considerations that may be needed to stimulate decoupling. The word "Resources" usually refers to materials, water, energy and land. This report focuses on material resources, namely fossil fuels, minerals, metals and biomass. As such, it is not the intention of the International Resource Panel (IRP) to cover all resources in a single report, rather this report will be complemented by concurrent reports of the IRP on land and soil, water, metals and other topics.

Future work of the IRP will build on the foundation of this scoping report on decoupling. The first prioirity will be to identify which product groups and materials have the greatest negative environmental impacts, or are reaching alarming levels of scarcity. The priority attention will be given to those resources that are amenable to policy interventions and improved forms of management that will decrease any negative impacts while continuing to contribute to human wellbeing. The IRP expects to identify a substantial list of such resources, and provide policy options for improving their management. It is expected that this more systematic approach will lead to others – governments, the private sector, and civil society – adopting decoupling as an essential component of sustainable development.

One IRP working group is focusing on the flows of metals, providing accurate assessments of the global flows of metals and indicating where recycling and reusing of metals will reduce demand for opening of new mines (which are often associated with negative environmental impacts). The first reports from the working group are already indicating some key metals that can be recycled at far higher levels, with substantial economic savings and reducing environmental impacts (in other words, resource decoupling).

Another working group is addressing water, a scarce resource in many parts of the world. A better understanding of the hydrological cycle is especially challenging as climate change is leading to unpredictable distribution of water in both time and space. Torrential rainfalls and subsequent droughts are clear indicators that improved water management is an essential part of human wellbeing. The working group on water will be working at the landscape scale, examining new approaches to more efficient use of water (such as drip irrigation), demonstrating how both agricuutre and industry can enhance water-use efficiency. Methods being assessed include improved efficiency in water harvesting, more effective water storage, more comprehensive approaches to water sharing so that all users have a fair allocation of water, greatly enhanced recycling of water, and reducing demand. Already, many companies in the private sector are enhancing water efficiency in

their production processes and signficantly reducing water pollution. The IRP will be assessing the various approaches and providing policy options on how water-use efficiency can be substantially improved across multiple sectors.

Water is an essential resource for virtually all aspects of human enterprise, from agriculutre to energy to industrial production to human health. Many of these applications will receive attention from IRP working groups in due course, but one urgent matter is the more efficient use of land and soil. With food prices now at an all-time high, due to factors such as increased energy prices, growing demand, climate change, conversion of food crops to biofuels, and many others, it becomes all the more important to assess the management of land and soils at a global level. A new IRP working group is now beginning such an assessment, with the objective of enhancing sustainable management of land and soils. Land is seen in the broad sense of land use and land use planning, which is becoming more urgent as multiple demands are being placed on this limited resource; indeed, the amount of land may be declining as sea levels rise, making it all the more important that land use is well informed by solid science as well as social and economic factors. The focus on soil is on maintaining its productivity, including the diversity of soil micro-organisms, reducing pollution, and developing new approaches to maintaining soil productivty without excessive use of chemical fertilizers. Significant investments are being made by both governments and the private sector toward these ends, and the IRP working group will be working with them to assess the most promising approaches to decoupling the use of lands and soils from the economic production of these important natural systems.

As the concept of resource decoupling is further developed, the IRP expects to identify other materials and resources that can benefit from decoupling. Sustainable development and new approaches to "green economics" will greatly benefit from the contributions that the IRP will be making through its work on decoupling resource consumption from economic growth.

1 Introduction

1.1 Why decoupling?

Human well-being and its improvement, now and for a still growing world population in the future, is based upon the availability of natural resources such as energy, materials, water and land. Economic development so far has been associated with a rapid rise in the use of these resources. Many of them are becoming less abundant relative to demand, and some run the risk of critical scarcity in the near future (as indicated by declining grades of ores being mined, in Figures 2.12, 2.13, and 2.14). Undesirable environmental impacts can arise from any part of the life cycle of resources: in the phases of extraction, production/manufacture, consumption/use or post-consumption. These impacts may be caused by deliberate interventions into natural systems such as land cover change and resource extraction, or by unintended side effects of economic activities, such as emissions and wastes. Thus, a focus on decoupling requires attention both to the amount of resource use linked with economic activity, and to the environmental impacts associated with this resource use at all stages of the life cycle. These impacts may lead to a disruption of the ecosystem services that are essential to human well-being.

This Report is one in a series of reports by the International Resource Panel (IRP) that seeks to assess the key challenges of decoupling resource use and negative environmental impacts from economic activity. Addressing these challenges successfully will contribute to the overall goals of meeting the needs of a growing world population, eradicating poverty, and supporting economic development, with a minimum of strain on the world's resource base and without threatening future earth and ecosystem services. In order to achieve these goals, natural resource use and associated negative environmental impacts, on a global and long term level, must as far as possible be decoupled from the economic activity required to support a growing population.

Natural resources can be given a broad definition that includes anything that occurs in nature that can be used for producing something else. This inclusive definition can cover the song of a bird inspiring a composer, the shine of a star used by a captain to find his way, or a stone in a farmer's field. The first two are 'immaterial resources', whose use has no effect on the qualities that make them useful; nor can they easily be given an economic value. The third – the rock in the field – is a 'material resource' whose value is characterized by the qualities that render it useful for certain applications. Its value for building a wall, for example, is different from its value if it is merely an annoyance for the farmer trying to plough his field. But if the rock contains gold, its value is suddenly increased, assuming that the farmer recognizes this value.

Using immaterial resources does not change the qualities that make them useful, or reduce the range of available applications. The same song of the bird

may be used by still another composer or give highly-valued pleasure to a bird-watcher, and the same starlight can provide information for hundreds of captains and later provide information to astronomers about the creation of the universe. With material resources, making use of them can eliminate at least some of the qualities that make them useful for the purpose at hand. A rock used to build a wall cannot then be used to build another wall or be converted to gold jewellery (if it contains gold) without destroying the first wall. Material resources do not disappear through transformation (basic physics does not allow for the disappearance of energy/matter), but their potential usefulness for the same purpose is no longer available. How much of a resource declines as it is used (or converted from one state to another) depends largely on how much the resource is modified through use.

Most material resources are scarce in economic terms, which provides the basis for determining their price. But a few material resources, such as wind, sunshine or tidal energy, are so abundant that they cannot possibly be depleted. Their economic price is determined not by their supply but rather by the cost of converting them into forms that can then be applied to other uses (for example, running wind farms, solar panels, or tidal energy generators).

The broad definition provided above makes everything in the material world potentially a material resource, and everything may be put to a theoretically infinite number of uses.[1] Because **resources and resource use conceptually serve as one of the most important links between the environment and economic activities**, this report chooses a more precise definition of material resources that considers only the *actually used* resources and thus better complies to the use of this term in economics: **Material resources are natural assets deliberately extracted and modified by human activity for their utility to create economic value. They can be measured both in physical units (such as tons, joules or area), and in monetary terms expressing their economic value**. Such a narrower focus allows generating a finite and (on the most aggregate level) short list of 'material resources' for which also, in principle at least, accounting schemes exist: energy, materials, water and land.

As far as resources are concerned, this report seeks to remain complementary, not replicating existing similar efforts. It will focus on material resources, with the main classes being biomass, fossil fuels, industrial minerals and ores, and construction minerals. It will pay relatively little attention to energy resources and the carbon cycle, as these issues are well addressed by IPCC assessments and by the ongoing Global Energy Assessment (GEA) being conducted by International Institute for Applied Systems Analysis (IIASA)[2]. It will leave issues of water resources and land and soil resources to future reports under preparation by the IRP.

The use of material resources in this report will be addressed at global, national, and city levels, where information on population and economic activity level (GDP) is available. This has been complemented by four case studies of countries that have taken a particular policy interest in dealing with decoupling resource use from development: China, Germany, Japan and South Africa. In a follow-up report on decoupling, the IRP plans to supplement this country-level focus with a more sector- and technology-oriented focus.

The degree to which resource use causes detrimental environmental impacts depends not only on the amount of resources used, but also on the types of resources used and on the ways in which

1 This wide definition was adopted by the Commission of the European Communities (COM 527, 2003) in preparation of its sustainable resource strategy, and also used by the Technical Report on the Environmental Impact of the Use of Natural Resources (JRC 2005, p.11)

2 See www.iiasa.ac.at/Research/ENE/GEA/index_gea.html

© Luke Metelerkamp

they are used (see IRP report on the Environmental Impacts of Production and Consumption[3]).

This report seeks to establish the quantitative frame from which strategies for decoupling can be designed. For the assessment of resource uses and their environmental impacts, a global and long-term perspective will be employed. However, while the challenges of resource depletion and environmental disruption are global challenges, they affect people differently in different regions of the world. Extraction of a resource, its conversion into a commodity, and its ultimate consumption, often occur in different countries, and the benefits as well as the environmental impacts associated with each stage in the life cycle are widely distributed across time and space. This report also assesses these distributional issues.

This report is structured as follows: Chapter 1 defines decoupling more specifically. Chapter 2 then deals with observed trends in global resource use and associated undesirable environmental impacts, and closes with a section on scenarios for global resource use up to the year 2050. Chapter 3 discusses the need for system innovations in order to achieve decoupling beyond the incremental improvements of resource productivity that have been demonstrated as being part of business-as-usual. It closes with lessons from the four country case studies, which are spread across different stages of development, and efforts of these countries to achieve decoupling. Chapter 4 describes the interrelation of decoupling and development dynamics: the role of trade and the link between decoupling, development and inequality, and rebound effects. The major policy challenges, deriving from the outcomes of these chapters are summarized in Chapter 5, and the four country case studies are included in Chapters 6 to 9.

3 See www.unep.org/resourcepanel

1.2 Defining decoupling

1.2.1 Roots of the decoupling concept

The **OECD** appears to have been the first international body to have adopted the concept of resource decoupling, treating it as one of the main objectives in their policy paper 'Environmental Strategy for the First Decade of the 21st Century' (adopted by OECD Environment Ministers in 2001)[4]. The OECD defines decoupling simply as breaking the link between 'environmental bads' and 'economic goods'.[5]

Much earlier, the **World Business Council for Sustainable Development** (WBCSD) coined the term 'eco-efficiency', which is achieved through the delivery of "competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life cycle" (Schmidheiny, 1992). Thus, without mentioning the word 'decoupling', the substance was already being used, including the life cycle approach.

Similarly, the **European Union** (EU) in 2005 adopted the Lisbon Strategy for Growth and Jobs,[6] which gave high priority to more sustainable use of natural resources, and called upon the EU to take the lead towards more sustainable consumption and production in the global economy. This was followed by the adoption of the EU's Thematic Strategy on the Sustainable Use of Natural Resources under the 6th Environmental Action Program (6th EAP). This strategy has the objective of achieving a more sustainable use of natural resources by reducing the negative environmental impacts generated by the use of natural resources while ensuring economic growth. The Strategy recognizes decoupling of both resource use and its impacts from economic growth.

In a developing world context, the Sustainable Development and Human Settlements Division of the **United Nations Economic Commission for Latin America and the Caribbean (ECLAC)** recommended that sustainable development for developing economies could best be achieved by pursuing a strategy of "non-material economic growth" (Gallopin, 2003). Although the specific term 'decoupling' was not used in this report, the distinction made between 'material' and 'non-material' economic growth was effectively about decoupling growth from resource consumption.

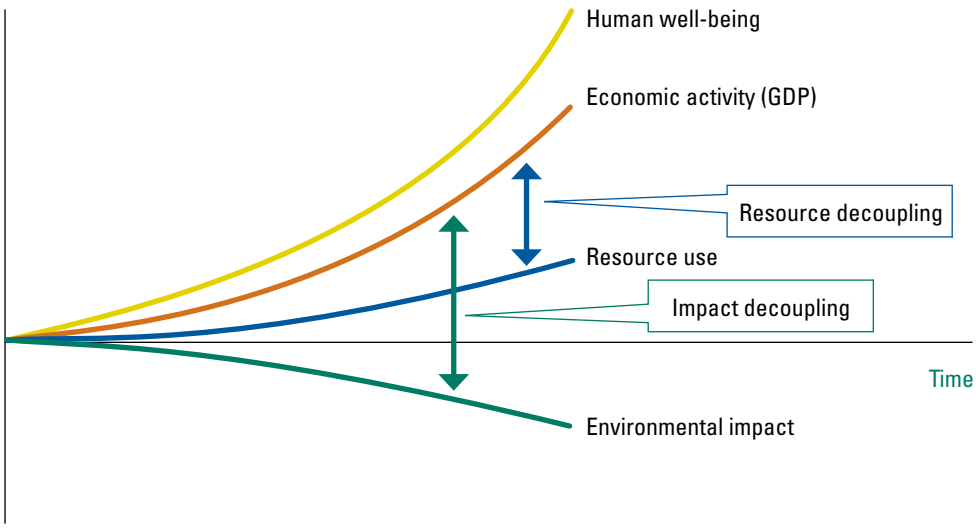
In line with this literature, resource decoupling could be referred to as increasing resource productivity, and impact decoupling as increasing eco-efficiency.

Resource decoupling means reducing the rate of use of (primary) resources per unit of economic activity. This 'dematerialization' is based on using less material, energy, water and land resources for the same economic output. Resource decoupling leads to an increase in the efficiency with which resources are used. Such enhanced resource productivity can usually be measured unequivocally: it can be expressed for a national economy, an economic sector or a certain economic process or production chain, by dividing added value by resource use (e.g. GDP/Domestic Material Consumption). If this quotient increases with time, resource productivity is rising. Another way to demonstrate resource decoupling is comparing the gradient of economic output over time with the gradient of resource input; when the latter is smaller, resource decoupling is occurring (see Figure 1.1).

Impact decoupling, by contrast, requires increasing economic output while reducing negative environmental impacts. Such impacts arise from the extraction of required resources (such as groundwater pollution due to mining or agriculture),

4 http://www.oecd.org/dataoecd/33/40/1863539.pdf
5 http://www.oecd.org/dataoecd/0/52/1933638.pdf
6 Lisbon Strategy for Growth and Jobs, 2007, document available at ec.europa.eu/economy_finance/structural_reforms/growth_jobs/index_en.htm [accessed 01/07]

Figure 1.1. Stylized representation of resource decoupling and impact decoupling



production (such as land degradation, wastes and emissions), the use phase of commodities (for example transport resulting in CO_2 emissions), and in the post-consumption phase (again wastes and emissions). Methodologically, these impacts can be estimated by **life cycle analysis** (LCA) in combination with various input-output techniques (see UNEP, 2010b). Impact decoupling means that negative environmental impacts decline while value is added in economic terms. On aggregate system levels such as a national economy or an economic sector, it is methodologically very demanding to measure impact decoupling, because many environmental impacts need to be considered, their trends may be quite different or not even monitored across time, and system boundaries as well as weighting procedures are often contested.

A distinction can be made between 'relative' and 'absolute' decoupling. Relative decoupling of resources or impacts means that the growth rate of the environmentally relevant parameter (resources used or some measure of environmental impact) is lower than the growth rate of a relevant economic indicator (for example GDP). The association is still positive, but the elasticity of this relation is below 1 (Mudgal *et al.*, 2010). Such relative decoupling seems to be fairly common. With absolute decoupling, in contrast, resource use declines, irrespective of the growth rate of the economic driver. This latter relation is shown by the Environmental Kuznets Curve that claims that if prosperity rises beyond a certain point, the environmental impact of production and consumption decreases. **Absolute reductions in resource use** are rare (De Bruyn, 2002; Steger and Bleischwitz, 2009); they **can occur only when the growth rate of resource productivity exceeds the growth rate of the economy.**

This assessment deals with resource decoupling and impact decoupling as the two interrelated modes under the decoupling concept as used by the IRP. Strategically, they differ in various respects. Resource decoupling seeks to alleviate the problem of scarcity and respond to the sustainability challenge of intergenerational equity by reducing the rate of resource depletion, while reducing costs by raising resource productivity. Resource decoupling may be expected to simultaneously reduce the environmental impacts of certain resources over the full

life cycle by using less of them. Resource decoupling is relatively easy to measure and monitor, but may be more difficult to achieve than impact decoupling.[7] By contrast, impact decoupling means using resources better, more wisely or more cleanly. Reducing environmental impacts does not necessarily have a mitigating impact on resource scarcity or production costs, and may even sometimes increase these. An example of this is carbon capture and storage (CCS): since this technology currently requires more energy per unit of output, resource decoupling does not take place, but since CO_2 is no longer released into the atmosphere, the environmental impact over the life cycle is reduced.

This discussion of the two modes of decoupling being considered here implies that:

1. **resource decoupling is particularly important when:**

    - a specific resource is scarce and its further depletion could frustrate societal progress (such as oil, rare minerals, or fertile land to produce food for the growing human population) (see UNEP, 2010a; UNEP, 2010b)

    - a specific resource poses high environmental risks that cannot be alleviated by using the resource better. Reduction of its use is then the only solution. Historical examples are asbestos and chlorofluorocarbons used in cooling devices. At present, fossil fuels are the most important case, even if using CCS could alleviate some part of the CO_2 problem through impact decoupling.

2. **impact decoupling is particularly important when:**

    - the use of a resource poses immediate threats to human and ecosystem health (such as toxic emissions, persistent organic pollutants, or impacts on soil fertility)

    - technological solutions have substantial potential to prevent harm to humans and ecosystems.

While numerous forms of economic activity have negative environmental impacts of one form or another, some are deliberately designed to have positive environmental effects, for example forest reserves, agricultural set-asides, or payments for ecosystem services. Socio-technical changes that have reduced negative environmental impacts in the past may have resulted in the decoupling of economic growth from certain specific impacts, while other impacts remained unchanged or even accelerated. Therefore, it can be problematic to consider impact decoupling in general without acknowledging that specific interventions can have unintended consequences or else ignore some impacts. It follows that it may be difficult to design a system-wide set of interventions capable of decoupling resource use from all negative environmental impacts simultaneously.

7 The well-known "Jevon's paradox" states that productivity increases, in the end, do not result in resource savings but in accelerated economic growth. This rebound effect is discussed further in section 4.3. Some argue that the exergy – the energy available to be used – of resources is an indispensable driver of economic growth (Ayres, 2005; Ayres and Warr, 2005).

2 Global long-term trends in the use of natural resources and in undesirable environmental impacts

Designing strategies for a decoupling of economic activity from undesirable environmental impacts requires an improved understanding of trends and their drivers. This chapter will assess past trends and project resource consumption into the future to outline the magnitude of the challenge. The first section will deal with the temporal dynamics of resource use[1] of materials, water and land.[2] Wherever possible, the sources used will employ a global and long-term perspective. The second section will inquire into the dynamics of related environmental impacts and assess to what degree, and in which respects, environmental impacts have followed the dynamics of resource use, and where an additional impact decoupling – allowing impacts to be dissociated from increasing resource use – could be observed. Finally, the third section will present three scenarios for future resource use until the year 2050, based upon previous trends and the existing knowledge of drivers.

2.1 Note on methodology

While measuring consumption of energy resources is fairly straight-forward, seeking a consistent methodology for documenting the extent of use of other resources is a relatively new field that is still under development.

For material resources, such a methodology and sets of indicators have been developed only recently under the term of 'material flow accounting' (MFA), which accounts for all materials used in economic activities. Some approaches (for example Bringezu *et al.*, 2004; Rodrigues & Giljum, 2005) account not only for the resources used in economic processes, but also for the total material mobilized during the extraction process (i.e. the 'total material requirement'). This is clearly justified, as these additionally mobilized materials are responsible for substantial additional impacts, though the analysis can be compromised by data reliability. For convenience and clarity, this report will focus on materials actually used in economic processes measured in terms of their mass (metric tons), i.e. total *used* extraction. As a rule of thumb, total extraction is about double total *used* extraction. The MFA methodology generates accounts in physical terms that are analogous to national accounting in economic terms, and according to the same system boundaries (Eurostat, 2001; Eurostat, 2007). Thus it yields data that support an analysis of decoupling of economic activity from material resource use. Until now, SERI (2008) is the only dataset presenting time-series data on global materials extraction, country-by-

1 From now on, for reasons of brevity and simplicity, we shall use the term "resources" to mean "natural resources". Of course, economic activity is based on a number of different resources, apart from natural resources, in particular also on capital, labour, and knowledge.

2 The terms of reference for this working group did not include a focus on energy resources, as they are dealt with in many other contexts. We are aware that from several perspectives, the energy (or exergy) aspects of natural resources are crucial (Ayres & Warr, 2005; Smil, 2008), but the purpose of the task at hand is to illuminate other aspects of resource use that are often neglected.

country.[3] It provides a quantitative estimate of global resource extraction for the period 1980 to 2005. Based partly on this dataset, and on other sources, Krausmann *et al.* (2009) recently published a centennial time series of global material extraction and use (see Figure 2.1).

For **assessing the use of water and land** in relation to economic activities, the data situation is somewhat less well developed. While estimates of global freshwater use in long time series are available (see Gleick, 2009; Hoekstra & Chapagain, 2007; Alcamo and Vörösmarty, 2005; Shiklomanov and Rodda, 2003), no country-by-country database is available to support an analysis of the coupling between economic activity and water use. This paucity of data is related to the fact that water use is often considered a free common good not reflected in economic statistics. System boundaries also raise problems, as the same water can be used many times over. Future IRP reports will explore water decoupling issues in greater depth.

With land, the statistical situation is much better, at least as far as cropland is concerned. The main focus of accounting for land resources is put on land cover (such as cropland, grassland or forest) and its change over time (Erb *et al.*, 2007). However, the coupling of economic activity and land use is reflected not only in land cover change, but also in the intensity of use. An increase in yields or multi-cropping on existing arable land, or an increase in livestock grazing on grassland, does not necessarily lead to change in land cover types, but nevertheless represents an increased use of land resources. For this reason, existing land use statistics are not easily applied to an analysis of decoupling.

3 See, for example, Adriaanse *et al.*, 1997; Rogich *et al.*, 2008; Eurostat, 2007; Gonzalez-Martinez and Schandl, 2008; and Russi *et al.*, 2008. Economy-wide material flow accounts for historical periods have been compiled for a growing number of individual countries. Most of these country-level case studies document historic trends ranging from several years up to several decades. Only very few studies include time periods before 1970 (see e.g. Matos and Wagner, 1998; Schandl and Schulz, 2002; Petrovic, 2007). Several attempts have been made to compile global country-by-country material flow accounts for recent years (Schandl and Eisenmenger, 2006; Behrens *et al.*, 2007; Krausmann *et al.*, 2008b).

© Luoman/iStockphoto

As a result of these data constraints on water and land, the assessment of resource decoupling in this report will focus mainly on the use of materials as accounted for by MFA.

Indicators for undesirable **environmental impacts** of economic activities and resource use globally and in long time series do not exist on an aggregate level. In recent decades, a broad literature on environmental impacts and impact assessment has evolved. Environmental impacts are usually described as impacts on environmental media and on human health. An assessment of environmental impacts is mainly operationalized on the product level in life cycle assessments (LCA) and a definition is found in ISO 14.040 standards where the following seven impact categories are differentiated (Nielsen *et al.*, 2005): acidification; climate change and global warming; ecotoxicity; human toxicity; eutrophication/nutrient enrichment; photochemical ozone formation (summer smog); and stratospheric ozone depletion. This list considers negative environmental impacts that "are known, well explored and operationalized, and for which statistical information is available" (Moll *et al.*, 2004, p.4). This literature did not, however, converge in a shared understanding of what environmental impacts actually are and how they should be conceived and classified (see the effort in UNEP, 2010b). On the most general level, **negative environmental impacts can be considered as undesirable changes in the natural environment (or one of its compartments) that can be causally linked to some socio-economic activity.**

The 'undesirability' of an environmental impact of a socio-economic activity always needs to be legitimized, as the socio-economic activity as such usually pursues desired goals and environmental impacts occur as trade-offs, or unintended side-effects, in reaching these goals. This legitimacy can be most easily established for cases having two or more functional equivalents for pursuing the goal (products, production processes, materials, etc.) that can be compared in terms of their environmental trade-offs. It is now broadly accepted that the choice between alternatives should take into account potential negative side effects. Classical examples of this kind are the choice between plastic or paper bags, and between chloride and ozone bleaching in paper production. If the outcomes of impact assessments are contested, they can be debated impact by impact on this level of complexity.

On higher levels of aggregation, overall impact assessments become increasingly indeterminate. Among the difficulties encountered are problems of:

- impact selection: which environmental concerns need to be accounted for, on which spatial and temporal level, on which level of causal proximity (e.g. habitat loss or threat to biodiversity)
- impact weighting and composing aggregates
- system completeness (potential omissions) and double counting.

Even the few high-quality studies that have made serious attempts at comprehensive solutions (such as van der Voet *et al.*, 2005; EEA, 2005) were not able to establish solid conventions for the field. An assessment based upon this research strand was provided in one of the previous IRP reports (UNEP, 2010b).

CO_2 emissions (and, to a certain extent, greenhouse gas (GHG) emissions) are the only well documented environmental impact indicator available at the global level. Having these data available in longer time series and on a country-by-country basis makes it possible to analyse the coupling between population dynamics, economic activity and the carbon/temperature matrix.

2.2 The global dynamics of material resource use

The **global** use of natural material resources corresponds to the sum total of raw materials extracted.[4] At the beginning of the 21st century, estimates for the quantity of global raw materials extraction ranged between 47 and 59 billion metric tons (47–59Gt) per year (Fischer-Kowalski *et al.*, 2011). At the global level, the amount of raw materials extracted is roughly equivalent to the global amount of raw materials then used in economic processes. On the level of **individual countries,** the materials they extract in their domestic territory (termed DE, *domestic extraction*) is not equivalent to their materials use, as they may export or import products for use.

Figure 2.1 shows global material extraction for the period 1900 to 2005 in a breakdown by the four major material classes: biomass, fossil energy carriers, ores and industrial minerals, and construction minerals. **Total material extraction increased over that period by a factor of 8.** The strongest increase can be observed for construction minerals, which grew by a factor 34, ores and industrial minerals by a factor of 27, and fossil energy carriers by a factor of 12. Biomass extraction increased only 3.6-fold. This comparatively low increase of biomass extraction, while the world population needing food had quadrupled, is mainly due to a substitution of biomass use for combustion by fossil fuels. For much of the 20th century, biomass had dominated among the four material types: in 1900, biomass accounted for almost three quarters of total material use. One century later, its share had declined to only one third. Thus **on top of using more biotic renewable resources, the global socio-economic metabolism has increasingly turned towards mineral resources.**[5]

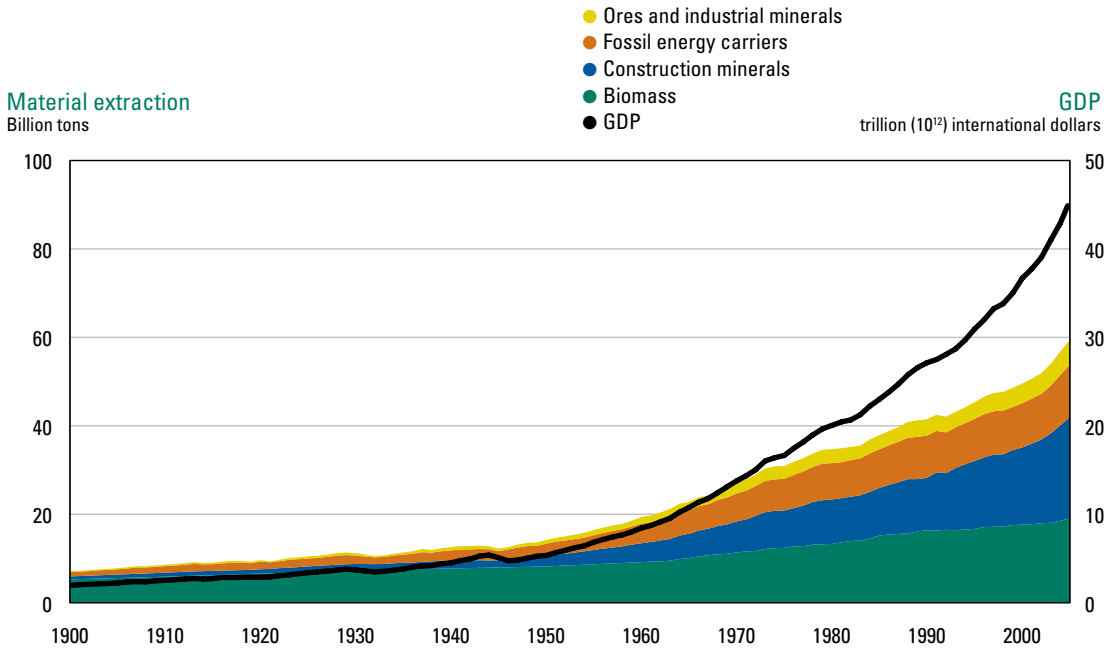
A major driver of the overall increase in raw material extraction and use is population numbers (Steinberger *et al.*, 2010; Krausmann *et al.*, 2008). The world's, and each country's, material use (called *domestic material consumption*, DMC) is tightly coupled to the number of inhabitants. This is plainly evident for food, for example, but it also holds true for other material resources that have become part of a certain material standard of life. Thus it is common to calculate *metabolic rates,* that is resource use per capita, as a fairly robust overall measure of material standard of living (see for example Krausmann *et al.*, 2008; Behrens *et al.*, 2007; Haberl *et al.*, 2009). From another perspective, metabolic rates can be seen as the 'material footprint' of an individual person living by a certain country's average level of consumption. These metabolic rates are by more than one order of magnitude different for different countries. For example, one person more in India means on average an additional 4 tons of resource use, while one person more in Canada means on average 25 tons more resource use per year.

While global resource use has increased eightfold during the course of the 20th century (Figure 2.1), average resource use per capita merely doubled (Figure 2.2). A global inhabitant in 2005 required somewhere between 8.5 (Behrens *et al.*, 2007) and 9.2 tons (Krausmann *et al.*, 2009) of resources annually, while a hundred years earlier the average global metabolic rate was 4.6 tons.

4 System boundaries of extracted materials can be defined in various ways. What is reported here is the fraction of extracted materials actually used afterwards in the economic process, so, for example, no overburden in mining or harvest residues. Variations in storage are not considered.

5 The issue of renewability of resources that had played such a prominent role in the environmental and sustainability debate (see for example Daly, 1977) is today difficult to evaluate. On the one hand, the use of renewable biotic resources, even if it is not plainly an overuse beyond the regeneration capacities of the resource, is considered to cause some of the most severe environmental impacts (van der Voet *et al.,* 2005). On the other hand, for example with minerals used for construction, the distinction between renewable and non-renewable is not so easy. Most of these minerals are abundant in the earth crust, but not necessarily close to those population centers where they are needed.

Figure 2.1. Global material extraction in billion tons, 1900–2005



Source: Krausmann *et al.,* 2009

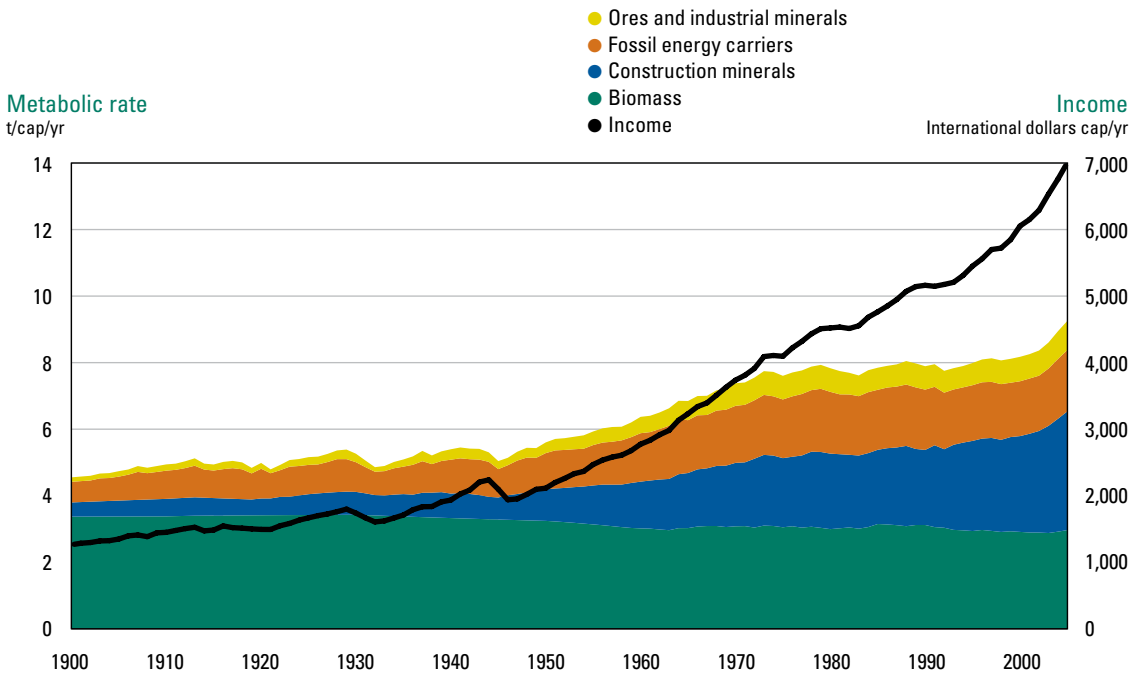
Average global metabolic rates have sometimes stagnated (such as the period from 1900 to the end of World War II), and sometimes grown rapidly (such as the period from the end of WW II up to the global oil crisis in the early 1970s).[6] From this first oil shock in 1973 until the turn of the century, the global average has again remained stable (see Figure 2.2) and has continued to do so in the industrialized countries up to now (Figure 2.3). Globally, though, in recent years the metabolic rates started to rise again, due to a large extent to the growth of large emerging economies such as Brazil, China and India. This marks a new phase of international convergence in metabolic patterns in which a number of developing countries have adopted growth strategies that make it possible for a rapidly expanding middle class to achieve high consumption levels that are similar to those OECD countries achieved during the decades after WWII.

The phases of metabolic patterns are not reflected economically in terms of average income (see Figure 2.2 and Figure 2.3), which showed a more or less continuous exponential growth (with minor downturns during the first world economic crisis in the 1930s and World War II). These findings warrant further investigation, as they indicate some decoupling of economic development and resource use.

These data indicate that global material resource use during the 20th century rose at about twice the rate of population, but at a substantially lower pace than the world economy. Thus **resource decoupling has taken place 'spontaneously' rather than as a result of policy intention.** This occurred while resource prices were declining, or at least stagnating. Further research is needed on this relationship between 'spontaneous' relative decoupling and declining resource prices.

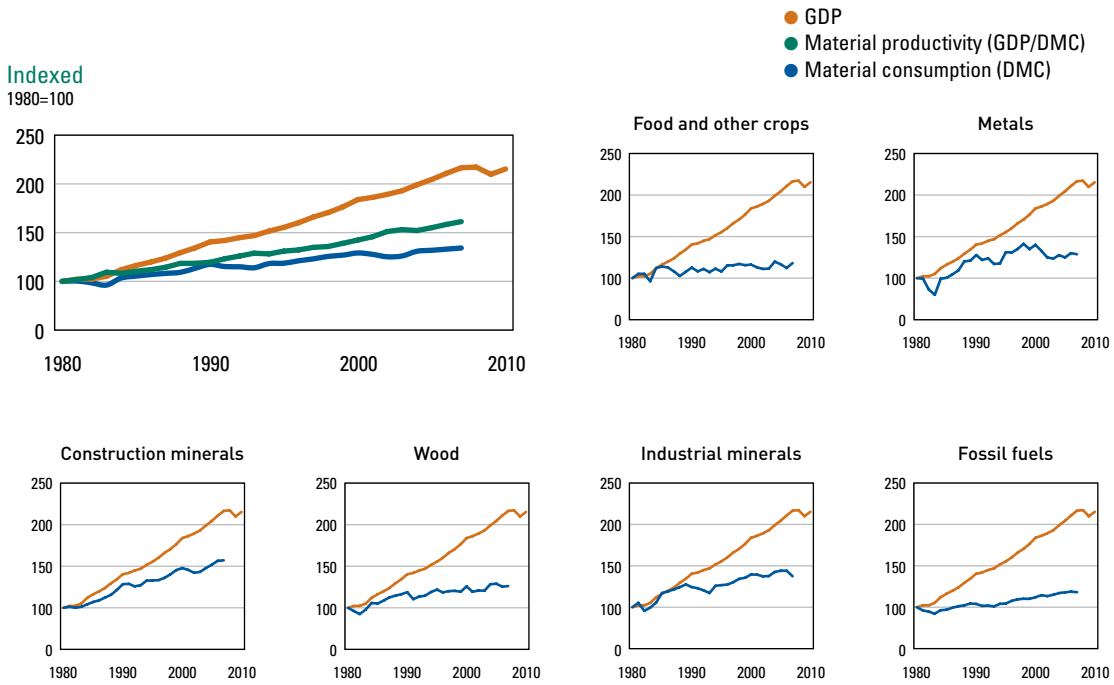
6 This phase is known as the "Fifties Syndrome" (Pfister, 1996), but might also be addressed as the US-American New Deal spreading across the world, in combination with decolonization and the "green revolution" .

Figure 2.2. Global metabolic rates 1900–2005, and income



Source: Krausmann *et al.,* 2009; based on SEC Database "Growth in global materials use, GDP and population during the 20th century", Version 1.0 (June 2009): http://uni-klu.ac.at/socec/inhalt/3133.htm)

Figure 2.3. Gross Domestic Production and Domestic Material Consumption in OECD countries, 1980–2000

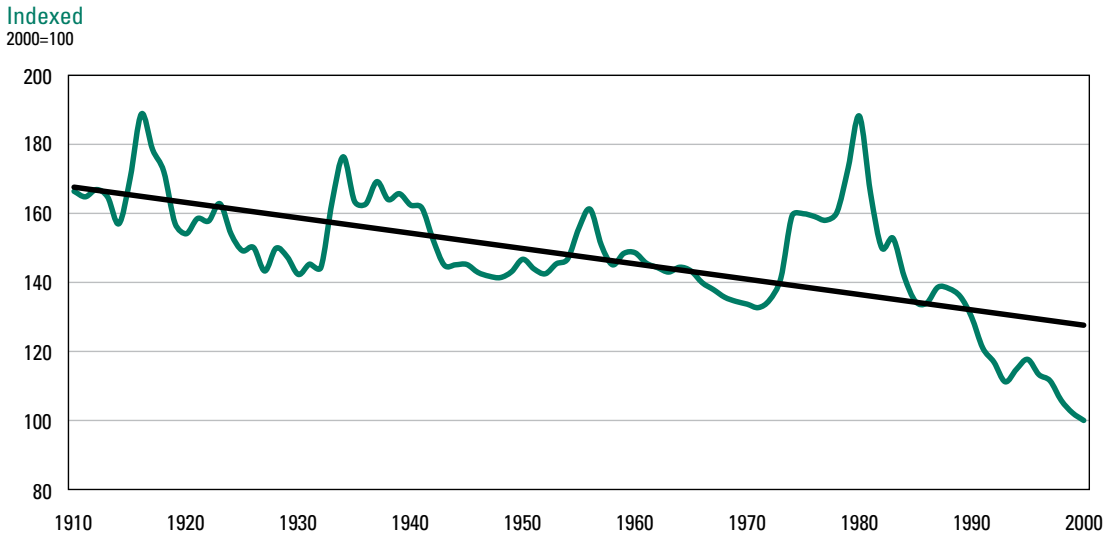


Source: OECD, 2008b. Data update provided by OECD on 1 April 2011, http://www.oecd.org/dataoecd/55/12/40464014.pdf

According to Wagner (see Figure 2.4), **resource prices declined by about 30% in the course of the 20th century.** After the first oil crisis, the price level increased to a first centennial climax, only to return to its trend of decline after less than a decade.

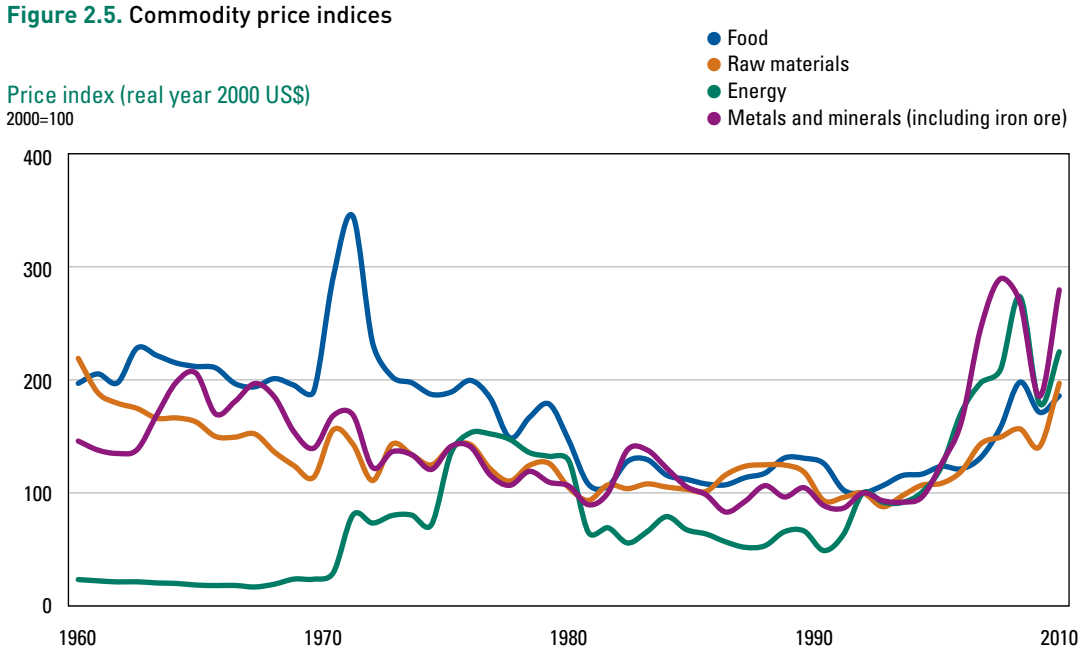
A similar phenomenon may now be happening in conjunction with the present economic crisis (see Figure 2.5). A steep rise in raw material prices reached its peak in 2007, and a return to usual price levels may have started already in 2008. For the

Figure 2.4. Composite resource price index (at constant prices, 1900–2000)



Source: Wagner *et al.*, 2002

Figure 2.5. Commodity price indices

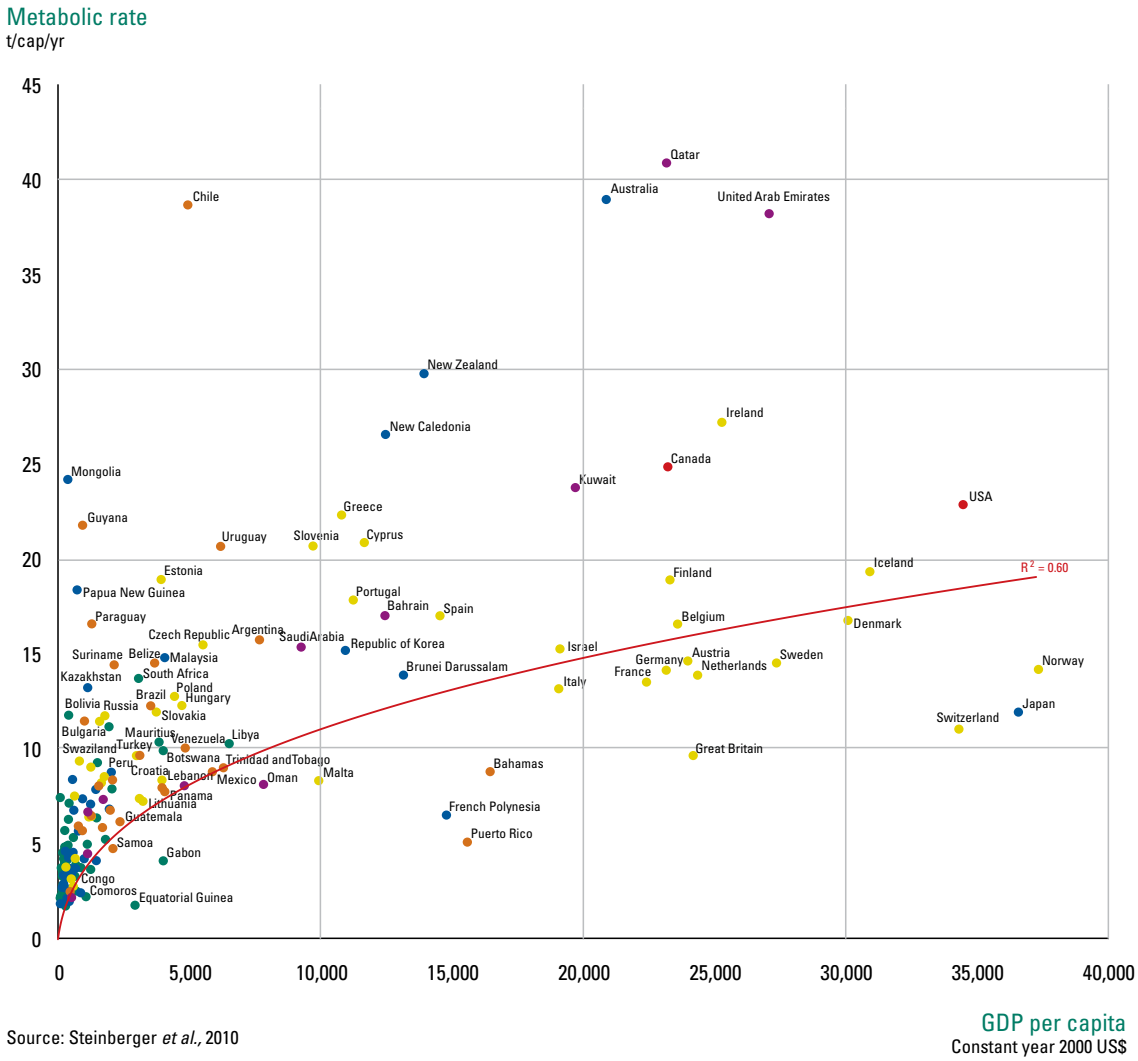


Source: World Bank Commodity Price Data (Pink Sheet), historical price data, available from http://blogs.worldbank.org/prospects/global-commodity-watch-march-2011

time being, though, it is hard to tell whether such a return to price levels 'as usual' with a further tendency of decline will actually take place. It could just as well be that symptoms of increasing scarcity in conjunction with steeply rising demand will lead to financial speculations that keep raw material prices at higher levels than before, and even enforce a reversal of the long-term trend of decline (see for example AIECE, 2009).

Nevertheless, even in a context of declining raw material prices, the growth rates of global raw material extraction throughout the 20th century remained below the growth rates of economic activity as measured by GDP (see Figure 2.1). While material resource use increased by a factor of 8, world GDP increased by a factor of 23 (OECD, 2008). This means that **even under the unfavourable conditions of price decline, a certain amount of resource decoupling is evident, or put differently, a certain level of 'dematerialization' of the world economy has spontaneously occurred, effectively raising resource productivity**

Figure 2.6. The global interrelation between resource use and income (175 countries in the year 2000)



Source: Steinberger *et al.*, 2010

(added value/resource use) by about 1–2% annually at the global level (Krausmann *et al.*, 2009). This decoupling has been particularly marked among the industrial countries. Similar findings have also been presented by Bringezu *et al.* (2004).

Statistically, the relation between economic activity (measured in terms of GDP) and resource use is robust, as has been shown by an analysis by Steinberger *et al.* (2010) of 175 countries for the year 2000 (see Figure 2.6). However, while globally the loglinear correlation was $R^2 = 0.60$ (weighted by country size), the scatterplot demonstrates a large number of outliers. Redrafting on linear scales shows that the steepness of the function is much higher in low-income ranges, declines with level of income, and no saturation is evident.

This suggests that **it is possible for some countries to achieve relatively high incomes per capita while consuming fewer resources per capita, while other countries display very high resource consumption levels per capita without a corresponding rise in incomes per capita.** This is related to factors like population density (see below), but it is also strongly related to trade. Countries may shift their domestic economy towards services, reducing their primary and secondary sectors, and increasing their dependence on imported manufactured goods. This leads to a lowering of domestic

resource use (measured in tons) while income per capita rises, and to **a shifting of the material and environmental burden into developing countries.** Other countries may specialize as raw material producers (e.g. many African countries) or manufacturers (e.g. many Asian countries), with a high domestic material resource use and environmental burden as a consequence, without significant corresponding increases in income per capita. These issues have become a strong focus of research that will be assessed in Chapter 4.

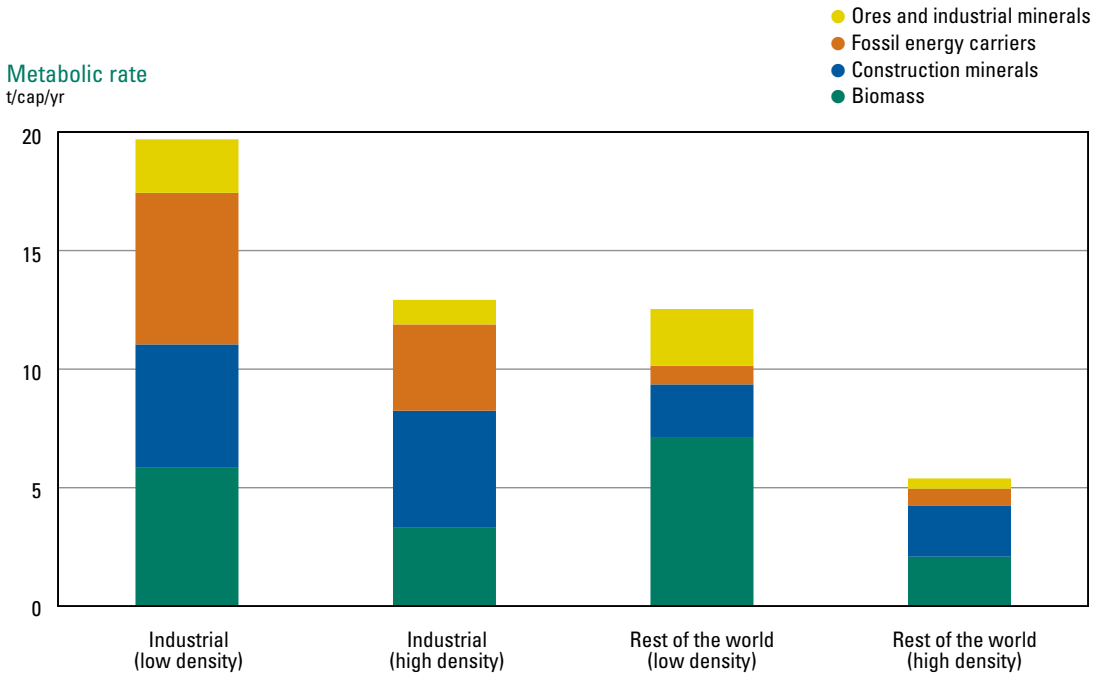
Clearly **the global average metabolic rate rests upon highly unequal metabolic rates across countries, varying by a factor 10** or more (Fischer-Kowalski and Haberl, 2007). According to a recent analysis (Krausmann *et al.*, 2008), two key factors account for much of this variation: **development status** (developing or emergent vs. fully industrialized countries with concomitant income) and **population density**.[7] Each of these factors, looked upon independently, seems to be responsible for roughly a doubling of the metabolic rate. For the industrial countries, those with high population density (among them many European countries and Japan) have an average metabolic rate of about 13 tons/capita, while those with low population density (for example Finland, the USA and Australia) have a metabolic rate twice as high and more, although income and material comfort do not substantially differ. The same variation can be observed among the rapidly industrializing countries: while among them the high-density developing countries (such as China and India) showed average metabolic rates of 5 tons/capita in the year 2000, the metabolic rates in comparable low-density developing countries (e.g. Brazil and South Africa) were more than twice as high. **It appears that densely populated areas and regions, for the same standard of living and material comfort, need fewer resources per capita.** This still needs to be corroborated by research, for each of the larger components of material flows. The apparent difference in the use of biomass (see Figure 2.7) may be partially due to the fact that food and feedstock is produced in less populated areas, and only the lower-weight refined produce such as meat, milk or cheese is exported to densely populated regions. But regions with a traditionally high population density often tend towards a diet less dependent on meat and dairy, and livestock that causes large material flows tends to be kept and used in low-density regions. Densely populated areas also have less need for transport fuels (as has often been demonstrated for cities, see Newman and Kenworthy, 2007), and the supply of heat for housing can be provided more efficiently. Industrial facilities requiring particularly high material flows (such as mines), on the other hand, tend to be located in sparsely populated areas.[8] Finally, the per capita use of construction minerals follows a similar pattern: understandably, people in urban areas save space and therefore construction material and use infrastructure more frequently and thus more efficiently.

The decrease in need for materials with rising population density is essentially good news in a world of rapid urbanization. The doubling of per capita material use due to resource and energy intensive modes of industrialization, which can be seen in Figure 2.7, is a major challenge for those high-density countries themselves if the 'material footprint' of each of their inhabitants doubles. It is also a challenge for the rest of the world in terms of resource depletion and environmental impact, especially if this conventional industrialization mode is coupled to growth strategies in developed economies that are driven by ever-rising consumer demand and globalized capital

7 A similar typological effort was undertaken by Romero-Lankao *et al.* (2008) to explain carbon emissions, putting the ecological modernization theory to a test. She developed a typology combining income, urbanization and stage in the demographic transition to explore trends of global convergence of carbon emissions.

8 Why the per capita use of ores tends to be higher in low density areas needs further research.

Figure 2.7. Average metabolic rates (resource use in tons/capita) by development status and population density



High-density means a population density of 50 people/km² or higher. Share in world population: 13% industrial, high density, 6% industrial, low density, 62% rest of the world, high density, 6% rest of the world, low density.
Source: Krausmann *et al.,* 2008

investment flows. **It is necessary, therefore, to relate strategies dealing with resource use to developmental strategies.** While it seems fully justified to discuss resource use reductions for industrialized countries, this is not applicable for developing countries. Low metabolic rates in developing countries often reflect a lack of satisfaction of basic needs and a low standard of material comfort, and social justice calls for environmental and economic space to eradicate poverty through investment in the necessary material infrastructures.

However, the key question is *how* these countries go about this. If they emulate the technologies and industrial processes of the developed economies, their efforts will be undercut by the consequences of resource depletion and environmental impacts. Their optimal strategy, therefore, is to exploit this space while simultaneously pursuing a less resource and energy intensive growth and development pathway. **Decoupling (resource and impact) as discussed in this report can help describe what such a less resource- and energy-intensive pathway could look like and how it can be achieved.**

2.2.1 Conclusion

Annual global resource extraction and use increased from about 7 billion tons (7 Gt) in 1900 to about 55 billion tons (55 Gt) in 2000, with the main shift being from renewable biotic resources to non-renewable mineral ones. Even in the existing economic environment of continuously declining resource prices, some decoupling of resource use from economic activity has taken place: the world economy has been dematerializing. The most inelastic relationship exists between resource use and population numbers. The 'metabolic rate', the annual resource use per capita, represents the material standard of living in a country, and if population rises or

declines, so proportionally does resource use. The global average metabolic rate has doubled from 4.6 tons/capita in 1900 to 8–9 tons/capita at the beginning of the 21st century. The metabolic rate strongly depends on the development status of a country (doubling or tripling in the course of the industrial transformation), on income and on population density: regions with high population density display substantially lower metabolic rates for the same standard of living. These insights can be used for projecting future resource use and for modelling resource depletion, development strategies and resource decoupling. An important finding is that metabolic rates[9] have stabilized[10] in highly industrialized countries in the past three decades, irrespective of further rising incomes, while the metabolic rates in many parts of the rest of the world keep rising.

2.3 Assessing the dynamics of global environmental impacts

The key questions of this report are whether a decoupling of environmental impacts from resource use and economic growth is taking place, and what are the challenges facing the further supporting and enforcing of decoupling by policy measures. Resource use has been shown to have numerous indicators – not fully comprehensive but statistically robust – that enable the assessment and monitoring of the degree of decoupling of resource use from population dynamics and economic growth, both globally as well as at the level of individual countries. For assessing the decoupling of (undesirable) environmental impacts from population and economic dynamics, no such aggregate comprehensive indicators exist.

However, substantial historical evidence indicates that the **same level of economic activities can be associated with a higher or a lower level of environmental impacts.** Most environmental policies in the past decades have been directed at specific impacts, such as putting a halt to deforestation, keeping the stratospheric ozone layer intact, reducing carcinogenic or other toxic substances in the human food chain, preventing eutrophication of water bodies, or reducing air-polluting emissions detrimental to human health. In relation to economic activities, they tended to impose additional costs (often addressed as 'internalizing externalities') and met with variable levels of success.

2.3.1 Strategies to reduce impacts

In relation to resource use, undesirable environmental impacts can be reduced by basically two strategies: **(a) changing the mix of resources used through substitution of more harmful by less harmful resources, and (b) using resources in a more environmentally benign way throughout the life cycle.**

Strategy (a) is certainly effective but also has its limits. An informative example is the substitution of coal for combustion by petroleum or natural gas; the latter have a lower amount of carbon emissions per unit of mass and per unit of energy delivered. The more recent example of substituting biofuels for fossil fuels needs careful assessment on a case-by-case basis, as a recent IRP report (UNEP, 2009) has demonstrated. The IRP reports on metals demonstrate that a key trend is using increasing amounts of ever more substances as resources, across all naturally occurring mineral elements. This expansion puts limits to (present or future) substitution. Further, the purposes for which material resources can be used do not allow for an indefinite range of substitutions: energy resources, freshwater and land are required for practically all economic activities, though in different qualities and quantities. The substitutability of materials is limited by their physical and chemical properties. Of course, it has been

9 Including traded products, but not the upstream material requirements of traded products.
10 A similar phenomenon can be observed for total primary energy consumption (TPES).

very important in terms of environmental impacts to reduce the amount of SO_2 or lead in transport fuels, thereby reducing the overall environmental impacts of fuel use in transportation.[11] But beyond a certain point, it is crucial to use less transport fuels, i.e. less resources. The same applies to many other economic activities.

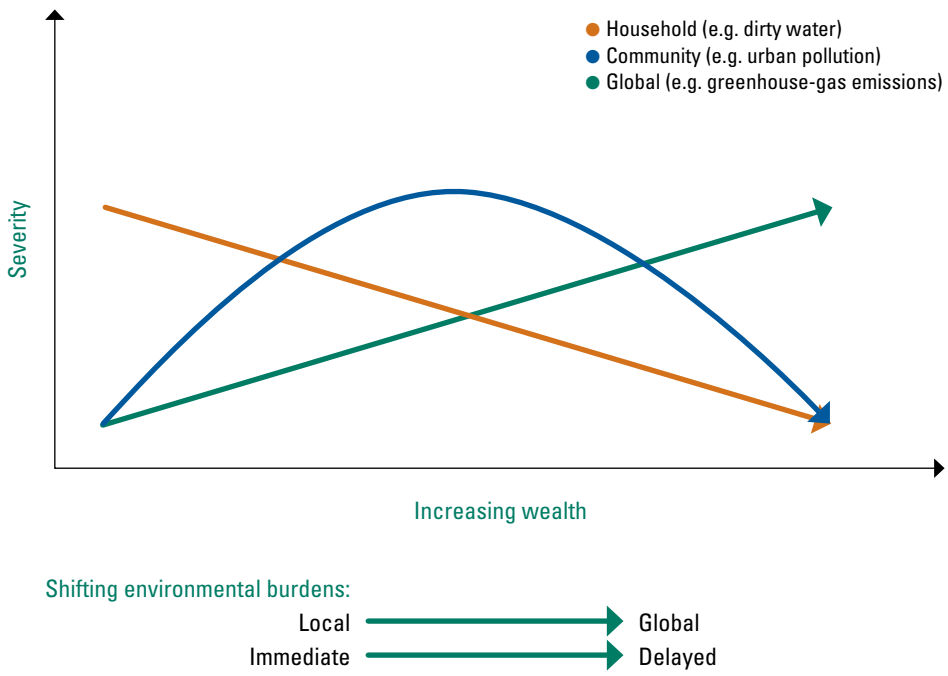
Strategy (b), using resources environmentally more carefully or smartly throughout their life cycle, is doubtless a key strategy for environmental policies. For example, using construction minerals for thermal insulation and refurbishment of houses probably has an overall positive environmental impact, while using them for an extension of the road network probably does not, more or less independently of the amounts used. Some environmental impacts, such as the energy and associated carbon emissions required for the transportation of the construction minerals, probably remain in both cases a function of amounts of resource use.

11 For a further step in reducing the environmental impact of transport fuels, namely reducing the emission of NOx by the use of catalysers, an important additional scarce resource, platinum, was required.

2.3.2 The Environmental Kuznets Curve

Working at a global level, Wilkinson *et al.* (2007) revived a hypothesis that had already been expressed by Holdren *et al.* (2000) in UNDP's world energy assessment (see Figure 2.8). This hypothesis claims interdependence between the scale level of environmental impact and its relation to economic activity and increasing wealth. It assumes that household-level environmental burdens (such as dirty water or indoor pollution) decline with a rise in wealth and community-level burdens (such as urban air pollution) display a hump-shaped, typical environmental Kuznets function, while global environmental burdens (such as greenhouse gas emissions) rise.

Figure 2.8. Environmental risk transition framework



Source: Adapted from Wilkinson *et al.*, 2007

It assumes that over time, global impacts on the environment are becoming more important than local ones, and delayed impacts are becoming more important than immediate ones (see green arrows at the bottom of Figure 2.8). Across those scale levels, impact decoupling is not easy to assess.

2.3.3 Empirical studies of impacts

On the global level, the only well-researched and quantified coupling between economic activity (and/or resource use) and environmental impact is the one between the use of fossil fuels and CO_2 emissions and greenhouse gas (GHG) emissions. On the centennial time scale (1900–2000), world GDP had been rising by a factor of about 22 (see Figure 2.1, depending on GDP indicators), fossil fuel use by roughly a factor of 14, and global CO_2 emissions had been rising by a factor of 13 (Smil, 2008, p.328). The relation between world GDP and world CO_2 emissions across this time span can be very well represented by a loglinear function.[12] The growth rates of CO_2 emissions (the environmental impact of concern) are smaller than the respective growth rates of GDP, so a relative decoupling has occurred. However, the degree of impact decoupling across this longer time period has been practically the same as for resource decoupling. In recent years, the increasing use of coal again raised the level of CO_2 emissions per unit of fossil fuel use, though future CCS (carbon capture and storage) may reduce net CO_2 emissions (IPCC, 2007).

Another illuminating case is the relation between biomass use and its impact on the global cycles of sulphur, nitrogen and phosphorus. While these impacts are considered substantial, with human-induced flows being of the same order of magnitude as natural flows (Ayres, 1994; Smil, 2002; Tilman, 1999), no time series data exist that allow judging how closely these flows are related to changes in global GDP or global biomass extraction. Figure 2.9 shows that cereal production growth since 1960 has been decoupled slightly from land area, but coupled to increasing amounts of fertilizer use.

Very much the same may be said about one of the environmental impacts of human resource use that is considered most important: biodiversity loss, due largely to biomass extraction and land use. Although long-term data documenting biodiversity loss on a global level are sparse, the available data indicate a global decline of biodiversity in marine (see Sala and Knowlton, 2006), freshwater (see Dudgeon *et al.*, 2006) and terrestrial (e.g. Sanderson *et al.*, 2006) ecosystems. Whether this decline is steeper than the rise in resource use, or even steeper than growth in GDP, cannot yet be quantified. Thus, any decoupling of these environmental impacts from economic activity cannot be documented.

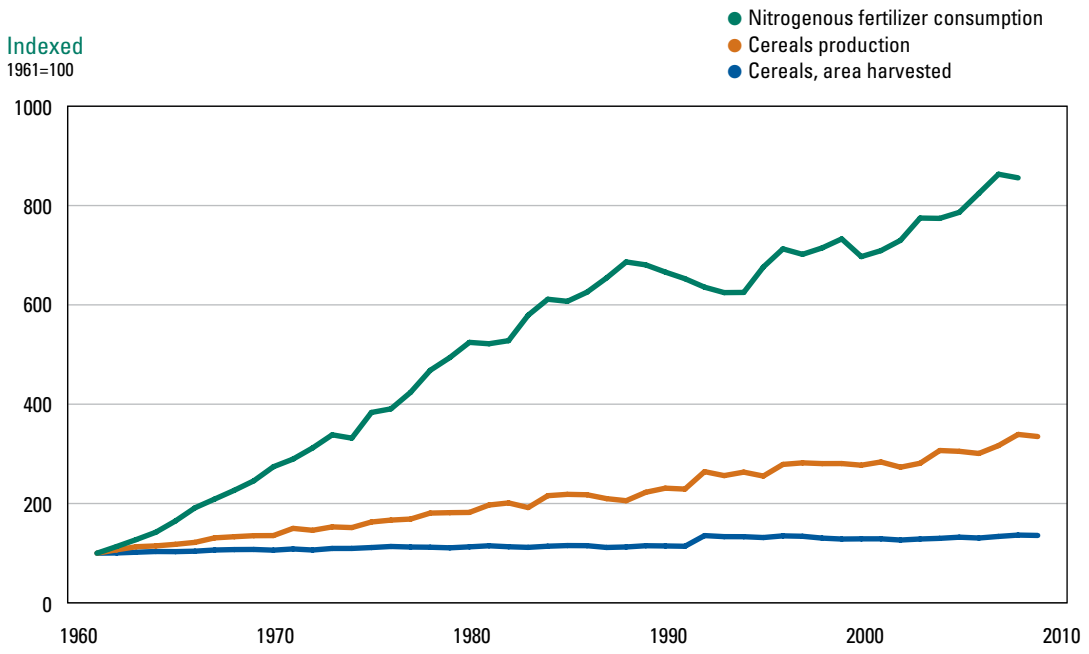
The environmental impacts associated with the extraction and use of fossil fuels are another very important issue.[13] In the past decades, the use of coal and oil shifted towards natural gas that was environmentally relatively beneficial; it reduced the specific CO_2 emissions per ton of fossil fuel used, but it also increased the rate that natural gas resources were depleted. Now, the use of coal is on the rise again (IEA, 2008), which has an impact in the opposite direction.

Estimates of remaining recoverable oil resources vary greatly (and depend to an extent on shifting economic and technological conditions), but are ultimately less important than annual flow rates of oil production. Hubbert (1956) presented a model wherein oil production in any given region follows a roughly

12 After many efforts to the contrary, it may be concluded that fossil fuel use and CO2 emissions do not follow an Environmental Kuznets Curve, that is they do not rise during earlier stages of development or at low income while declining at later stages of development or at higher incomes (Stern, 2004; Luzzati and Orsini, 2009).

13 This section on oil resources was prepared by Jeremy Wakeford of the Sustainability Institute, Stellenbosch University, South Africa.

Figure 2.9. Global growth of cereals production and fertilizer consumption

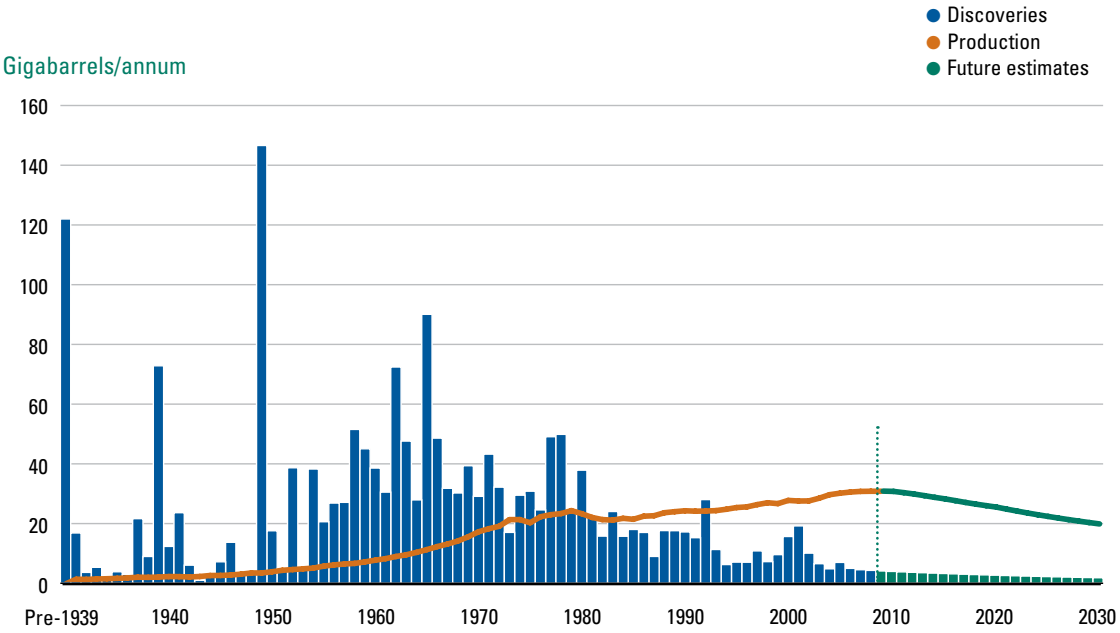


Note: Global growth in the production of cereals since 1961 almost exclusively depended on intensification (nitrogen input, tractors, yields and many other factors not shown on this graph), whereas the expansion of harvested area played an insignificant role.
Source: UNEP GEO Portal, as compiled from FAOSTAT database, Food and Agriculture Organization of the United Nations (FAO), http://geodata.grid.unep.ch

bell-shaped curve, reaching a 'peak' rate when approximately half of the ultimately recoverable resource has been consumed. Oil production has already peaked and declined in the majority of individual oil producing nations, and in large regions such as North America and Europe (Hirsch, 2008). Thus 'peak oil' is an empirically verifiable phenomenon (Sorrel *et al.*, 2009, p.vii). Evidence suggests that the world is rapidly approaching a world oil production peak. Global new oil discoveries reached their height in the 1960s and have been on a declining trend ever since (see Figure 2.10), despite remarkable improvements in exploration, drilling and extraction technologies, and episodes of high prices in the 1970s and 2000s (ASPO, 2009).

A comprehensive review of recent oil production capacity forecasts by academics, industry experts and international agencies (Sorrel *et al.*, 2009, p.ix) concluded that "a peak of conventional oil production before 2030 appears likely and there is a significant risk of a peak before 2020". Although unconventional oil reserves (e.g. oil sands and extra-heavy oil) are large, their flow rates are severely constrained by high energy and economic costs as well as environmental factors (Aleklett *et al.*, 2009). An additional concern is that it is requiring increasing amounts of energy to find, extract, refine and deliver oil to markets (Gagnon *et al.*, 2009). The easier to access oil deposits, typically discovered decades ago, are being rapidly depleted and the frontier for new oil has moved into areas that are economically more costly and technically more difficult to access (such as deep off-shore wells and polar regions). Thus the 'net energy' derived from oil – i.e. the energy output minus the energy inputs – is set to decline faster than the 'gross energy'; this will in turn further raise the monetary and possibly also the environmental costs of oil. In effect, as long

Figure 2.10. World conventional oil discoveries and production



Source: ASPO, 2009

as carbon capture and storage (CCS) technologies are not proven to be fully operational and provide substantial relief on emissions, it cannot be expected that the overall environmental impacts of fossil fuel use will decouple from the amounts used. Perhaps even the opposite will be the case.

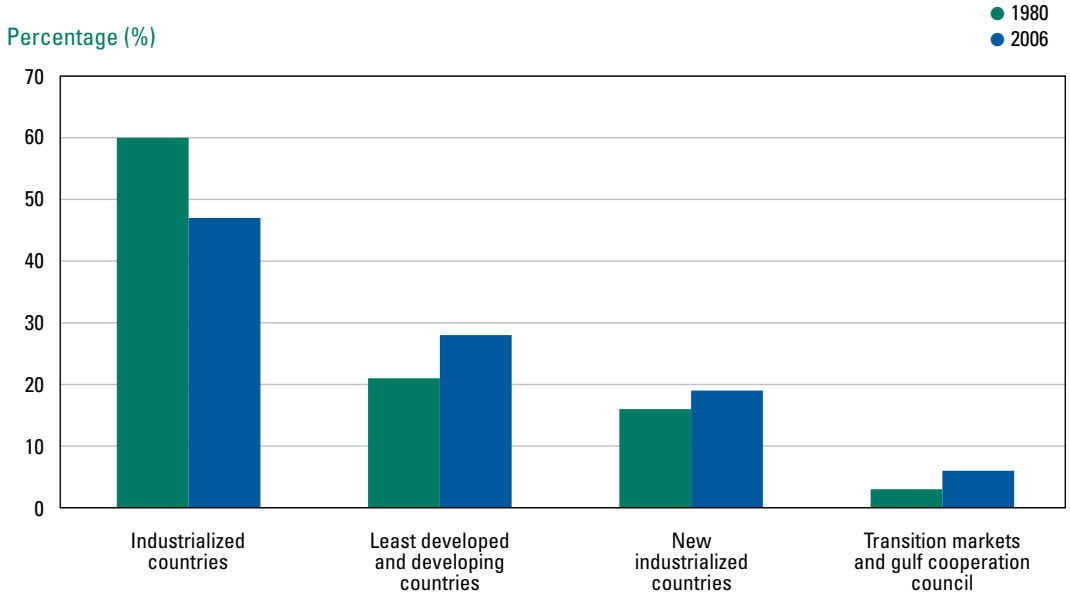
Industrial minerals and ores are a very heterogeneous class of resources, dominated quantitatively by ferrous metals and mineral fertilizers. These resources are used in highly diverse processes, so it is impossible on this level of generality to assess potential environmental impacts (see also IRP metals reports). The most accessible issues are connected to the extraction phase in the life cycle of those resources.

While issues of use and recycling are subject to other IRP reports on metals (UNEP, 2011), here some issues concerning a potential decoupling of impacts for the extraction phase in the life cycle of those resources are discussed. The location of resource extraction is relevant from an environmental impact point of view under the assumption that environmental regulation standards differ across the world. Most likely, those standards are tightest in wealthy industrial countries, and less tight in poorer, developing countries. According to SERI's Mosus database, extraction of industrial ores and minerals has not only doubled in the last 25 years, it has also shifted from industrial towards developing and newly industrializing countries (NIC) (see Figure 2.11); in 2006, more than half of all minerals and ores were extracted outside of industrial countries.

This finding has implications for environmental impacts associated with extraction activities. If legal standards on average are likely to become weaker, environmental impacts per unit of extracted material might become more severe. An equally indirect indication may be derived from worldwide declining ore grades.

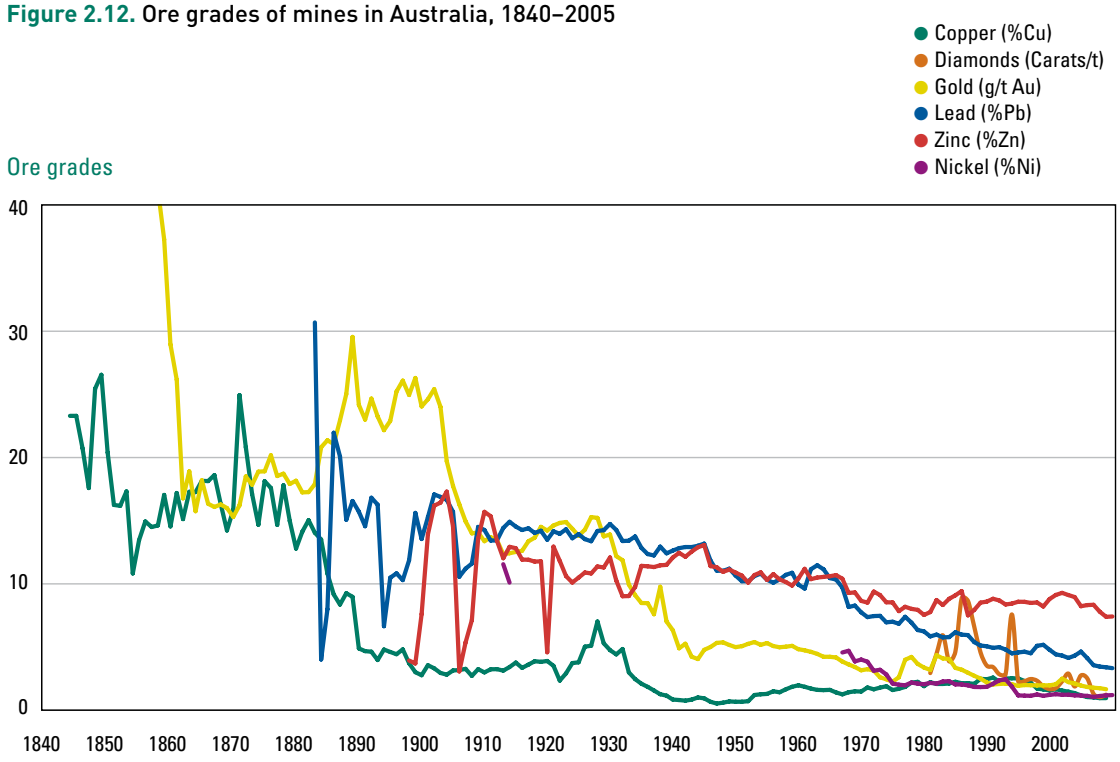
Figures 2.12, 2.13 and 2.14 display the decline of ore grades for several key

Figure 2.11. Global extraction of industrial minerals and ores 1980 and 2006, by type of country



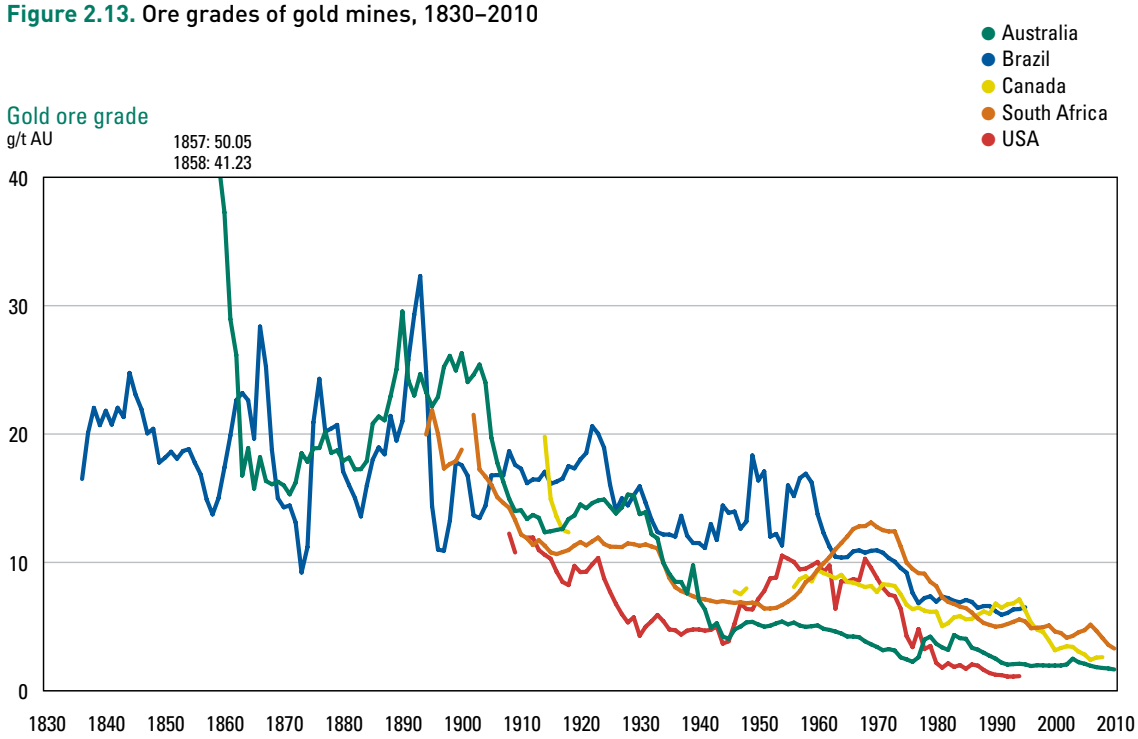
Source: SERI, Mosus data base, own calculation, http://seri.at/projects/completed-projects/mosus

Figure 2.12. Ore grades of mines in Australia, 1840–2005



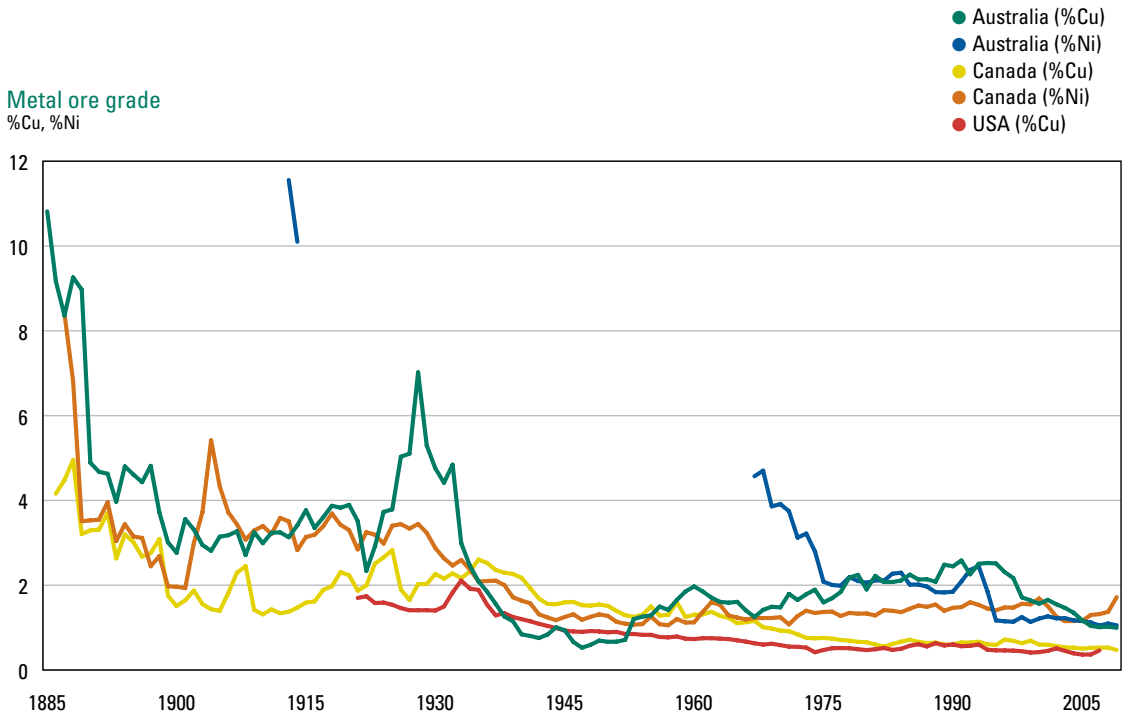
Source: Mudd, 2009

Figure 2.13. Ore grades of gold mines, 1830–2010



Source: Giurco *et al.*, 2010

Figure 2.14. Ore grades of nickel and copper mines, 1885–2010



Source: Giurco *et al.*, 2010

metals and countries that belong to the world's major providers of industrial minerals and ores. Today, **depending on the metal concerned, about three times as much material needs to be moved for the same ore extraction as a century ago**, with concomitant increases in land disruption, groundwater implications and energy use. Therefore, even if today's extraction is done more carefully than a century ago, and even if the release of aggressive chemicals has declined, no data are available to suggest that the growth rates of environmental impacts will lag behind the growth rates of the amount of ores extracted.

Most of the environmental impacts of extraction and use of construction minerals occur only at a regional level. All extraction activities of these minerals lead to the disturbance of land, air and water ecosystems. Futhermore, energy use for extraction and transport needs to be considered.[14] Similarly, a large part of the processing involves the production of concrete, 15% of which involves cement that is a major source of CO_2 emissions (1kg of cement generates about 1kg of CO_2 emissions). Due to the normally high waste-to-product ratios, extractive operations often generate large volumes of waste; similarly, at the end of the life cycle high volumes of waste require disposal. Therefore, many European countries have introduced mining charges or aggregate levies to reduce the demand for primary materials and encourage recycling (EEA, 2008, p.25). As most of the environmental impacts of the extraction of construction minerals are a direct function of their volume, one should expect their dynamics to be fairly proportional to the amount of resource extraction and use, perhaps with the exception of concrete: lowering the proportion of concrete, and improving the technology of cement production, could be a pathway to further decoupling of environmental impact from resource use.

Different considerations apply to impacts in the use phase of construction minerals, with impacts depending on what is being built, where and how it is being built, and possibly relate only weakly to the amounts of resources used. By using additional material to provide thermal insulation to buildings, for example, CO_2 emissions may be reduced.

2.3.4 Conclusion

The environmental impacts associated with resource use are multifold, vary between the resources under consideration,[15] and are not documented in a quantitative fashion that renders them accessible to a statistical assessment or target-setting for decoupling. It appears that **short term and local environmental impacts of resource use across the life cycle have been and can be mitigated in a way that allows for impact decoupling beyond resource decoupling. With global and far-reaching environmental impacts, this is less likely to be the case.** While the extraction of different classes of resources must be assumed to have very different environmental impacts, a substitution between them as a strategy to reduce impacts is not easily feasible, because they serve very different functions.

For fossil fuels, at least in the extraction phase, environmental impacts appear to be rising both with the recent sharp increase in coal mining, and with the rise in the extraction of so-called unconventional fuels (which include increasing risks posed by the shift of oil and gas production into socially and politically unstable environments).[16] In the use phase (main impact considered: CO_2 emissions), most research results point in the direction of a proportionality of resource use with CO_2 emissions, which might tip in the direction of even less decoupling with increasing use of coal. In the future, it is hoped that carbon capture and storage will reverse this tendency, but this is far from

14 In Germany, for example, 45% of the tonnage of freight vehicles is consumed by aggregates, see Bundesamt für Güterverkehr. 2006.

15 See in more detail in the IRP report 2010 on environmental impacts.

16 As well illustrated by the 2010 major accident in offshore drilling in the Gulf of Mexico.

certain. For biomass use, some global evidence indicates impact decoupling in the sense that while material flows (harvest) are increasing, the amount of land required remains stable. At the same time, though, fertilizer use and irrigation are increasing; it is therefore difficult to judge whether overall environmental impacts are stable, or whether some remain stable or decline at the expense of others that keep rising. In particular, impacts on biodiversity loss are not quantified in a way that enables decoupling to be assessed. For industrial minerals and ores (main impacts considered: land degradation at extraction sites and energy consumption) indications suggest that impacts associated with the extraction phase may be rising over-proportionally, due to a shift in the location of extraction sites (towards developing countries with possibly lower environmental standards) and a global decline in ore grades implying rising overburden and land degradation relative to the amounts extracted. With construction minerals (main impacts: land degradation, wastes and CO_2 emissions from transportation and cement production) some environmental impacts are closely proportional to the volumes of extraction and use of the respective resource. Other environmental impacts associated with the use phase of construction minerals entirely depend on the quality of use and may not be related to the quantities of the materials used.

2.4 Scenarios for future global materials use

The preceding sections indicated that the present high level of annual raw material extraction and the future trend of further strong increases in demand constitute a serious threat of resource overuse and depletion, as well as a challenge to the world's climate and various ecosystem services in the future. In the 20th century, it was mainly the highly industrialized countries (Europe, America and a few Asian countries) that contributed most to global resource consumption, at least on a per capita basis. However, the newly industrialized and developing countries are now playing an increasingly important role. Two relevant factors are population numbers and rising metabolic rates (resource use/capita). Metabolic rates vary between countries by a factor of ten or more, depending especially on development status and population density (see Figure 2.7). The global average per capita metabolic rate in the year 2000 is somewhere between 8 tons (Behrens *et al.*, 2007; Krausmann *et al.*, 2009) and 10 tons (Krausmann *et al.*, 2008) of annual resource use. However, the average metabolic rate for the industrialized countries (which make up only one fifth of the world population) is twice the global average and four or five times that of the poorest developing countries.

The scenarios presented here assume a continuation of the current patterns documented in Figure 2.7, that densely populated regions and countries require only about half the metabolic rate (annual resource use per capita) for the same standard of living as sparsely populated areas. All scenarios also assume that developed industrialized and developing countries (some of which are already committed to rapid industrialization of their economies) should over time **converge to a point where all countries have similar levels of resource use. This does not at all imply that developing countries must all follow the Western industrial model.** This option is the Business-as-Usual scenario (Scenario 1). Scenario 2 implies a significant deviation from the traditional Western industrial model, possibly similar to the model adopted by many Latin American economies. Scenario 3 envisages a very radical break from the traditional Western industrial model, in particular for developing industrializing countries like China, Brazil, South Africa, Mexico, Turkey, India, Indonesia, and the Philippines. Scenario 3 also means that

© Samrat35/Dreamstime

developed industrialized countries will need to fundamentally break from the resource- and energy-intensive high consumption economic growth model that remains a central point of agreement for political parties in these countries. All three Scenarios assume that this convergence process will be completed by the year 2050. Furthermore, **all three Scenarios accept similar assumptions to those that underlie the IPCC's SRES scenarios**,[17] without explicitly introducing GDP growth as a variable.

The Scenarios are optimistic about the future in two respects. First, similar modes of analysis (Romero-Lankao *et al.*, 2008) have shown that at present convergence trends can be observed for some countries, but not for others. The implications of this are that the vision of 'convergence by 2050' (which expresses a normative commitment to socio-economic justice) is unrealistic and the 'fortress world' scenario as outlined in the GEO scenarios (UNEP, 2004) might be more likely. This scenario is excluded from the Scenarios because **the purpose here is to reveal the implications for resource consumption of the normative assumptions that underlie different economic growth and development models.** For example, Scenario 1: Business As Usual reveals the underlying resource use implications of the growth and development model advocated by the *Growth Commission* which, in turn, reflects a mainstream economic policy consensus at a global level. Scenario 3 is pointing out the resource use implications of the IPCC's recommended scenario for preventing warming by more than 2 degrees that most governments in the world approved. No doubt, a 'fortress world' scenario would require far less than the projected 140 billion tons (140 Gt) of resources annually, but the result would be

17 In the SRES scenarios, convergence of income (GDP/capita) is somewhat more protracted and occurs, depending on the scenario, between 2050 and 2100 (see the analysis of Romero-Lankao *et al.*, 2008, p.23).

severe conflict between those who benefit and those who do not – or what is referred to these days as *Resource Wars.* Second, **no assumption of physical constraints is built into the model.** This is clearly unrealistic, but intentional because nearly all the mainstream growth and development models make a similar assumption. These scenarios seek to demonstrate the consequences of this. For example, Scenario 1 shows that business-as-usual means assuming that 140 billion tons (140 Gt) of resources are available for annual extraction, use and disposal. This may not be stated explicitly in any global growth projection that advocates either explicitly or implicitly a business-as-usual approach, but it is nevertheless a glaring unsubstantiated assumption about available resources for use over the long term. The purpose here is to reveal this assumption in order to validate the need to question it empirically. Wherever the global consumption of a resource comes close in future to supply constraints, the threat of distributional conflicts will always arise. To confirm this one needs only to refer to the many resource-based conflicts that already exist in the world today (see UNEP report on resource conflicts[18]).

Based upon these considerations, the following Scenarios for the year 2050 may be compared to the baseline of the year 2000.[19] All Scenarios assume a population change according to UN projections (medium variant), calculated country by country. **They assume the ratios of metabolic rates between high and low density countries to remain stable, and they assume that the composition by material components remains the same.**

2.4.1 Scenario 1: Business as usual

Freeze (industrial countries) and catching up (rest of the world)

In this scenario, relative decoupling in industrial countries continues as it has since the early 1970s. This means their average metabolic rates remain stable at year 2000 levels (freeze), while developing countries build up to the same metabolic rate by 2050 (catching up). For developing countries, this implies something more than a doubling of their metabolic rates, which, in combination with projected population growth, boosts their material demand as their most important method for eradicating poverty. For some of the least developed countries, convergence implies a fivefold increase in their metabolic rates. This scenario complies well with the trends observed in recent decades ('business as usual'). For industrialized countries, metabolic rates remained fairly stable since the mid 1970s (Bringezu and Schütz, 2001; Eurostat, 2002; Weisz *et al.*, 2006; NIES/MOE, 2007; Rogich *et al.*, 2008; and several other national MFA studies[20]), while in many developing countries a steep increase could be observed (Giljum, 2002; Gonzalez-Martinez and Schandl, 2008; Xiaoqiu Chen and Lijia Qiao, 2001; Perez-Rincon, 2006; Russi *et al.*, 2008; see also OECD, 2008). In short, for this scenario the long-term trend is a continuation of relative decoupling for developed economies, and effectively no decoupling for emerging and developing economies.[21]

This scenario results in a global metabolic scale of 140 billion tons (140 Gt) annually by 2050, and an average global metabolic rate of 16 tons/capita. In relation to the year 2000, this

18 http://www.unep.org/pdf/pcdmb_policy_01.pdf

19 The year 2000 is used as a baseline, as it best reflects a metabolic equilibrium that dominated the 25 preceding years (see Figure 1.2) and was mainly shaped by trends in the industrialized countries. In the years since, a new phase of growth can be observed that we chose to capture in the scenario part of our analysis, as according to more detailed data it is already due to a "catching up" process by major developing countries (such as China and India).

20 Barbiero *et al.*, 2003; Schandl *et al.*, 2000; Scasny *et al.*, 2003; Pedersen, 2002; Maenpaa und Siikavirta, 2007; Muukkonen, 2000; German Federal Statistical Office – Statistisches Bundesamt, 2000; Hammer and Hubacek, 2003; De Marco *et al.*, 2000; Femia, 2000; Isacsson *et al.*, 2000; Schandl and Schulz, 2002; DETR/ONS/WI, 2001.

21 This BAU-scenario complies very well with what SERI Global and Friends of the Earth Europe (2009) have calculated as trend projections, in which they arrive at an increase of annual global resource use from 55 billion tons in the year 2000 to 100 billion tons in the year 2030.

would imply more than a tripling of annual global resource extraction, and establish global metabolic rates that correspond to the present European average.

This scenario assumes no major system innovation towards sustainability such as a switch away from fossil energy, which represents an **unsustainable future in terms of both resource use and emissions, probably exceeding all possible measures of available resources and assessments of limits to the capacity to absorb impacts.** Average annual per capita carbon emissions would triple and global emissions would more than quadruple to 28.8 GtC/yr. Such emissions are higher than the highest scenarios in the IPCC SRES (Nakicenovic and Swart, 2000), but since the IPCC scenarios have already been outpaced by developments since 2000 (Raupach *et al.*, 2007), it might in fact be closer to the observable trends.

2.4.2 Scenario 2: Moderate contraction and convergence

Reduction by factor 2 (industrial countries) and catching up (rest of the world)

In this scenario, industrial countries commit to an absolute reduction of resource use and reduce their metabolic rates by a factor of 2 (i.e. from an average of 16 tons/capita to 8 tons/capita), while developing countries would then moderately increase their metabolic rates and catch up to these reduced rates by the year 2050. This scenario presupposes substantial structural change, amounting to a new pattern of industrial production and consumption that would be quite different from the traditional resource-intensive Western industrial model. So far, despite efficiency gains in various domains, metabolic rates in the past have declined in absolute terms in only a few industrialized countries. Given the resource productivity gains that have occurred in the past, these metabolic rates could support a comfortable middle class lifestyle for all in both developing and developed economies. For developing countries, this scenario implies relative decoupling to increase their metabolic rates by no more than a factor 1.2 to 1.3 (depending upon density) which, in turn, represents a substantial commitment to sustainability-oriented innovations for decoupling.

This scenario amounts to a global metabolic scale of 70 billion tons (70 Gt) by 2050, which means about 40% more annual resource extraction than in the year 2000. The average global metabolic rate would stay roughly the same as in 2000, at 8 tons/capita. The average CO_2 emissions per capita would increase by almost 50% to 1.6 tons per capita, and global emissions would more than double to 14.4 GtC.

Taken as a whole, this scenario would be achievable only with significant decoupling through investments in sustainability-oriented innovations that result in systems of production and consumption that generate far more per unit of resources than is currently the case. While overall constraints (e.g. food supply) will not be transgressed in a severe way beyond what they are now,[22] developing countries in this scenario have the chance to achieve a rising share of global resources, and for some an absolute increase in resource use, while industrial countries have to cut their consumption. The emissions that correspond to this scenario are more or less in the middle of the range of IPCC SRES climate scenarios.

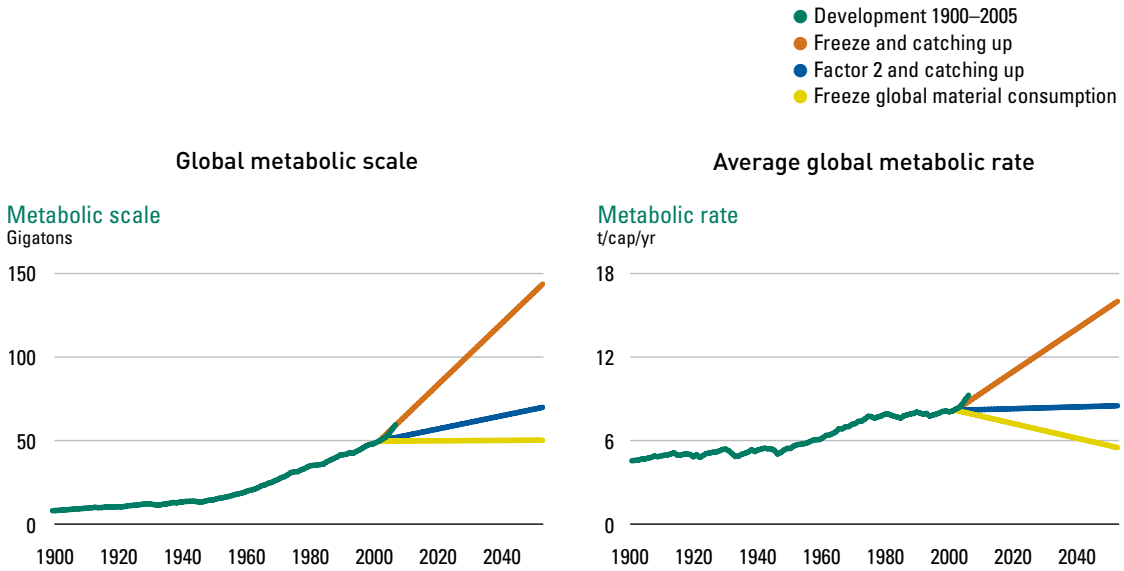
2.4.3 Scenario 3: Tough contraction and convergence

Freeze global resource consumption at the 2000 level, and converge (industrial and developing countries)

In this scenario, the level of global resource consumption in 2050 is limited to equal the

22 In terms of global footprint; existing resource consumption exceeds the Earth's carrying capacity, let alone another increase of 40%.

Figure 2.15. Resource use according to three different scenarios up to 2050



Source: Krausmann *et al.,* 2009 (Development 1900–2005) and own calculations (see text)

global resource consumption of the year 2000. It is anticipated in this scenario that metabolic rates of industrial and developing countries converge at around 6 tons per capita. This scenario requires far-reaching absolute resource use reductions in the industrialized countries, by a factor of 3 to 5. In this scenario, some countries classified as 'developing' in the year 2000 would have to achieve 10–20% reductions in their average metabolic rates while simultaneously eradicating poverty – an outcome that is only conceivable if it is accepted that sustainability-oriented innovations can result in radical technological and system change.

This scenario amounts to a global metabolic scale of 50 billion tons (50 Gt) by 2050 (the same as in the year 2000) and allows for an average global metabolic rate of 6 tons/capita. The average CO_2 per capita emissions would be reduced by roughly 40% to 0.75 tons/capita, so global emissions would remain constant at the 2000 level of 6.7 GtC/yr.

Taken as a whole, this would be a scenario of tough restraint that would require unprecedented levels of innovation. The key message of this scenario is that despite population growth to roughly 9 billion people, the pressure on the environment would remain roughly the same as it is now. The emissions correspond approximately to the lowest range of scenario B1 of the IPCC SRES, but are still 20% above the roughly 5.5 GtC/yr advocated by the Global Commons Institute for contraction and convergence in emissions (GCI, 2003).

The implications of these scenarios are far reaching. Given that the 'business-as-usual' (BAU) scenario **(Scenario 1)** assumes that developing countries adopt growth and development strategies aimed at 'catching up' with the resource consumption patterns of industrialized countries, this will result in the tripling of global annual resource extraction and consumption by 2050. Specifically, **this means more than doubling biomass use, while almost quadrupling fossil fuel use and tripling the annual use of metals (ores) and construction minerals.** This scenario would place an equivalent burden on the planet as if the human population

Table 2.1. Metabolic scales and rates, overview of scenario analysis

		Baseline	Scenario 1: Business as usual	Scenario 2: Moderate contraction and convergence	Scenario 3: Tough contraction and convergence
	Year	2000	2050	2050	2050
World population (Billions)		6.0	8.9	8.9	8.9
World Metabolic rate (Tons/capita/year)		8	16	8	5.5
World Metabolic scale (Billion tons/year)		49	141	70	49
Metabolic rate	Industrialized High density	13	13	6.5	5
	Industrialized Low density	24	24	12	8
	Developing High density	5	13	6.5	5
	Developing Low density	9	24	12	8

tripled by the year 2050 to 18 billion people, while maintaining the resource consumption patterns (metabolic rate) of the year 2000. Moreover, this increase would, if global manufacturing continues to be concentrated in low-wage environments endowed with viable infrastructures and institutions, take place in countries that were classified as developing countries with a very high population density in the year 2000, such as China and India. Thus, the burden of resource flows *per unit area* would in 2050 be substantially above the European or Japanese levels of today. This BAU scenario is incompatible with the IPCC's climate protection targets.

Although **Scenario 2 (moderate contraction and convergence)** assumes substantial structural change in the dominant industrial production and consumption patterns, it still implies a roughly 40% increase in annual global resource use with associated environmental impacts. If global manufacturing continues to be concentrated in low-wage environments, practically all of that increase would occur in the countries classified as 'developing' in the year 2000. Such a fast increase in resource consumption would render the existing policies of a 'circular economy' (OECD, 2008) very difficult, if only because the potentially reusable wastes are very much smaller than the required inputs. **For the industrialized countries, achieving a factor 2 reduction of metabolic rates would imply resource productivity gains of 1–2% annually** (which is within the range of the productivity gains of the past two decades), net of any income-based rebound effects (Greening *et al.*, 2000). More realistically, it would require much higher innovation rates and productivity (efficiency) gains.[23] In either case, this scenario would require substantial economic structural change and massive investments in innovations for resource decoupling.

Scenario 3 (tough contraction and convergence) does not raise global resource consumption above the 2000

23 One should be aware that achieving a substantial reduction in resource use on an economy-wide per capita level is much more difficult than achieving substantial resource productivity gains within certain areas of production. For an overall "Factor 2"-reduction of metabolic rate, much larger resource productivity gains have to be achieved in some areas (cf. Weizsäcker *et al.*, 1997 "factor 4"; or Schmidt-Bleek, "factor 10" cf. Hinterberger and Schmidt-Bleek, 1999; or "factor five" in, Weizsäcker, *et al.*, 2009), while, for example, food supply can only be reduced by a much smaller margin.

levels; thus it would be most compatible with the existing (if unknown) limits to the Earth's resource base, and best adjusted for as much circularity in economies as is technically feasible. To achieve this overall strategic goal, absolute resource use reductions will not only be necessary in developed economies, but also in already advanced developing countries. Most politicians are likely to regard this scenario as too restrictive in terms of developmental goals such as reducing poverty and providing for the material comfort of a rapidly expanding middle class. Thus this scenario can hardly be addressed as a possible strategic goal, but is valuable insofar as it illuminates the implications of a hypothetical barrier to further global increase of resource extraction.

All scenarios demonstrate that without significant improvements in resource productivity, it will not be possible to meet the needs of nine billion people (including the eradication of poverty) by 2050. Nevertheless, the business-as-usual scenario (Scenario 1) is a projection into the future of the currently structured and managed global economy. It assumes limited investments in innovations for both resource and impact decoupling. The policy implications are clear: as the economic consequences of resource scarcities and degraded environments start to work their way through the economy, policy-making will start to take more and more seriously the implications of scientific research about both the consequences of BAU and possibly solutions. However, even if it were possible to build a global political consensus on the need for absolute resource use reductions in developed economies and relative decoupling in developing countries (Scenario 2), change will only be able to go as fast as the levels of investment in innovations for decoupling across the entire value chain. Although it has been assumed in these scenarios that impact decoupling follows resource decoupling, in reality it is impossible to predict where innovations for decoupling will have the greatest impact. It is conceivable that impact decoupling could even accelerate ahead of resource decoupling (e.g. via radical pollution reduction), but the reverse could also be true (e.g. biomass production to reduce CO_2 could exacerbate soil and water scarcities).

Whatever the dynamics, the single clear policy implication of Scenario 2 is that any Government that gets ahead of the game by facilitating investments now in innovations for decoupling in the future will clearly reap the benefits when pressures mount for others to change rapidly by depending on technology transfers from elsewhere.

Scenario 3 is more or less consistent with the IPCC assessments of what would be required to prevent global warming beyond 2 degrees. Although Scenario 2 envisages a mix of absolute reductions and relative decoupling, the policy implication is clear: Scenario 3 will require greater global consensus on the need for convergence than Scenario 2, and this consensus would need to be supported by a clear case as to why **poverty reduction in a resource scarce world will depend more on innovations for decoupling** than if investments continue to prioritize BAU production and consumption technologies and systems. Equally, threats to over-consumption need not be equated to threats to well-being and middle class lifestyles, but rather as threats to particular kinds of resource-intensive modes of consumption.

3 Decoupling and the need for system innovations

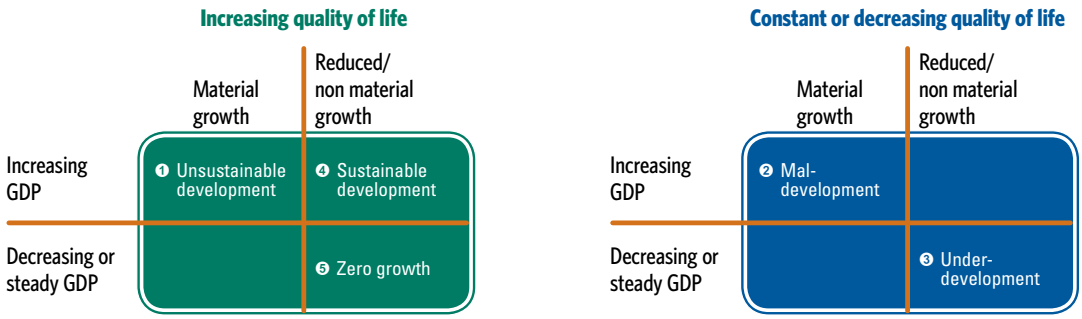
3.1 Rethinking growth

The logic of decoupling as defined in this report has significant implications for the understanding of economic growth, based on a rich tradition within the sustainable development literature that has attempted to redefine growth from a sustainability perspective.

The term 'growth' is surrounded by confusion, as the term means different things to different audiences. When businesses and governments talk about growth they generally mean economic growth, the amount of economic value and monetary transactions using indicators such as GDP. For environmentalists, growth tends to be focused on the growth of physical throughput in the economy, or physical/material growth.

Economic growth and physical growth are different. *Economic growth*, measured by the GDP of a country, is defined as the added (monetary) value of all final goods and services produced within a country in a given period of time, usually a calendar year. It includes the sum of economic value added at every stage of production (the intermediate stages) of all final goods and services produced during that time.

Figure 3.1. The different guises of development



Source: Redrawn from Gallopin, 2003, p. 27

Physical growth of the economy means that it spreads over more physical area, or it has a larger material and energy throughput, or it has a larger stock of physical products, buildings or infrastructure. **Physical growth is often coupled to increased environmental pressures, damage and resource depletion.**

Based on this understanding of these two types of growth, it becomes conceptually possible for economic growth (defined now as money flow, or value) to be decoupled from physical growth of the economy (resource consumption) and associated environmental pressures. Ekins (2000) made the same point when he argued:

> *"It is clear from past experience that the relationship between the economy's value and its physical scale is variable, and that it is possible to reduce the material intensity of GNP.* ***This establishes the theoretical possibility of GNP growing indefinitely in a finite material world."***

Writing from a developing country context, Gallopin (2003) develops a similar line of argument. He distinguishes between *development* (improvements in well-being plus material economic growth), *maldevelopment* (material economic growth with no improvements in well-being), *underdevelopment* (no material economic growth and no improvements in well-being), and *sustainable development* (improvements in well-being plus non-material economic growth) (Figure 3.1). He argues as follows:

> *"In the very long-term, there are two basic types of truly sustainable development situations: increasing quality of life with non-material growth (but no net material growth) and zero-growth economies (no economic growth at all). Sustainable development need not imply the cessation of economic growth: a zero growth material economy with a positively growing non-material economy is the logical implication of sustainable development. While demographic growth and material economic growth must eventually stabilize, cultural, psychological, and spiritual growth is not constrained by physical limits." (Gallopin, 2003, p.27)*

The logic of Gallopin's framework is that development strategies for developing countries should be split into two modes (which could be consecutive phases in certain circumstances). The first mode would entail moving from *maldevelopment/ underdevelopment to development* whereby improvements in well-being for the majority are achieved via inclusive material economic growth. This is what mainstream development economics is all about, and it is the central focus of *The Growth Report*

that brings together the perspectives of the most influential economists in the world today (Commission on Growth and Development, 2008). However, it virtually ignores ecological sustainability, except for a minor reference to global warming.

The second development mode would entail a shift into *sustainable development* whereby improvements in well-being are achieved via *non-material economic growth*. When references are made to 'leapfrogging', this usually means either shortening the transition from the first to the second mode considerably, or skipping the first phase altogether (Sachs, 2002). Leapfrogging, however, will depend entirely on whether the capacity for innovation exists within a particular developing country and whether, in turn, an appropriate set of institutional arrangements are in place to provide incentives and harness innovations that demonstrate economically viable 'leapfrog' technologies.

The UK Sustainable Development Commission (UK-SDC) has produced a report entitled *Prosperity without Growth: the Transition to a Sustainable Economy* (Jackson, 2009). What Gallopin calls 'non-material growth', the UK-SDC calls 'prosperity' which is when "humans can still flourish and yet reduce their material impact on the environment". Once prosperity ceases to mean increasing consumption of material goods, then the focus shifts towards the capabilities that citizens will need to "participate meaningfully and creatively in the life of society". However, the report dismisses relative decoupling on the grounds that this simply implies increasing consumption in more efficient ways. It dismisses absolute decoupling on the grounds of lack of evidence that this has happened in practice, or that it can happen in practice in developed economies. Instead, the report turns to an updated version of Herman Daly's classic notion of a steady-state economy (or what Gallopin calls 'non-growth economies'), coupled to a programme to dismantle the insatiable hunger for goods that drives contemporary consumer culture. It lacks a conception of transition, something that the concepts of resource and impact decoupling can provide.

In conclusion, decoupling can lead to a rethinking of assumptions about economic growth and, by implication, GDP as the key indicator of growth. Alternative indicators of growth will be required to encourage decoupling and dematerialization. An example of this is the Genuine Progress Indicator (GPI) (Talberth, 2008; Talberth *et al.,* 2007) or a Happiness Index (Stiglitz *et al.*, 2009). The GDP indicator on its own will always depend on rising quantities of extracted resources, especially as they are depleted and prices are pushed upwards, which, in turn, will accelerate their depletion. The GPI puts in place different incentives, especially if it can be reinforced by a material flow analysis perspective (Haberl *et al.,* 2004). However, it would not be advisable to eliminate the use of GDP as an indicator altogether. It should be retained as a good measure of economic activity, but not as a good measure of human progress and ecological sustainability. **Other indicators are needed to complement the GDP indicator in order to generate a more balanced understanding of development.** The Human Development Index is one example. The next step is to find an agreed indicator of development that reflects progress towards more sustainable modes of production and consumption by means of decoupling. As the China case study in Chapter 8 suggests, a **Decoupling Index** might be one element of such an indicator.

3.2 Innovation and decoupling

The core logic of the argument thus far is that a more sustainable global economy will depend on the decoupling of growth rates from the rates of resource consumption

('resource decoupling') and environmental degradation ('impact decoupling'). To bring about these changes, radically new visions of a future global socio-ecological metabolism will be required. To translate these visions into practice will require rapid improvements in the capacity for instigating innovations for more sustainable resource use. The second report of the Decoupling Working Group will document many of these innovations in more detail, but this section will outline the rationale for linking innovation to sustainability.

Economists who accept the assumptions of endogenous growth theory see knowledge and information as the key drivers of economic growth, and that the returns on investments in knowledge outweigh the returns on investments in capital and un- and semi-skilled labour. New knowledge and information processing capacities that get built into production processes as technologies, operating routines or managerial/organization systems at the firm and/or macro-economy level are considered innovations. These innovations are a function of 'milieus of innovation' where overlapping networks of expertise, knowledge and system design mesh together in ways that create information-driven growth engines that replace the old 'smokestack' industrial nodes that were the primary drivers of economic growth until the 1960s (with Silicon Valley being the archetypal model of the new approach) (Evans, 2006; for overviews see Castells, 1997; Evans, 2005).

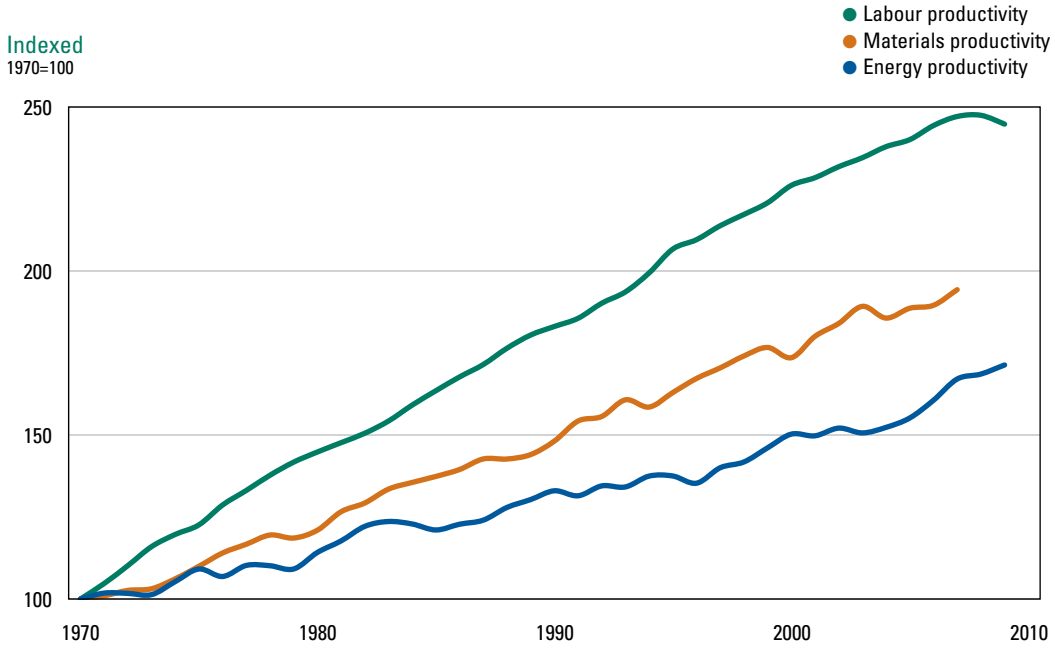
The problem with the national innovations systems that have been promoted by many governments around the world over the past two decades is that they are aimed at promoting economic growth with insufficient attention paid to the various dimensions of decoupling (cleaner production being an obvious exception). In other words, innovation is not in and of itself a good thing from a sustainable resource management perspective. A new concept of innovation will be required (Montalvo, 2008).

Eco-innovation is such a new concept. For the European Commission, eco-innovation is defined as "the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation [sic.] (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives." (Kemp and Pearson, 2008). Building on this definition, eco-innovation is defined by OECD (2009) as "the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives". In this definition, eco-innovation is not limited to environmentally-motivated innovations, but includes "unintended environmental innovations". The environmental benefits of an innovation can be a side effect of other goals, such as recycling heavy metals in order to reduce abatement costs. Institutional innovations such as changes in values, beliefs, knowledge, norms, and administrative acts are included, along with changes in management, organization, laws and systems of governance that reduce environmental impacts. However, eco-innovation tends to focus on what this report has referred to as 'impact decoupling'. Sustainability-oriented innovations for resource decoupling is a different matter altogether.

Whereas the first generation of innovation investments has focused on labour productivity through the application of knowledge embedded in information systems, the second generation will need to focus on resource productivity. In Figure 3.2, the results of the first generation show substantial increases in labour

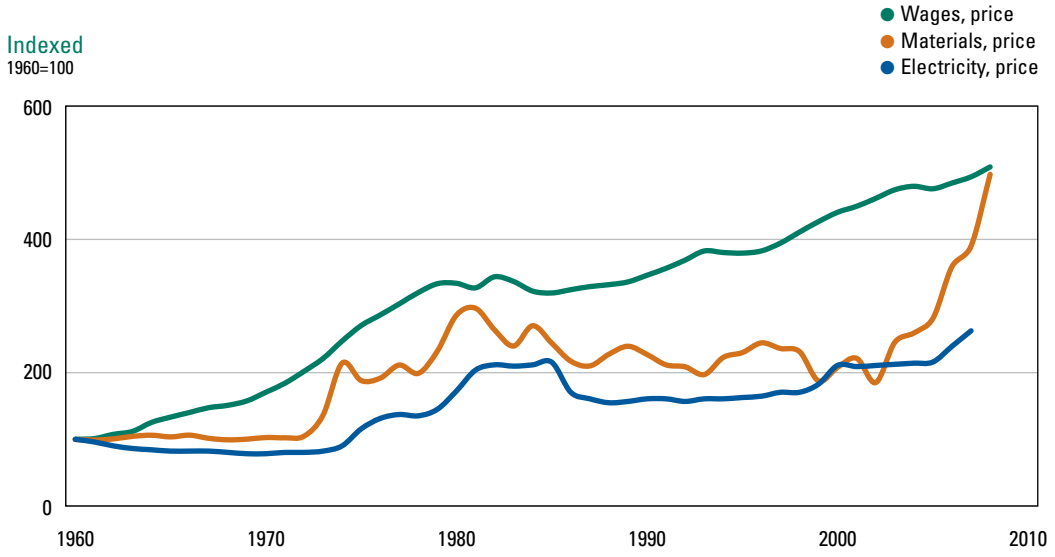
productivity, with materials and energy productivity lagging behind. Prices as the key driver of first generation innovations are reflected in Figure 3.3, showing that labour costs have gone up steadily, while materials and energy prices remained static or even declined (until recently, when many material costs increased rapidly).

Figure 3.2. Resource productivity, labour productivity and energy productivity in EU-15



Note: Labour productivity in GDP per annual working hours; material productivity in GDP per domestic consumption (DMC) and energy productivity in GDP per total primary energy supply (TPES).
Source: EEA, 2011

Figure 3.3. Price dynamics of wages, materials and electricity



Note: All series are in real prices without direct taxes. Wages are based on collectively agreed wages (CAO) in the Netherlands (source CBS). Materials are from the CRB Commodity Price Index (CCI) reflecting world-wide prices. Electricity prices are from CBS and Eurostat. Own calculations in the wages series and electricity series in order to standardize different series on each other (multiplicative standardization).
Source: De Bruyn *et al.*, 2009

The key to decoupling in practice will be innovations that make it possible to increase resource productivity, thereby reducing metabolic rates. Increasing resource productivity may also justify increasing resource prices, benefitting resource producers (often in developing countries). Innovation for resource productivity, therefore, may well define the core challenge for sustainable resource management for the coming decades. One lesson from innovation studies is that state intervention is required to sustain high levels of consistent investment in innovation, because the returns on investment in innovation accumulate within the public domain, even if these are funded by private agents who, therefore, do not always have an incentive to invest in innovation, especially during recessionary times.

Four key insights on innovation are relevant for sustainable resource management (Lundvall, 2007):

- Innovations are different from inventions. An invention results from a new idea emerging for a new product or process, while an innovation is the synthesis of the idea with the necessary set of financial and institutional arrangements to implement the new idea on a broader scale;

- Innovations are not random events, but are rather the result of specific incentives and investments;

- Innovations do not arise from single individuals or single firms, but rather from well-networked economic agents working collaboratively with knowledge institutions (such as universities) and in ways that are open, creative, problem-driven and connected to learning from practice; and

- Innovations are not about building up stocks of knowledge capital (patented ideas) created for trade in the so-called 'knowledge economy', but rather innovations are continuous learning processes responsive to the fact that in a highly complex globalized world, fixed bits of knowledge rapidly become obsolete – the modern economy, therefore, is a learning economy, not a knowledge economy.

Innovation is not simply about technological solutions (the so-called 'techno-fix' approach). Rather, innovation is a process that has three different forms:

- *technological innovations*, providing specific techniques for managing/processing materials and energy (e.g. the steam engine, hydrogen fuel cell, micro-chip, or a process that achieves more with less);

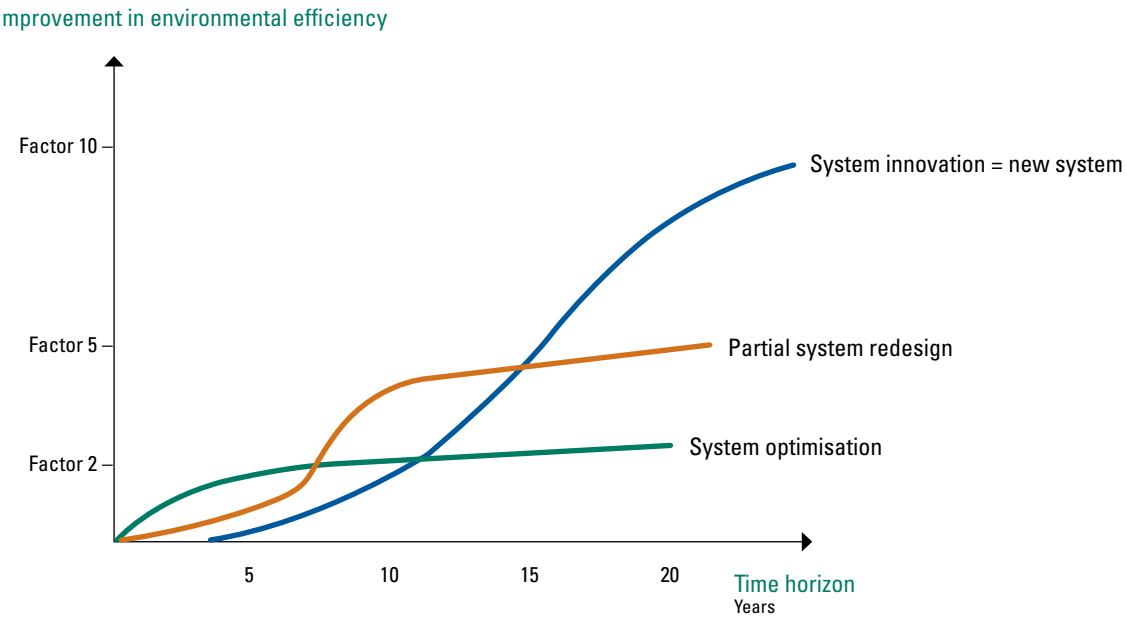
- *institutional innovations* for managing on a society-wide basis – or even globally – incentives, transaction costs, rents, benefit distribution, dispersal, contractual obligations, precautions, and individual obligations; and

- *relational innovations* for managing cooperation, social cohesion, solidarity, social learning and benefit sharing .

These three forms of innovation provide different outcomes. As Figure 3.4 suggests, to achieve the radical break from BAU patterns (i.e. Factor 5 to Factor 10 improvements in resource productivity), all three will be required.

Past innovation concerned with economic competitiveness and growth has contributed to an extraordinary increase in production, consumption and economic activity and therefore improvements in the average human welfare. However, this has occurred along an unsustainable trajectory. Innovation now needs to be harnessed for resource productivity and environmental restoration. Merging these seemingly disparate themes of sustainability and systems of innovation offers an opportunity to realize

Figure 3.4. Conceptual model of innovations



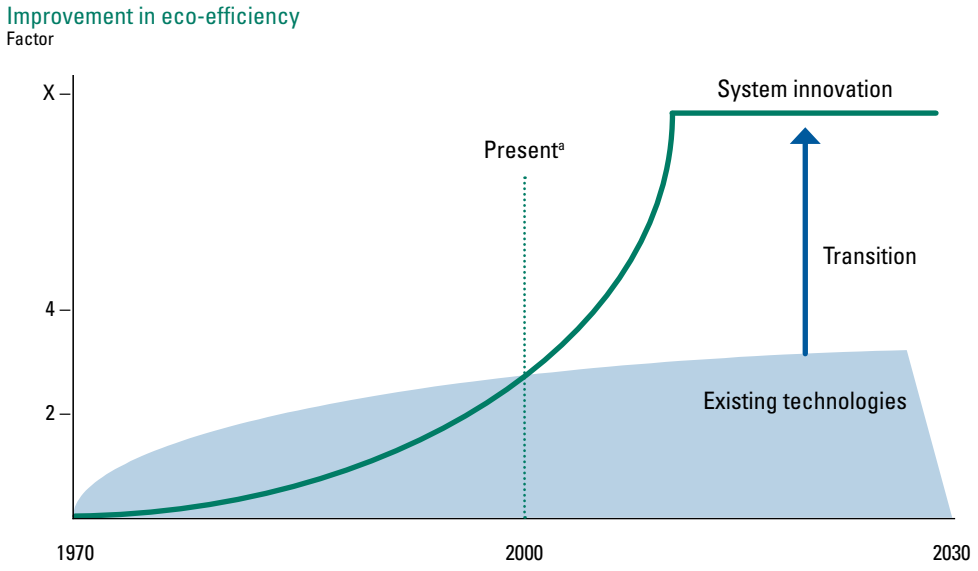
Source: Weterings *et al.*, 1997

'sustainable systems of innovation' (Montalvo, 2008), or 'sustainability-oriented innovation systems' (Stamm *et al.*, 2009). This requires innovations that contribute to decoupling through reducing environmental pressure and contributing to sustainability during economic activities (Stamm *et al.*, 2009; Montalvo, 2008). A sustainability-oriented innovation system (SOIS) "refers to the transition from one socio-technical system to another, qualitatively different one" (Geels & Elzen in Stamm *et al.*, 2009, p.26).

Stamm *et al* (2009) advocate the SOIS approach, showing how innovation has been linked to sustainability through 'system innovation' in which socio-technical systems provide the lens through which systems transitions can be analysed and understood. Therefore SOIS provide a departure point for decoupling, a reduction of socio-economic metabolism and sustainability.

Geels (2004) extended the narrow focus of innovation at the sectoral level to encompass a broader perspective of technology, including production, distribution and use within society. This furthers understanding of transitions which affect both technology and the system in which that technology is embedded (Geels, 2004); in these cases the system and technology adapt and co-evolve as socio-technical systems (von Malmborg, 2007). Furthermore, the scope provided at the system scale allows for the radical innovation (paradigm shift) needed to address sustainability challenges (Tukker, 2005). However, the 'radicalness' of innovations is dependent on the actors present within the system, the learning that occurs, and behavioural changes, which are attributed to the process of system innovation during which new knowledge is learnt and explored, while old knowledge undergoes creative destruction (von Malmborg, 2007). Figure 3.5 is an idealized image that demonstrates the difference between incremental innovations, which have been described above as technological improvements, and systems innovation. Changes at the system level offer the most effective way to achieve decoupling (Vollenbroek, 2002).

Figure 3.5. System innovation



a At time of publication
Source: Vollenbroek, 2002

If growth and development are dependent on the capacity for innovation, what are the implications for developing countries that clearly lag behind developed economies when it comes to scientific and technological capacity? Many economists are pessimistic about the possibility of developing countries 'catching up', precisely because they will never be able to bridge the 'ingenuity gap' (Homer-Dixon, 2000). However, **developing countries may not wish to 'catch up' to a level and mode of economic development which is now regarded as ecologically unsustainable.** If it is recognized that development is about accelerating the spread of sustainable economic alternatives, are developing countries still at a disadvantage? Following Montalvo (2008), **developing economies actually may have an advantage over developed economies concerning eco-innovations** in the following respects: firms in developing countries do not always face the power of entrenched financial interests vested in technological paradigms; new technologies in developing countries may have more regulatory space to flourish; in many developing countries investment in fixed infrastructures has only just begun which provides space for innovation that does not exist in countries where existing infrastructures are a sunk cost and difficult to change; and markets in developing countries may not be saturated or mature and can, therefore, be moulded to adapt to new kinds of consumer behaviours.

An important question from a decoupling point of view is how **technological leapfrogging** can enable developing countries to skip some of the dirty stages of development experienced by industrialized countries (Sauter and Watson, 2008). For example, many developing countries have partly skipped landline phone systems in favour of mobile phone systems. A crucial condition for leapfrogging is that a nation possesses a sufficient level of *absorptive capacity* (that is, the ability to adopt new technologies). This capacity includes technological capabilities, knowledge and skills as well as supportive institutions. A strong role for government may be needed. For example "leapfrogging in the Korean steel and automobile industries was enabled by

Summary of a theory of socio-technical transition to sustainable development

A multi-level-perspective (MLP) provides a framework for "...understanding sustainability transitions that provide an overall view of the multi-dimensional complexity of changes in socio-technical systems" (Geels, 2010, p.495). The MLP is a three-tiered framework which consists of the landscape (macro), regime (meso) and niche (micro) levels.

The socio-technical landscape, or macro level, is considered as an external factor and it provides the greater structure for activities in a system. As it is external, it is out of the control of actors within the system and thus cannot be changed according to preference and is in relatively stable condition, adapting slowly according to indirect adjustments at a lower level. But the landscape by nature is unpredictable, responding to variations in macro-economic, environmental and social conditions (Tukker, 2005).

At the micro level are socio-technical niches, isolated protected pockets where creation, development and testing of radical novelties and innovations take place. These novelties are learning experiments that respond to changes or demands at both the meso and macro levels; while the isolation provides a mechanism for protection against other market products, niches are the starting points for change (Geels, 2002; Geels & Schot, 2007). Furthermore, niche innovations usually occur within a small network of actors who provide the financial and technical support for their realization.

The meso level, or socio-technical regime, represents the existing configuration of institutions, rules, culture and techniques, forming the set of practices, exhibiting dynamic stability carried out by social groups (Geels, 2002).

This stability is reinforced by the consistent reference to a particular regime – whether it is science, technology, economics, politics or culture – identified according to its function, which hampers the introduction of niche innovations. Geels and Schot (2007) argue that the meso level is deeply embedded within the 'cognitive routines' of engineers, policy makers, the private sector and even academic institutions, consequently inhibiting the entry of radical innovations onto the market.

Through the interaction of its three embedded interconnected and interdependent components, the MLP allows for the emergence of socio-technical transitions. Changes at the macro and micro levels exert pressure on the socio-technical regime, which can lead to a transition. At the micro level, small networks developing radical innovations exert upward pressure through a build up of internal momentum which weakens the barrier of the regime level; eventually 'breaking through' when sufficient and simultaneous pressure has been exerted from the macro level. This breakthrough or 'window of opportunity' is created via the mutual tension from the macro and micro levels which destabilize the particular socio-technical regime, allowing competition between new and existing regimes, be it technological, cultural, political, economic or scientific. These changes have the capacity to influence or change the landscape level, while the landscape and regime levels directly affect or influence the niche innovation level. While numerous radical innovations are necessary to resolve the ecological crisis, technological transitions occur via step by step processes as opposed to radical regime changes. Various niche innovations, when connected, can thereby accrue to a system transition.

investments in technological capabilities in the countries concerned. This was enhanced by a balanced and coherent policy mix of economic, industrial and R&D policies" (Sauter and Watson, 2008, p.2). The success of the Indian and Chinese wind industries owed a great deal to the benefits of incentives for the deployment of wind technology. In these countries, international market creation was allied with the development of domestic wind manufacturing industries. This, in turn, was enabled by access to external knowledge and the creation of knowledge networks.[1] This last case reflects only a partial leapfrogging, as the majority of the power generation investments are still in coal technology in these countries.

The difficulties with leapfrogging may be generally underestimated. "To begin with it is far from clear that the evidence of the first-tier Asian newly industrializing countries can be replicated in developing countries today. For one thing, the

1 Based on http://www.dfid.gov.uk/Documents/publications/DFIDLeapfroggingReportWeb.pdf

development success of the first generation of Asian tigers was predicated on a number of country-specific characteristics (competent, goal-directed and insulated bureaucracies, etc.) not found in many other parts of Asia, Africa and Latin America. For another, many of the state interventions (trade protection, subsidies, procurement, etc.) that were used to promote local industrial development in the past are no longer available to developing countries under today's international trade and investment rules" (Perkins, 2003, p.181)

For leapfrogging, Perkins suggests:

- Clearer and more specific definition of what it is to be 'leapfrogged';
- Targeting priority sectors for investment;
- Supporting the development of leapfrogging capabilities and technologies; and
- Promoting cooperative partnerships between key actors.

In conclusion, over the past two decades much has been learned about the dynamics of the innovation process. Investments in innovations, however, have been motivated primarily by the desire to accelerate growth, with little attention paid to various dimensions of decoupling (although impact decoupling has received a lot more attention than resource decoupling). The challenge is to apply the insights about innovation to resource productivity. Sustainability-oriented innovations hold the key to decoupling as a practical framework for action. In this regard, developing countries may enjoy a strategic advantage because they do not face the same market and institutional rigidities that stem from a dependence on technological and physical infrastructures that are rapidly becoming obsolete as more ecological thresholds are breached.

3.3 Cities as spaces for innovation and decoupling

Cities have historically been centres of political, economic, cultural and informational power. As of 2007, over 50% of people live in cities (United Nations, 2006); yet cities occupy only 2% of land surface. Nevertheless they consume three quarters of all natural resources and in 2006 accounted for 71% of the world's energy-related CO_2, with transport, industry and building sectors being the largest contributors. This share will rise to about 76% by 2030 as urbanization continues (IEA, 2008).[2]

As the world's population grows from the current 6.8 billion people (2010 estimate) to 8 billion by 2030, and perhaps at least 9 billion by 2050 (United Nations, 2004b), cities will most likely become the home for the additional 2 to 3 billion people of the future world population. This is driving what is called the 'second urbanization wave'. Whereas the 'first urbanization wave' from the mid-1800s to the mid-1900s involved the urbanization of only about 400 million people mainly in Europe and North America, the next 2 billion people who will be living on Earth are most likely to be living in Asian and African cities (United Nations, 2006). However, the bulk of this expansion will be in secondary and tertiary cities, not the existing sprawling mega-cities like Cairo, Calcutta, Mumbai, Shanghai, San Paulo, Seoul, Dhaka, Karachi, Buenos Aires and Manila (National Research Council, 2003). It has been projected that **by 2015 nearly 60% of the total urban population will be living in cities of less than a million people.**

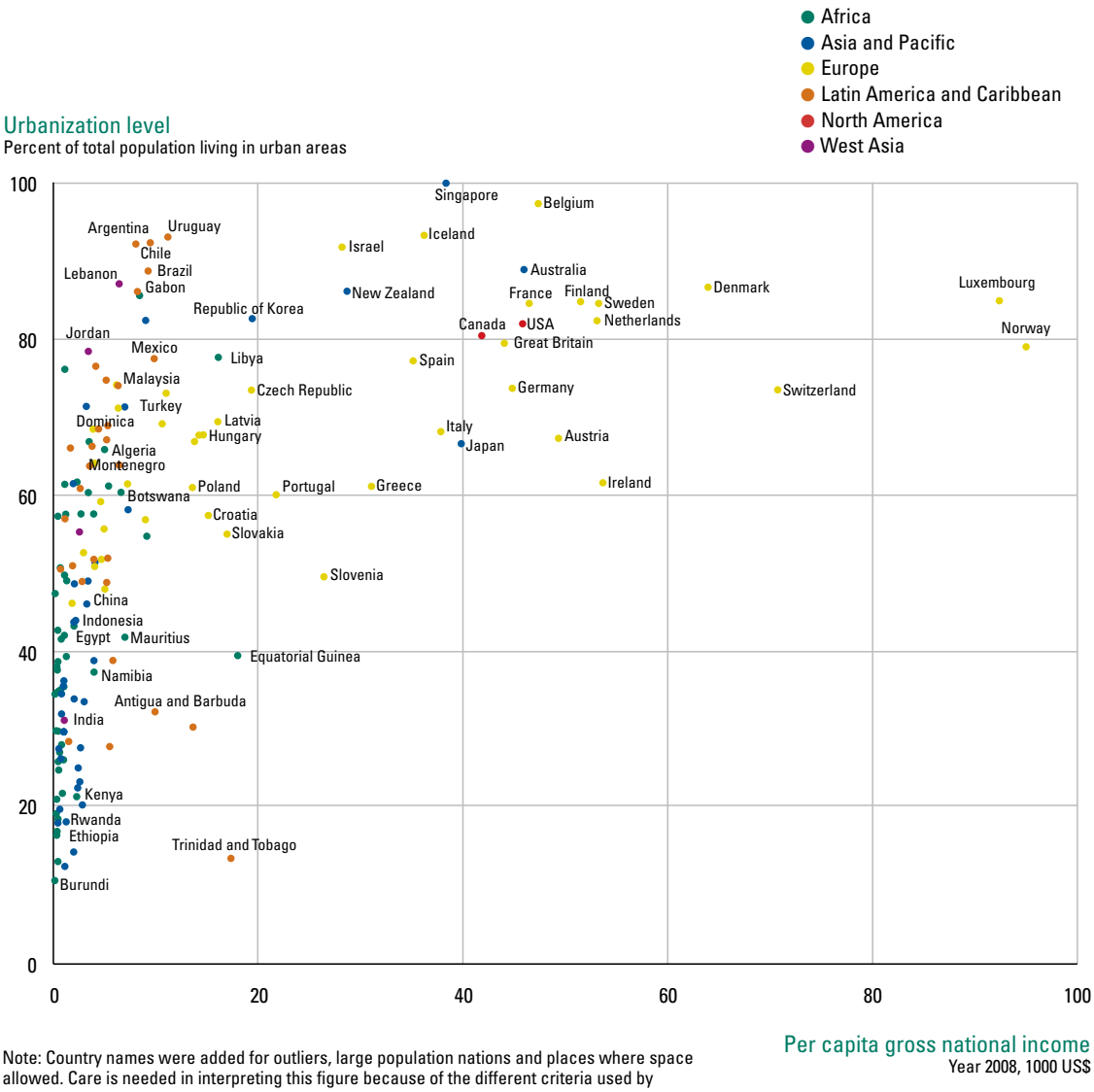
The global networks of primary and secondary cities have become the locales of massive population concentrations due to factors such as globalization, resource efficiency, improved infrastructure, economic opportunities, and the information

2 International Energy Agency (IEA) (2008): World Energy Outlook 2008

and communication technology (ICT) revolution. The global economy is now organized into intensely concentrated clusters of economic activities that are dispersed across a networked set of cities across the globe, each of which has a place in the new international division of labour created by globalization. Computerization made it possible to set up the coordination and logistical systems for these globally networked activities, attracting millions for jobs, education, shelter, protection, cultural assimilation, and access to information. Unsurprisingly, levels of urbanization correlate with rising levels of GDP per capita (Figure 3.6). Inequality, however, is pervasive – 1 in 3 urban dwellers in the world today live in slums (United Nations Centre for Human Settlements, 2003).

The 'second urbanization wave' in the developing world plus the rise since the 1980s within developed country cities of the property development industry as a key driver of growth (as cheap credit was used to fuel consumption of imported goods securitized against property), helps explain why the extraction of industrial and

Figure 3.6. The relation between urbanization level (%) and Gross National Income (GNI)



Note: Country names were added for outliers, large population nations and places where space allowed. Care is needed in interpreting this figure because of the different criteria used by governments to define urban areas.
Source: Adapted from Satterthwaite, 2007, with 2008 (GNI) and 2009 (Urbanisation) data

construction minerals increased by 40% (Behrens *et al.,* 2007). The construction industry worldwide is a US$4.2+ trillion global industry, is responsible for 10% of global GDP, employs over 100 million people, and consumes around 50% of resources, 45% of global energy (5% during construction), 40% of water and 70% of all timber products (Van Wyk, 2007).

Just as countries have metabolic rates, so do cities. Cities usually have a lower metabolic rate than the countryside, as they rely upon peripheral areas for highly energy- and materially-intensive services such as raw material extraction. As a general rule, as the GDP per capita increases, the metabolic rate of the city increases. At the same time, cities concentrate large numbers of people into small places, and they also concentrate the knowledge, financial, social and institutional resources required for sustainability-oriented innovations. This captures the dilemma of cities for sustainability: they drive the global unsustainable use of resources, but they are also where the greatest potential exists for sustainability-oriented innovations.

Judging from a review of the literature, daily reports from cities around the world and the proliferation of websites about sustainable cities and neighbourhoods, urban infrastructure could become one of the primary focuses of sustainability-oriented innovations around the world, in particular where energy use, mobility and the water cycle (sources, uses and reuses) are concerned. A new academic literature is emerging that addresses urban infrastructure from a sustainability perspective by examining the metabolic flows that are conditioned by the wide range of extremely complex 'socio-technical' and 'socio-ecological' networks that mediate these flows (Guy *et al.,* 2001; Graham & Marvin, 2001; Heynen *et al.,* 2006; Pieterse, 2008). Low carbon and even zero-carbon sustainable cities are being planned, for example the Zero Emission City planned in Boughzoul, Algeria or in Dongtan on Chongming Island off Shanghai, Masdar in Abu Dhabi, Songdo in South Korea and Treasure Island in San Francisco Bay. While these are capital-intensive, they may be pioneers for future decoupling.

It has been estimated that the urban infrastructure of the world's cities over the next 20 years will require US$41 trillion for investments in urban infrastructure, including US$22.6 trillion on water and sanitation, US$9 trillion on energy, US$7.8 trillion on road and rail services, and US$1.6 trillion on air/sea ports. This represents an opportunity for sustainability as "...cities that ignore environmental impact will themselves face another collapse of infrastructure 30 or 40 years from now ..." (Doshi *et al.*, 2007).

Worldwide networks of cities focus attention on the need for local authorities to find ways of reducing their metabolic rates. Prominent examples of international local government associations include ICLEI – Local Governments for Sustainability and United Cities and Local Governments (UCLG) with member cities from across the globe. In addition, the C40 Cities Climate Leadership Group, which lists 45 major cities as affiliates, including 22 from developing countries, builds local government coalitions to fight climate change. Building on the privatized urban infrastructures that have been built up over the past 25 years, the global league of Large Cities envisages investments in new forms of urbanism that will differ radically from the past, including sustainable transportation, reduced dependence on fossil fuels, increased dependence on locally grown food and localized supply of (recycled) water, compact urban form and much higher densities, integrated living and working neighbourhoods, zero waste systems, cleaner production, and responsible ecologically sustainable consumption.
In conclusion, innovations for more sustainable use of resources are already

underway in the world's cities. It may be time to transform the concept of decoupling into an operational tool that will help cities to determine their metabolic rates and the potential of different interventions to reduce these rates over time.

3.4 Experiences and lessons from the country case studies

This section draws lessons from the case studies contained in Chapters 6 to 9 of this report. These case studies of China, Germany, Japan and South Africa were written by Panel members (or by a team commissioned by a Panel member) during the course of 2008. Political conditions have since moved on in each country but the overall policy trend toward decoupling has not shifted fundamentally. The selection of cases was based on their approaches to decoupling and was not intended to be representative of the diverse global contexts, lacking, for example, a study of a large low-density developed economy (e.g. USA or Australia) or of a large low-density developing economy such as Brazil. Nevertheless, the four case studies demonstrate at country level emerging responses to resource depletion and environmental impacts. This suggests that more detailed and thorough country case studies that are representative of the different global contexts could be a useful topic for future research.

The case studies reveal that governments in these countries are responding to the threat of rising prices of resources that are at least partly caused by resource depletion. Although none of the countries have fully-fledged integrated policy frameworks for achieving comprehensive resource and impact decoupling, significant empirical trends and the key elements for comprehensive policies that could result in more sustainable use of resources are in many ways already in place across these very diverse contexts. Three themes were used to structure the case studies:

- whether rising prices of resources have been recognized either directly or indirectly;
- how policy responses to both resource depletion and negative environmental impacts have evolved over time; and
- what evidence indicates concerns for resource and impact decoupling, both empirically and at the level of policy intent.

Germany and Japan are advanced high-density industrial economies that are dependent on external sources of materials and markets for their products. China is a large rapidly-industrializing high-density developing economy that is both a massive resource importer and goods exporter as it has evolved into the world's manufacturer. South Africa is a small fairly low-density industrializing developing economy that is heavily dependent on exports of primary resources.

The case studies indicate that the **rising economic and environmental costs of resource depletion and negative environmental impacts have affected the economic growth and development trajectories of these countries.** Significantly, all four countries have responded by adopting policies (of varying degrees of efficacy) that commit the respective governments and industry players to some form of resource use reduction and impact decoupling. The language of resource efficiency, resource productivity, dematerialization, and material flows has clearly entered mainstream policy language in these countries, and most likely many others, in ways that reflect a very diverse understanding of what decoupling means in practice. These ideas are evolving in nationally-specific ways that make cross-country comparisons difficult.

3.4.1 Recognizing resource depletion and negative impacts

All four countries have been responding to the particular manifestations of resource depletion – in the case of Japan and Germany, the 1970s oil shocks were clearly important triggers of policy and scientific trends that culminated in more mature perspectives by the late 1990s. Although policy responses in these initial decades were to negative environmental impacts, the brief concern after 1973 with oil prices and security of supply did trigger responses that were concerned with resource inputs into the economy. Only after the 2002 World Summit on Sustainable Development in Johannesburg did China and South Africa start taking resource depletion more seriously (at least at the policy level).

In the case of **Germany**, policy changes that can be traced back to the late 1970s culminated in the adoption of the National Strategy for Sustainable Development (NSSD) in 2002. Its aim was to promote the doubling of 'resource productivity' by 2010. Although policies in the 1970s and 1980s focused on the environmental impacts of industrial growth, in particular on air, water and soil, by the late 1990s the focus was on resource productivity. Germany has clearly understood that resource productivity makes economic sense, and it provides the strategic framework for investments in technological innovation and capacity that could reposition Germany within a global economy facing resource depletion. For example, *DESERTEC,* a project driven by a group of German technology companies, is a massive solar power plant planned for the Sahara Desert to supply Europe with green energy.

South Africa's Constitution carries the injunction that the state must ensure "... ecologically sustainable *development and use* of natural resources while promoting justifiable economic and social

© sinopictures/viewchina/Still Pictures

development" (Section 24 (b)). This provided the basis for decisions in 2008 by the government to adopt two key policy documents: the National Framework for Sustainable Development which calls specifically for 'resource and impact decoupling'; and the Long-Term Mitigation Scenario (LTMS) which envisages GHG emissions cuts of 30–40% by 2050. These can be seen as a direct response to a long history of highly unsustainable resource use. But reversing this dependence on the so-called 'mineral-energy complex' will not be easy. Since the birth of democracy in 1994, South Africa has been a resource-rich resource-exporting developing country economy that is heavily dependent on its vast supply of cheap coal; earns the bulk of its external revenues from primary resource exports (often at prices below the real cost of natural capital); suffered the decline of manufacturing as it liberalized its capital markets and reduced tariff barriers; pursued growth by stimulating consumer demand (for an increasing number of imported products) with easy credit; and then suffered the consequences when commodity prices collapsed when the financial crisis hit in 2007/2008. However, the domestic economy became marginally more resource productive over the past two decades, showing some resource decoupling. Only since 2007 has the government begun to realize that due to abundant cheap coal, the carbon intensity (CO_2 emissions per unit of GDP) of South Africa's economy is the highest in the world (0.99) and its emissions per capita are 9.8 tons, double the world average and similar to developed high density countries like the UK and Germany.

In 2003 **China** adopted a *Scientific Outlook of Development* as its primary philosophy and guiding principle of development and in 2007 committed itself to the building of an 'ecological civilization'. This over-arching political vision informed the detailed commitments to mandatory targets such as energy conservation, pollution abatement and the 'circular economy' in the 11th Five Year Plan. This was in direct response to China's increasing concerns about the consequences of rapid industrialization and urbanization in a country with a weak natural resource base and increasingly polluted and degraded ecosystems. Calculated in contemporary prices and current exchange rates,[3] over the 30 years from 1978 to 2008, China's GDP expanded by an annual average of 9.8% to US$4.4 trillion. This growth has been non-linear and features an accelerated rate of growth in later years accompanied by massive emissions of pollutants. According to some calculations (which China questions), China is now the world's largest CO_2 emitter (although still one of the lowest when measured in terms of CO_2 per capita). It may also top the world in SO_2 emissions and chemical oxygen demand (COD) discharge. COD discharge in China has exceeded the environmental bearing capacity by 80% and the picture of SO_2 emission is similarly grave. On the resource input side, what Chinese researchers refer to as the 'resource intensity[4] per unit of GDP' is about 90% higher than the world average, while energy efficiency is 10% below that of the developed world. The Chinese government acknowledges that the environmental costs of economic growth have been excessive.

China has become a net exporter of energy (energy expended in producing a processed commodity). The China Council for International Cooperation on Environment and Development (CCICED) estimated that, from 2002 to 2006, China's net export of embodied energy jumped from 240 million tons (240 Mt) of standard coal equivalent (TCE) to 630 million tons (630 Mt), and the proportion of exported embodied energy in China's overall primary energy consumption increased from 16% to 26%.

3 US$1 against RMB 6.8337 in February 2009.
4 Including freshwater, primary energy, steel, cement and common non-ferrous metals.

Japan has explicitly recognized the need for system changes that respond to rising costs that are derived directly and indirectly from resource depletion. In response to the 1998 annual *Quality of the Environment* report, which was the clearest statement of the resource risks Japan faced by then, Japan adopted its *Sound Material Cycle Society* policy framework. The Japanese economy is highly dependent on imports of natural resources, such as energy, food and other raw materials. This geopolitical fact means that its use of primary materials is to a large extent separated from the environmental impacts at the point of their extraction. Yet Japan is facing serious problems associated with its increasing volume of solid wastes, such as shortage of disposal sites, risk of environmental pollution by waste treatment facilities, illegal dumping, and rising costs of waste. In addition to the challenge of waste disposal, the 1973 and 1979 oil shocks triggered changes that resulted in significant levels of decoupling between energy consumption and economic production by manufacturing industries during the late 1970s to early 1980s. While oil dependency of national primary energy supply has decreased gradually to less than 50%, it is still higher than other developed economies.

In short, the governments of all four countries have experienced the long-term consequences of resource depletion and negative environmental impacts, and responded by adopting policies that include decoupling.

3.4.2 Policy responses

In crude terms, policy making with respect to resource use and environmental impacts over the past four decades has gradually shifted from a 'command-and-control' focus on negative environmental impacts (especially pollution) to responses to resource depletion challenges that use economic instruments. This has taken place against a background of rapid global growth as economic globalization facilitated the relocation of key manufacturing sectors from developed to developing countries. The resultant increase in material flows from 40 to 55 billion tons (40–55 Gt) per year over the two decades starting in 1980 explains in part why resource depletion issues have become a concern of policymakers at national government level.

The **German** NSSD comprises strategic, mostly quantitative, trend objectives and a set of 21 indicators grouped under different headings. Indicator 1 ('resource conservation') is the most important one for the purposes of this Report, as it includes sub-indicators 1a 'energy productivity' and 1b 'resource productivity'. The NSSD goal is to double both energy productivity (base year 1990) and resource productivity (base year 1994) by 2020. These goals were affirmed by the government after 2005 and can now be considered as the cornerstone of the government's position on resource use. With the Integrated Energy and Climate Programme (IECP, 2007/2008) the German government reinforced the NSSD by adopting two dozen policies and measures whose collective aim by 2020 is to raise the share of renewables as a percentage of total supply of electricity to 30%, for heat to 14%, the share of Combined Heat Power (CHP) for electricity to 25% and to save energy in all sectors via substantial energy efficiency interventions. With the help of the IECP and additional measures it is expected to reach at least a 30% CO_2-reduction by 2020.

South Africa's key macro-economic policy frameworks (Accelerated and Shared Growth Initiative for South Africa and National Industrial Policy Framework) do not recognize resource constraints as an economic factor, although the South African scientific community has reached almost complete consensus that resource depletion is an urgent priority when it comes to water and soil, while relative decoupling is needed with respect to

energy and a wide range of environmental impacts. The views of the scientific community were reflected in the 2008 National Framework for Sustainable Development (NFSD), the first official policy since democracy was introduced that argued for 'dematerialization' and the 'decoupling' of rates of resource use from economic growth rates. The NFSD proposed five strategies: enhancing systems for integrated planning and implementation; sustaining ecosystems and using resources sustainably; investing in sustainable economic development and infrastructure; creating sustainable human settlements; and responding appropriately to emerging human development, economic and environmental challenges. During the course of 2010, the NFSD was transformed into a more comprehensive National Strategy for Sustainable Development.

Support for this strategic perspective has come primarily from the National Treasury and the Minister of Finance who has recognized that South Africa must keep up with global trends. In April 2006 the National Treasury circulated for comment its *Framework for Considering Market-Based Instruments to Support Environmental Fiscal Reform in South Africa*. As the title implies, this report recommends using economic rather than command-and-control instruments, including a gradualist approach of small steadily-rising taxes on a wide range of what it called 'environmental bads'. However, it is probably fair to say that compared to the other three countries studied, South Africa has the least developed policy and regulatory framework for linking economic policy to resource reduction and mitigation of negative environmental impacts.

Since the adoption of its Scientific Outlook of Development in 2003, the **Chinese** government has fundamentally altered its development philosophy, resulting in the move towards building an 'ecological civilization'. This approach made resource and environmental concerns top policy priorities. The 11th Five-Year Plan for Economic and Social Development (2006–2010) marked a key turning point for the process of reconciling rapid industrialization with the ambition to build an ecological civilization. The plan sets 22 quantitative indicators of which eight are mandatory targets, five of them related to environment and resources. The most challenging targets are a 20% reduction of GDP energy intensity and a 10% drop of SO_2 emission and COD discharge by 2010 (from 2005 levels). To ensure achievement of these targets, the State Council of China established the Leading Group on Energy Conservation and Pollution Reduction as well as Climate Change, headed by Premier Wen Jiabao, and issued the Action Plan for Energy Conservation and Pollution Reduction. An intensive programme was launched across the country, and significant progress has been made.

Since 2006, China has run nationwide mandatory energy saving and pollution reduction programmes to address what Chinese researchers refer to as 'low resource efficiency' and 'high pollution levels'. The so-called 'circular economy' strategies were implemented to address the linear process from primary resources to products and further to post-consumption wastes. In addition to the key 'circular economy' policies such as the Law on Circular Economy Promotion, other measures included the Law on Cleaner Production Promotion, management and taxation policies for comprehensive utilization of wastes and used resources; Assessment Standards to evaluate eco-industrial parks and set out codes for their establishment; green procurement by governmental agencies and public institutions; and investment policies for piloting the circular economy, including a special fund to support pilot projects.

In responding to climate change, the National Action Plan on Climate Change

was introduced in 2007 and a target of reducing 40–45% in CO_2 emission per unit of GDP by 2020 against 2005 levels was set by the Chinese Government in 2009. In the process of coping with the global financial crisis, initiatives to implement the green economy and low carbon economy approaches have been emerging nationwide.

China is, in many ways, the test case for the global economy. Because of China's dominant economic position, and because it wants to continue its rapid economic growth but use resources more sustainably, the measures that China introduces to reconcile these objectives will be of crucial significance for every other developing country with similar policy intentions.

In 2007 the **Japanese** government adopted a policy that committed Japan to becoming a 'Sustainable Society'.[5] It proposes to build a Sustainable Society through comprehensive measures integrating the three aspects of such a society, specifically, a Low Carbon Society, a Sound Material-Cycle Society and a Society in Harmony with Nature. This decision both consolidates a long period of sectoral policy development, and sets the stage for integrated planning in the future. The foundations were laid when the Basic Environment Law was adopted in 1993 followed by adoption of the Basic Environment Plan in December 1994. The Sound Material Cycle Society (SMC) concept is central to the Japanese approach and is firmly rooted in 3R principles.[6] As a result, material flow accounts (MFA) have become an integral feature of Japanese environmental policy, identifying the whole system of material flows in the national economy and providing itemized overviews for such flows.

A Fundamental Law for Establishing a Sound Material Cycle Society has been in place since 2000. The 1st Fundamental Plan for Establishing a Sound Material Cycle Society was adopted by the cabinet in 2003, and a revised 2nd Plan was adopted in 2008. These legal instruments provide the fundamental framework to integrate environmentally sound management of wastes and efficient use of natural resources into Japan's mainstream economic processes.

Much can be learned from what Japan has achieved because these instruments are probably the most advanced examples of measures aimed at increasing resource productivity and minimizing negative environmental impacts in practice.

As can be seen from this review, decoupling economic growth from negative environmental impacts and promoting resource productivity have found a place in the policy agenda of all four countries. They have adopted policies that call for the integration of economic and sustainable development policies. Although much more difficult to achieve in practice, the fact that consensus has been reached on what is needed is of great significance. All four are members of the G-20, thus suggesting that the G-20 statement below was more than just another global statement of good intent, but was rooted in the evolution of policy thinking at national government level:

> *"We will make the transition towards clean, innovative, resource efficient, low carbon technologies and infrastructure."*
> *Statement of the G-20, London, 2 April 2009*

To ensure the diffusion of learning, it will be essential to monitor these policy frameworks, how they are implemented, and their outcomes and impacts.

3.4.3 Decoupling

Although decoupling as defined in this Report is a long-term process of macro-structural transformation to build

5 See www.env.go.jp/en/focus/070606.html
6 Reduce, reuse and recyle.

© Yadid Levy/Robert Harding World Imagery/Corbis

sustainable socioecological systems, the trends at country level that emerge from the case studies confirm that relative decoupling with respect to resource use is already underway in developed economies. **Resource use reductions will be much more difficult but are, ultimately, what really is needed most.** However, the key factor that will determine whether this happens will be the degree of investment in innovations for more sustainable use of resources. A key driver here will be whether prices of critical resources rise in response to resource depletion.

Empirical evidence from the **German** context suggests that between 1994 and 2007 a seemingly impressive level of resource decoupling[7] occurred in Germany. While resource productivity (raw material) rose by 35.4% and GDP by 22.3%, raw material input decreased by 9.7%. However, these figures do not include biotic resource flows (that may increasingly replace abiotic resources such as fossil fuels), domestic *unused* primary material extraction, and the various environmental impacts embodied in imported materials and goods. If these are factored in, Germany's achievements might be somewhat less impressive.

A macroeconomic analysis for German industry demonstrates that even if only half of the existing 'resource efficiency' targets were realized, there would still be an increase in gross national product, creation of new business areas and growth in employment levels. These macroeconomic effects seem to justify a long-term modernization and innovation policy for increasing resource productivity as a way to boost growth and employment.

The Wuppertal Institute has also proposed an Innovation Programme for Resource Efficiency to form part of a comprehensive German effort to mitigate the economic crisis.[8] By scaling up existing experiences

7 This includes all used abiotic raw material extracted in Germany as well as imported abiotic materials.

8 See Hennicke & Kristof, 2008.

(see detailed case study in Chapter 6) with a total amount of €10 billion from the federal budget for the small and medium enterprise (SME) sector, its aim would be to foster 'ecological modernization' by creating new employment and business fields for GreenTech. It would be operated by a lean federal Resource Agency together with a network of regional and local partners. Support for SMEs would comprise a mixture of impulse and in-depth audits combined with investment subsidies.

To understand decoupling trends, a **Decoupling Index (DI)** is used in the **China** case study. Primary energy consumption appears to have become more efficient since 1992, providing evidence of relative resource decoupling. In most of the past 10 years, China achieved decoupling between rates of increase in freshwater consumption and economic growth rates; during 1998–2007, total freshwater consumption varied within a small range between 290.1 and 306.2 billion m^3 while GNP nearly doubled. But in terms of mineral consumption China still faces huge challenges. For instance, the country's steel consumption jumped nearly tenfold from 53 million tons (53 Mt) in 1990 to 520 million tons (520 Mt) in 2007, and steel consumption per unit of GDP increased at a rate higher than GDP growth.

On the environmental impact side, the emission/discharge of many pollutants began to decouple from economic growth in the early 1990s. Since 1992, industrial wastewater discharge and solid waste discharge have decoupled in many years, with the DI of solid waste falling below –1 several times. Progress in this area owes much to the improved recycling rate and proper disposal of industrial solid waste.

Following adoption of its 11th Five-Year Plan, the Chinese government has pursued a three-pronged strategy to raise energy efficiency and reduce pollution: industrial restructuring to reduce dependence on resource-intensive polluting industries; energy conservation programmes and construction of pollution treatment facilities; and strengthened environmental management. By the end of 2009, the GDP energy intensity had reduced by 15.6%, and SO_2 emissions and COD discharge dropped by 13.14% and 9.66% respectively against 2005 levels, suggesting that China may be able to achieve its mandatory targets for energy conservation and pollution abatement that were set in the 11th Five-Year Period by 2010/2011. However, whether these measures and achievements sufficiently succeed in countering the impact of rapid industrialization and urbanization remains to be seen.

Japan's fundamental plan for a Sustainable Material Cycle Society (SMC) sets a national target of resource productivity and binds the government itself to achieve it, but the plan does not set binding targets for industries. Nevertheless, voluntary efforts have been made to incorporate the 'Factor X' concept into businesses. For example, as many as eight Japanese leading electronics companies (Fujitsu, Hitachi, Panasonic, Mitsubishi, NEC, Sanyo, Sharp and Toshiba) are collaborating to develop the guidance system for the Common Factor X approach.

In many countries, the energy efficiency of electrical appliances is enhanced by Minimum Efficiency Performance Standards (MEPS). Japan followed a different strategy. Instead of setting a minimum efficiency standard, its Top Runner Programme searches for the most efficient model on the market and then stipulates that the efficiency of this *top runner model* should become the standard within a certain number of years. The Top Runner Programme applies to machinery and equipment in the residential, commercial, and transportation sectors, setting targets by product category.

The Fundamental Plan for Establishing SMC Society adopted a resource

productivity indicator that is simple and easily understood, i.e. GDP divided by DMI (total weight of direct inputs of resources). Since the adoption of the 1st Fundamental Plan in 2003, performance has been reviewed annually by the Central Environmental Council of Japan.

As far as **South Africa** is concerned, some evidence suggests that the domestic economy is becoming more resource efficient. The growth rate of domestic extraction used within the domestic economy has decoupled from the economic growth rate, but this ignores the increased dependence on exported primary products. Policies call for dematerialization and decoupling with respect to resource intensity, and for emissions cuts with respect to negative environmental impacts. Various sectoral responses to biodiversity degradation, depletion of fisheries, pollution of water resources, air pollution and excessive solid waste disposal are evident. However, South Africa has no integrated material flow analysis, nor a set of indicators for measuring future progress. To this extent South Africa lags far behind the other three countries. Over the past two years the focus of discussion has been on energy and water decoupling. South Africa's bulk energy demand has caught up with supply, and the traditional solution of building more coal-fired power stations contradicts the Long-Term Mitigation Scenario (which is South Africa's strategy for building a low-carbon economy). This has forced policymakers to focus on energy efficiency and renewable energy solutions. The same applies to water: South Africa is a water-scarce country and the scientific community and policymakers agree that no more water is available to be allocated for future development, leaving water efficiency and reuse as the only solution. One potential new water source is desalination of seawater, but this is sustainable only if it can be powered by renewable energy. Like many other developing countries, South Africa needs to introduce a capacity for material flow analysis linked to a set of indicators for evaluating future progress.

4 Decoupling, trade and development dynamics

4.1 Trade and the distribution of resources and environmental burdens

Global trade of the resources being assessed here is a complicated process, with different influences at the various stages of the life cycle (described in Chapter 1, section 1.1.), from initial extraction of a resource to the ultimate disposal of the commodity produced from the resource (though many products contain large numbers of material resources, each of which may have come from a different part of the globe). Different actors, often from distant countries, may play a key role at the various stages, making it challenging to determine where responsibility for decoupling should be assigned. Further complicating the challenge, different policies may be required at different stages of the life cycle. Ideally, every stage of the life cycle should be accompanied by appropriate policies promoting decoupling, though this ideal remains far in the future. This section will assess some of the current challenges.

Globally, the geographic distribution of resource extraction does not necessarily correspond to the geographic distribution of manufacturing processes and consumption, and to the environmental impacts coupled to these parts of the life cycle. The largest material flows occur at the point of extraction, and there they add most to the indicator of resource use. Once the raw materials have been extracted and become subject to trading, they have already left some of their original volume behind as wastes and emissions. Generally speaking, in the chain from extraction to manufacture to sale for consumption, each commodity gains economic value as it has embodied ever more labour and intellectual capital over the value chain, but at the same time loses physical weight as it travels. This creates a major problem for objective international comparisons of resource productivity and decoupling, because the benefits of international trade shift burdens in ways that often are difficult to unravel. The decoupling elements of 'greening of global trade' warrant further investigation.[1]

4.1.1 The dynamics of global trade in economic (monetary) and physical terms

Over the past few decades, international trade has increased dramatically. Between 1970 and 2006, worldwide trade volumes in monetary units (real terms) grew by an average of 7.2% each year. Compared with 1970, in 2006 the value of trade was almost a factor of 10 higher for manufactured products, 2.3 times higher for fuels and mining products, and more than 3 times higher for agricultural products (WTO, 2008).

Growing trade in monetary terms reflects an increase in physical trade flows, albeit somewhat dampened. In 1970, around 5.4 billion tons (5.4 Gt) were internationally traded, increasing to 19 billion tons (19 Gt) in 2005. A relative decoupling between

1 The IRP is planning to produce a report on the impacts of trade on resource use and environmental impacts.

monetary and physical trade flows has occurred: trade in manufactured products with a higher price per ton has grown faster than trade in primary materials. In 2005, manufactured products made up only 24% of physical trade, but contributed 74% to the economic value (Dittrich, 2009).

At the global level, physical trade is dominated by fossil fuels, which accounted for almost 49% of all exports in 2005. Biomass ranked second with over 20%, followed by metals (18%), minerals (10%) and other products (3%) (Dittrich, 2010).

Intensifying global trade also implies growing environmental pressures associated with trade activities. On the one hand, these include direct pressures, in particular due to the impacts of transportation. According to the IPCC's 4th Assessment Report, by 2004 the transport sector contributed 13.1% to the total CO_2-eq emissions. On the other hand, the indirect (or embodied) environmental pressures are augmented with growing trade volumes. According to recent model calculations, CO_2 emissions embodied in internationally traded products accounted for 27% of the total energy-related CO_2 emissions in 2005, up from 22% in 1995 (Bruckner *et al.*, 2010). Other studies have calculated the volume of CO_2 emissions embodied in global trade at 22% for the year 2001 (Peters and Hertwich, 2008a). For the issue of water consumption, measured by the 'water footprint' indicator (a measure of the direct and indirect use of water to produce a good), total water embodied in global trade was around 16% of the global water footprint in the 1997 to 2001 period (Hoekstra and Chapagain, 2007). First estimations of material extraction embodied in global trade are about 20% of total world-wide material extraction in the year 2000 (Giljum *et al.*, 2008).

Environmental pressures directly and indirectly linked to international trade thus make up a significant share of total environmental pressures. Therefore, different results are obtained when resource use and environmental pressures are accounted for from a production perspective (i.e. allocation to the country where the pressure occurs) versus from a consumption perspective (i.e. allocation to the country where the product is finally consumed). In established international accounting systems (such as the GHG accounts in the UNFCCC framework), production-based systems are far more common, particularly as they allow for the setting of clear system boundaries. However, in order to properly take trade-related effects into account, complementary consumption-based accounting systems are required at the global level (see for example Peters, 2008). Such a double system of accounts could serve as the empirical basis for developing options for sharing environmental responsibility between producing and consuming countries (Lenzen *et al.*, 2007).

4.1.2 The economic structure of global trade

From an economic perspective, the global trading system has four major players. The EU-27 (excluding intra-EU trade) is the largest exporting region with a 15.9% share of global exports and an 18.3% share of global imports in 2008. China ranked second as exporter (11.8%) and third as importer (9.1%), followed by the US, which held a 10.6% share of global exports and a 17.4% share of global imports, and by Japan at 6.5% and 6.1%, respectively. Half of the volume of world trade is shared between these four players (44.8% of world exports and 50.9% of world imports, WTO, 2009).

On the other end of the spectrum, a large number of – mostly developing – countries play a negligible role in global trade. Some 49 of the least developed countries, mostly in Sub-Saharan Africa and Central Asia, together account for only 1.1% of global trade (WTO, 2009). While some developing and emerging countries (most notably China, but also Brazil, Mexico, Malaysia, and India) have achieved successful

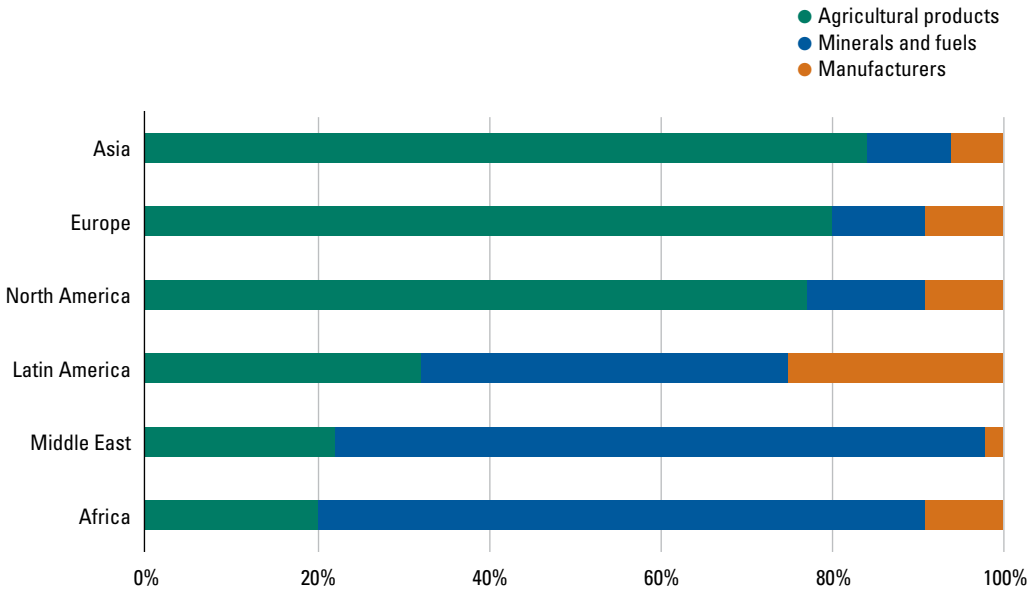
integration into the global trade system, globalization has not benefitted all countries and individuals.

The degree of economic integration into the world market is one issue, the role played in the international division of labour is another issue. A main distinction that matters needs to be drawn between mainly trading in raw materials and trading in manufactured products.

Industrialized countries largely export manufactured products. This segment of world trade is characterized by high value added, is associated with employment and has various positive spin-off effects. Many developing regions, on the other hand, continue to rely strongly on the export of primary materials. Latin America earns almost 70% of export revenues from agricultural and mineral raw materials, more than three quarters of total exports of the Middle East are fossil fuels, and Africa has the highest share in primary products (80% of exports, consisting of agricultural products, minerals and fossil fuels, see Figure 4.1).

However, this general pattern has some important deviations, as some industrial countries, typically those with a very low population density, also play a major role as exporters of primary products. Australia, for example, has significantly expanded its primary sectors (in particular, coal and iron ore) in the past few years in order to serve growing demand in Asian countries, notably China. Some 70% of Australia's exports in 2008/08 were primary products (food, fuels, minerals), up from 57% in 2003/04 (Australian Government, 2009). More than 47% of Canada's exports in 2008 were agricultural products, minerals or fuels, and the US, with 21% of its exports comprising primary products, is a major world market supplier of natural resources (WTO, 2009).

Figure 4.1. Composition of exports (in monetary units) by world regions, 2006



Source: WTO, 2008

4.1.3 The physical structure of global trade

The total extraction of material resources is not so unevenly distributed across the world, as becomes apparent from the physical data (see Figure 4.2). Looked at in more detail, biomass extraction is distributed most evenly (in close relation to population numbers), and the extraction of fossil fuels is distributed most unevenly, depending on resource endowment and previous exploitation. International trade redistributes these resources across the globe, allowing some countries to export resources and other countries to be supplied with primary products for manufacture and consumption (both domestic and abroad).

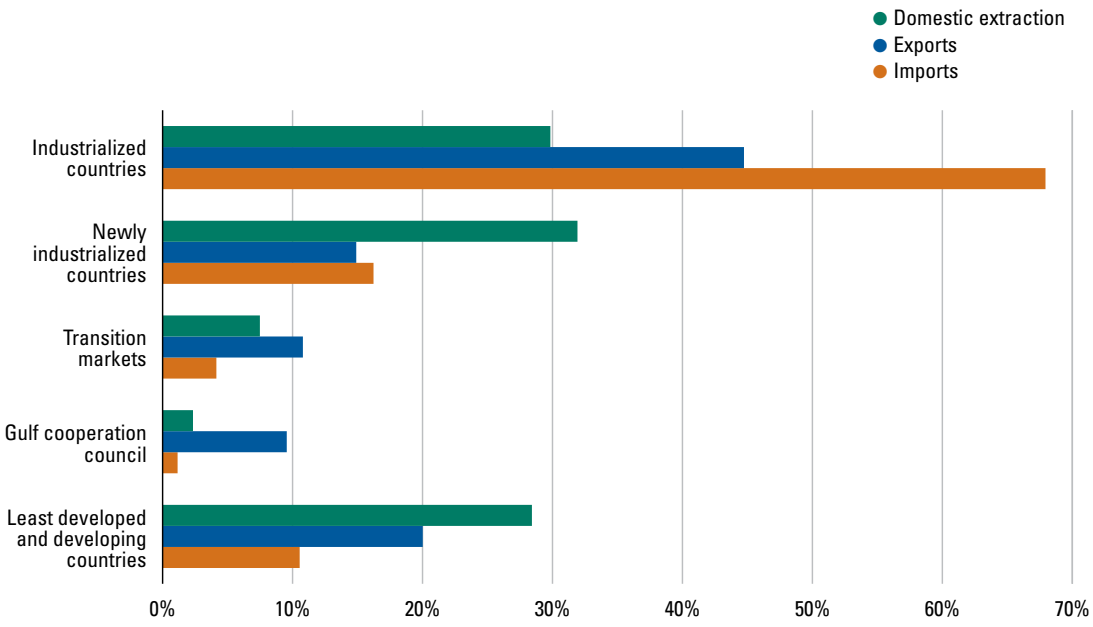
As Figure 4.2 illustrates, industrialized countries have the highest share in trade activities, while their share in materials extraction corresponds roughly to their share in world population. Even if they are also active exporters, they import two thirds of all traded materials.[2] This difference is also reflected when comparing economic (monetary) and physical trade balances (Figure 4.3).

While monetary trade balances tend to be relatively even,[3] physical trade balances have a systematic asymmetry: industrial countries tend to be net material importers, while developing countries have served as net exporters over the whole time period. During the last decade, the group of countries with economies in transition have also turned into net exporters. In 2005, the industrial countries imported around 2 billion tons (2 Gt), of which two thirds originated from developing countries and one third from the former Comecon countries.

2 See Figure 2.1 for global material extraction, amounting to nearly 60 billion tons (60 Gt) in 2005, though the amount traded is considerably less; the precise amount is difficult to determine because an unknown amount of materials extracted are converted into manufactured goods that may also contain some imported materials.

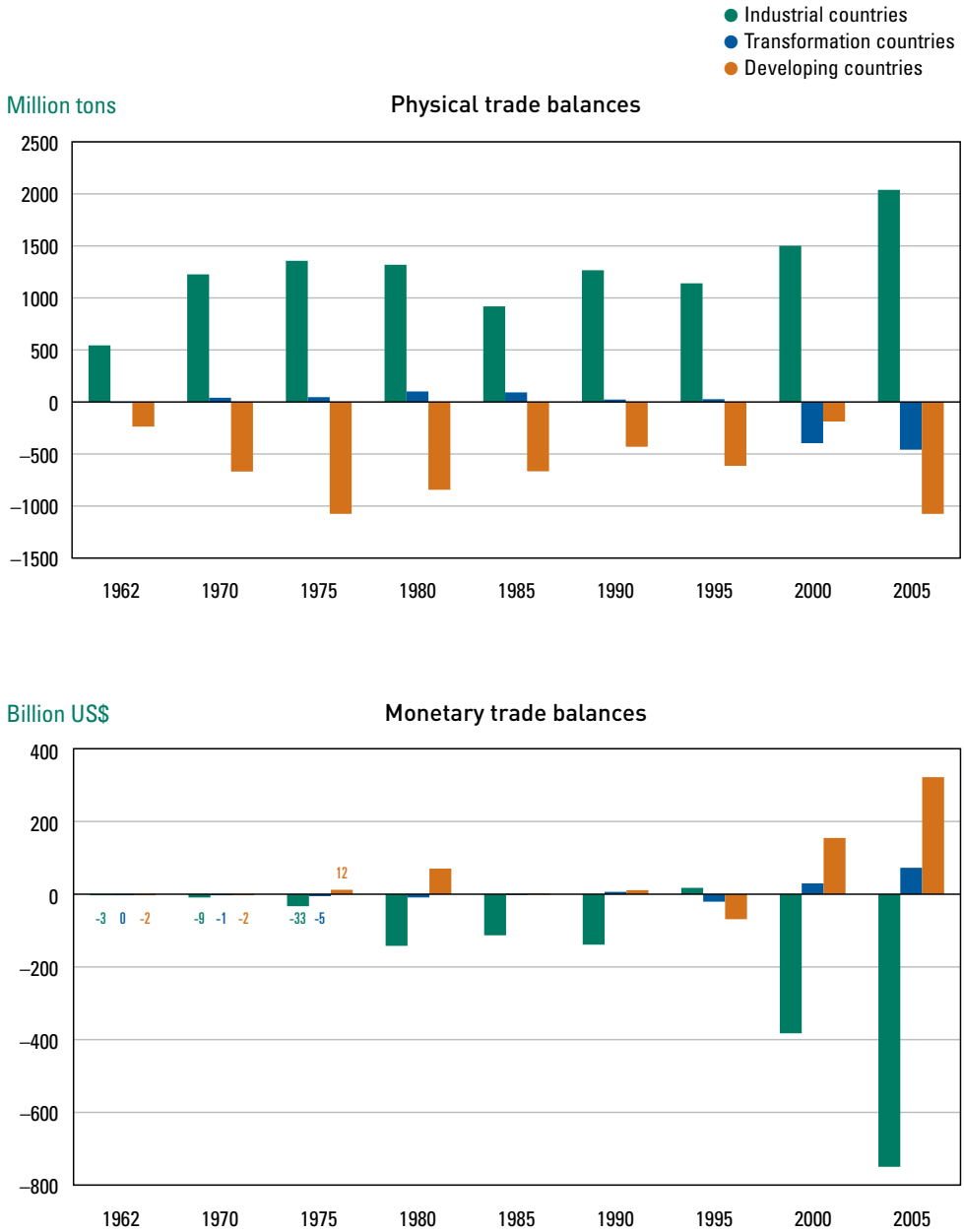
3 Since the late 1990s the trade balance of the industrialized countries has become negative, which is due mainly to the rapidly-growing trade deficit of the US.

Figure 4.2. Raw material extraction and trade by country type



Source: Drawn from SEC database, http://www.uni-klu.ac.at/socec/inhalt/3812.htm, see Steinberger *et al.*, 2010

Figure 4.3. Physical and monetary trade balances of three country types, 1962 to 2005[a]



a Note that net imports and net exports do not balance out, as many developing countries do not fully report their international trade to the UN, which provides the basic data for these calculations (UN Comtrade data base).
Source: Dittrich, 2010

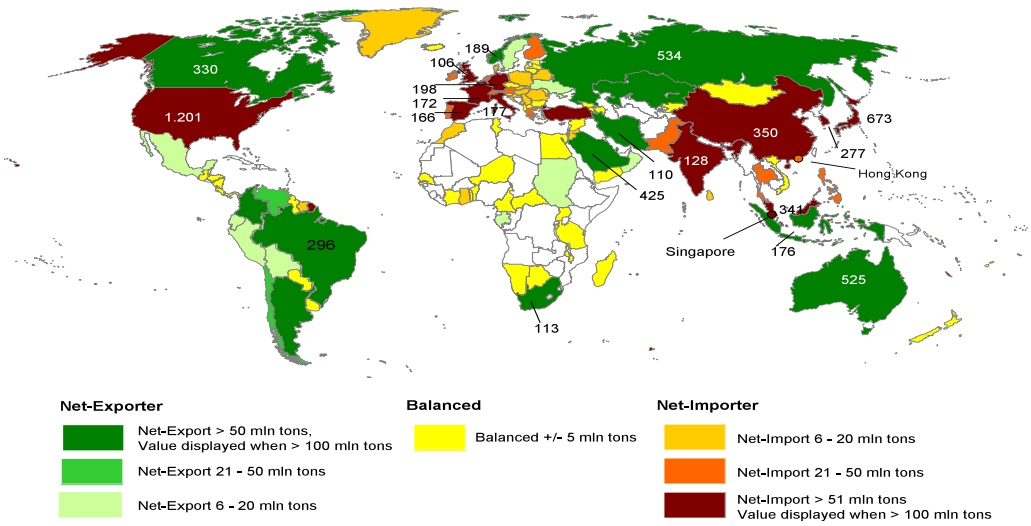
Figure 4.4 provides a detailed world map of net suppliers and net demanders of material resources. The map illustrates – as was to be expected – European countries, the US and Japan to be the most important net importers of resources in the world economy. What is new compared to earlier decades is that several emerging economies, particularly in Asia (such as China, India and South Korea) have now also become net importers, augmenting domestic resource use with resources imported from abroad. Important suppliers of material resources with net exports of more than 50 million tons (50 Gt) in 2005 were Russia, Kazakhstan, Indonesia, Saudi

Arabia, Iran, Brazil, Argentina and Venezuela. **In some countries that specialized in natural resource exports, such as Peru and Chile, domestic material extraction grew faster than GDP, resulting in a rising material intensity of these economies, i.e. a reverse decoupling effect** (see Russi *et al.*, 2008). However, as Figure 4.4 shows, some industrial countries are among the group of net exporting countries, in particular Australia and Canada. As a single country, Australia has accumulated the highest net exports in the past 40 years (Dittrich, 2009).

4.1.4 Indirect resource flows embodied in trade

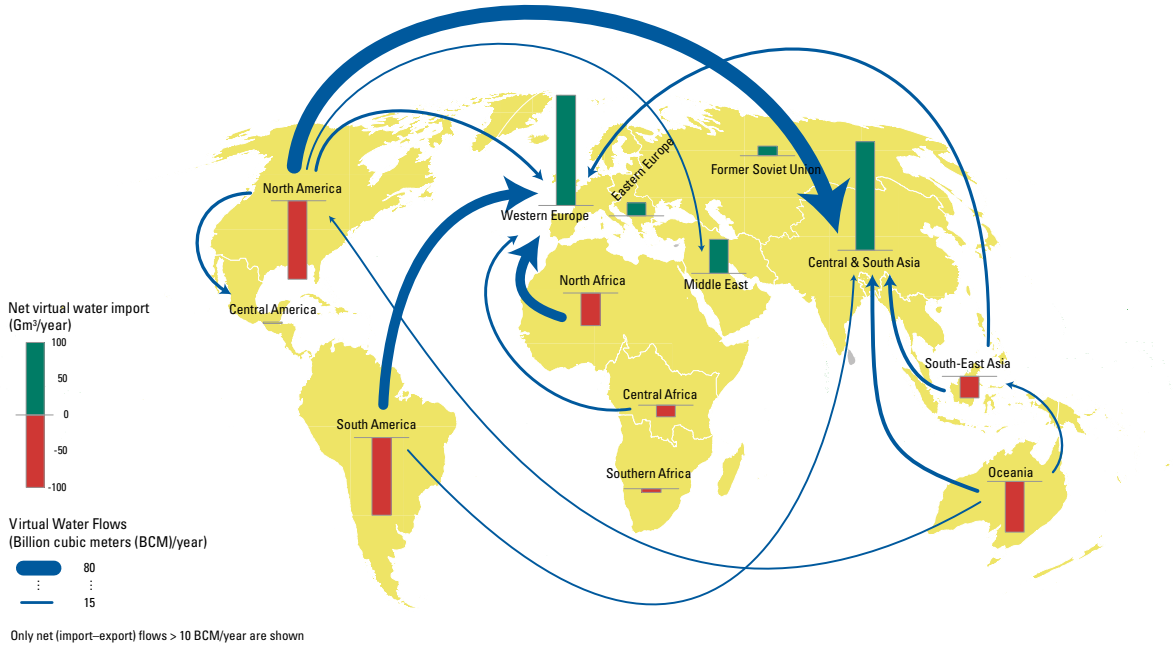
A growing literature deals with resource flows indirectly associated with traded resources or commodities. This is relevant to decoupling both economically (for respective domestic resource depletion) and in terms of environmental impacts. Standard economy-wide material flow indicators, as explained above, register the weight of traded commodities at point of entry into a country. Indicators under development (for example so-called Raw Material Equivalents (RME), as proposed by the European Statistical Office (Eurostat, 2001, p.22), or 'hidden flows' – materials that are extracted or moved but do not enter the economy – as calculated in the framework of the Total Material Requirement indicator seek to capture those indirect flows associated with trade, both for imports and for exports, in terms of weight. For European countries for which such research has been conducted, the results usually show that indirect flows are in the same order of magnitude or somewhat larger than direct flows, and that indirect flows associated with exports do not fully compensate for indirect flows associated with imports. **Thus, in effect, a certain amount of material burden and the associated environmental impacts are being 'externalized' from importing countries to the exporting countries** (Buyny *et al.*, 2009; Schaffartzik *et al.*, 2009; Weinzettel and Kovanda, 2009;

Figure 4.4. Physical trade balances, year 2005[a]



a For countries that are blank, no appropriate data exist.
Source: Dittrich and Bringezu, 2010

Figure 4.5. Virtual water trade balances and flows of agricultural products, 1997–2001



Source: Adapted from Chapagain and Hoekstra, 2008

Weisz, 2006; Schutz *et al.*, 2004). The importing countries become responsible for the last stage in the life cycle – disposal – but can also recycle these wastes or re-export them, often to developing countries.

Including indirect flows is crucial for assessing decoupling trends. Countries may improve their decoupling performance most easily by outsourcing material-intensive extraction and processing to other countries and by importing the concentrated products instead. Comprehensive indicators that include indirect flows are essential for comparing performance of countries in decoupling (Moll *et al.*, 2005). Over the past decades, these indirect flows have increased for net-importing world regions, such as Europe (Bringezu and Bleischwitz, 2009).

Such indirect material flows have also been calculated for resource-exporting countries. The biggest difference between direct trade flows and trade flows including indirect flows can be observed for countries that extract large amounts of crude metal ores with low concentrations, but export highly concentrated ores. In the case of Chile, the world's biggest exporter of copper, the physical trade balance in the year 2003 changes from net exports of 1 million tons (1 Mt) in terms of direct flows to net exports of 634 million tons (634 Mt), if calculated including indirect flows for the same year (Munoz *et al.*, 2009). **Resource-exporting countries thus may have an interest in applying comprehensive consumption-based accounting systems that can identify costs of these indirect flows,** which may increase the price of resources for the importing countries. The effects of such price increases for both exporters and importers remain to be seen, but may lead to at least some decoupling.

Related efforts are being undertaken to identify the amount of water embodied in international trade (also called 'virtual water', the amount of water required to produce a good or service). The concept of

virtual water is applied mainly to the trade in biomass and biomass products, but can apply to manufactured goods as well.

Europe, Japan, China, and India are the biggest net importers of water embodied in trade of agricultural products, followed by the countries of the Middle East (Figure 4.5). Contrary to the trade in materials described above, the US is the biggest net exporter of embodied water, due to its high net exports of agricultural products, notably cereals. Many net exporters of materials (Figure 4.4) are also net exporters of virtual water from agriculture, including Canada and Australia from the OECD, and South America, South Africa and Southeast Asia from the developing world (Hoekstra and Chapagain, 2007).[4]

The discussion on the allocation of embodied environmental factors to either the producing or the consuming countries also covers greenhouse gas emissions. For example, up to a quarter of China's total CO_2 emissions are embodied in Chinese exports to the rest of the world (Peters and Hertwich, 2008a; Yunfeng and Laike, 2010). This has important policy implications for the design of international environmental agreements: should the cost of these emissions be included in the price of the exports, or assumed by the importer?

The relocation of environmentally-intensive economic activities from developed to developing countries can also induce a net increase of global environmental pressures. For example, global CO_2 emissions increased by 720 million tons of CO_2 between 1997 and 2003 due to the outsourcing of production from the US to China (Shui and Harris, 2006), due to the high share of coal used for electricity production in China and less efficient manufacturing technologies in China's industrial sectors.

4 Similar patterns have also been found for the net trade of embodied HANPP (human appropriation of net primary production). The US by far leads the ranking of the top net-exporters of embodied HANPP, followed by Australia, Argentina and Brazil. Most important net importing countries are Japan, followed by China, the Netherlands and South Korea (Erb *et al.*, 2009)

4.1.5 Trade, decoupling and development

Current economic specialization and resulting physical trade patterns have had both positive and negative implications for economic development in developing countries (Eisenmenger and Giljum, 2006; Giljum and Eisenmenger, 2004; Muradian and Giljum, 2007; Muradian *et al.*, 2002; Pérez-Rincón, 2006; Russi *et al.*, 2008). The balance of positive and negative depends largely on the enabling and regulatory conditions and the specific conditions that are agreed. Factors cited for contributing to the negative impacts have included:

- Prices for raw materials have been falling for decades (Figures 2.4 and 2.5), forcing developing countries to export ever larger amounts of natural resources to maintain a constant level of income;
- Developing countries may export natural resources with little or no domestic processing and thus little creation of added value for the domestic economy;
- Multi-national enterprises are major actors in primary sector production and trade and these enterprises act according to the economic interests of their stockholders rather than the long-term development of the country where the activity takes place – this may include, for example, favouring the repatriation of profits instead of local re-investments into the regional economy;
- Some primary sectors are poorly connected to the rest of the national economy, representing 'extraction enclaves' with little spill-over effects on regional markets (agriculture is a significant exception);
- Resource extraction activities, in particular in the mining sector, are very capital intensive and provide only modest employment for local people;

- Rent-seeking and corruption are widespread phenomena in many countries specializing in resource-intensive sectors, with local elites often spending revenues on consumption or foreign investment rather than investing in domestic sectors which are crucial for sustainable development, such as infrastructure, education and health.

Despite these concerns, international trade can make an important contribution to global decoupling when guided by appropriate policies on environment and trade. These have hitherto been managed separately at country and global levels (with, for example, very limited connections between the work of the WTO and global environmental bodies such as the international environmental conventions and the UNEP Governing Council). Key policy principles that could inform an improved policy interface to support decoupling include the following (see Dittrich, 2007):

1. trade could contribute to reducing global resource use through exploiting transport and physical or geological potentials in a way that minimizes negative environmental impacts;

2. trade negotiations could consider the full value chain of the commodities being traded, agreeing prices that incorporate environmental factors and social costs that are now considered 'externalities'; and

3. trade agreements between countries whose economies are based on exporting primary resources could be accompanied by side agreements that assist these countries in diversifying their economies, including through adding value domestically and supporting impact decoupling.

Such measures could support the desire of developing countries to diversify their economies so that they can reduce

© Fabien Lapouge

dependence on the export of a small number of commodities, support the development of domestic markets, and promote sustainable economic development.

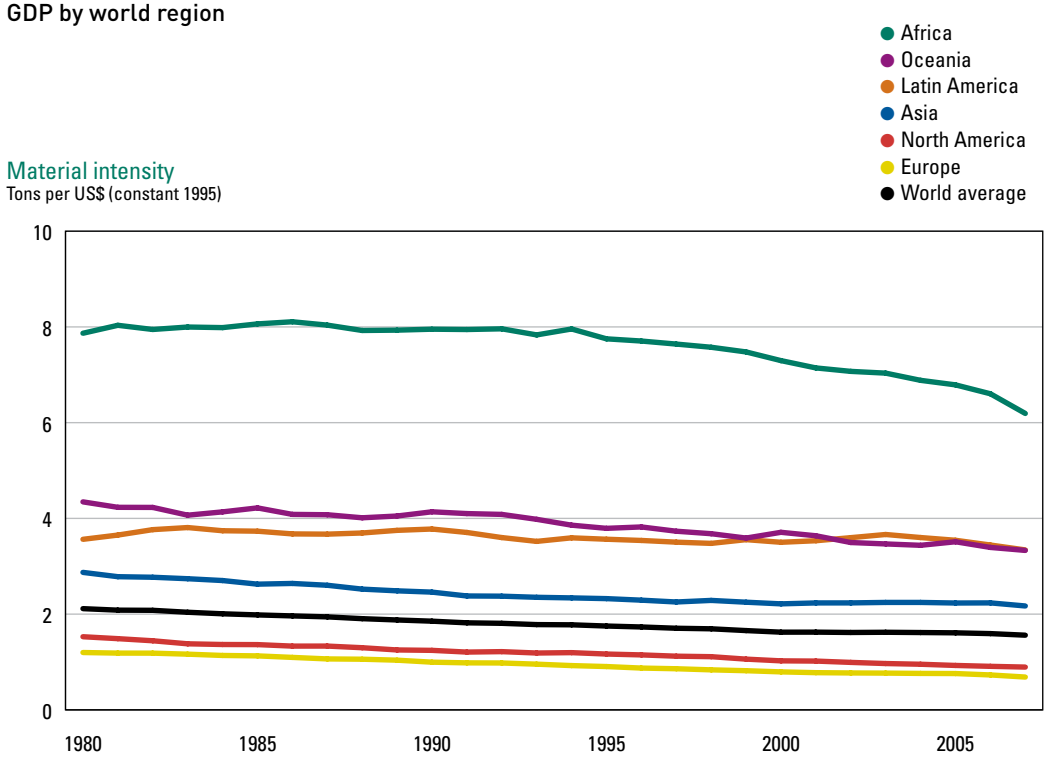
4.2 Decoupling, development and inequality

Global economic growth has accelerated over the past quarter century due in large part to the complex process of economic globalization that absorbed the newly-industrialized countries as major economic players into the global financial system. Although some assumed that computerization would lead to a dematerialized 'knowledge economy', material extraction also increased from about 35 billion tons (35 Gt) in 1980 to nearly 60 billion tons (60 Gt) in 2005, with substantial increases in particular in the extraction and use of construction minerals and ores (reflecting the twin impacts of accelerated urbanization and population growth on resource requirements).

The benefits of global economic growth were not evenly distributed. In 1998, the richest 20% of the world's population was responsible for 86% of consumption expenditure, whereas the poorest 20% were responsible for only 1.3% of consumption expenditure (United Nations Development Programme, 1998). While consumption expenditure does not translate directly into consumption of materials, these statistics are a dramatic reminder that the wealthy have ample room for resource decoupling, and associated impact decoupling would benefit all people.

Some decoupling accompanied the expansion of material consumption, as the overall material intensity of the global

Figure 4.6. Material intensity of the world economy: Domestic extraction of materials per unit of GDP by world region



Source: Behrens *et al.*, 2007

economy declined from 2.1 tons in 1980 to 1.6. tons per US$1000 in 2002 (Figure 4.6). In other words, **25% less material input was required in 2002 compared to 1980 to produce one unit of real GDP** (Behrens *et al.*, 2007). This decoupling was an economic response to the innovations made possible by the growth of information and communications technology, new materials, more efficient production methods, better health and education, and a host of other factors. It seems reasonable to conclude that resource decoupling on a global scale has been a significant part of global GDP growth, with many developing countries showing more rapid GDP growth than the industrialized countries, at least some of which experienced low, or even negative, GDP growth rates in at least some years. However, Figure 4.6 also reveals that Western Europe and North America remained the most efficient economies due to their knowledge infrastructures and technological capabilities, and the overall process of relocating extractive industries into other parts of the world. In contrast, the resource-rich resource-exporting countries in Latin America, Africa, Oceania (due mainly to Australia's rapid rise as a coal and iron ore producer) and Asia were either highly inefficient (Africa or transition countries) or were building fast-growing economies that were increasingly dependent on construction minerals, ores and fossil fuels (Asia and Oceania).

Is decoupling a realistic basis for further policy work to support the green economy that has been advocated in principle by the G20 (Barbier, 2009; Houser *et al.*, 2009; Pollin *et al.*, 2008; Renner & Sweeney, 2008; Green New Deal Group, 2008)? Will the solutions to the global economic recession depend on investments in 'green growth' rather than just be a return to business-as-usual? No definitive answers are available, but some evidence suggests cautiously positive answers.

UNEP considers a **green economy is "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive".**[5]

UNEP's Green Economy initiative commissioned a report (Barbier, 2009) that describes a 'business-as-usual' approach as follows:

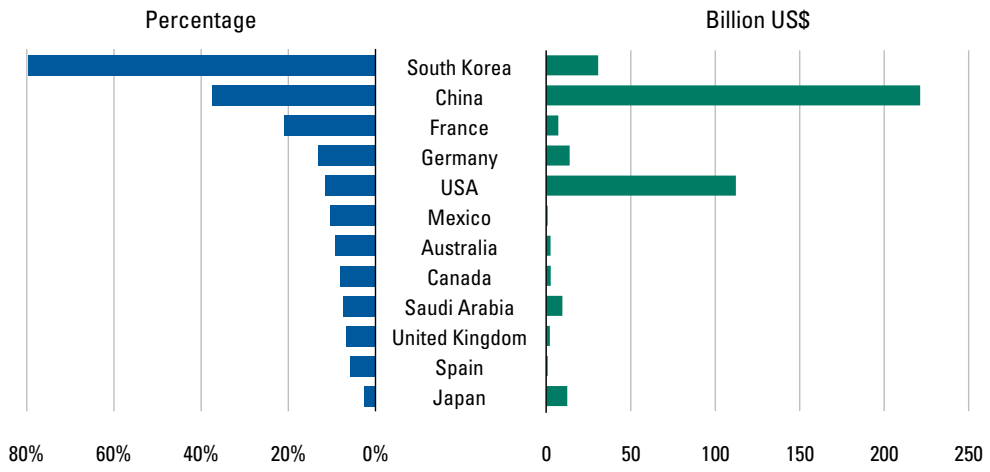
- global energy demand will rise by 45% by 2030, pushing oil prices to US$180/barrel;
- GHG emissions, coupled to energy demand, will increase by 45% by 2030, pushing average temperatures up by as much as 6 degrees;
- global GDP could shrink by 5–10%, with poorer countries suffering losses in excess of 10%;
- degradation of ecosystem services will continue and water scarcities will become more pervasive;
- over 3 billion people will be living on less than US$2 a day by 2015.

It then argues that the US$2–3 trillion that will be invested to revive the global economy should be inspired by more than a narrow economic recovery vision. It proposes three inter-linked investment objectives:

- revive the world economy through employment creation and protecting the most vulnerable;
- reduce carbon dependence, ecosystem degradation and water scarcity; and
- realize the Millennium Development Goal of ending extreme poverty by 2025.

5 See http://www.unep.org/greeneconomy/

Figure 4.7. Eco-friendly spending, total amount and percentage of total fiscal stimulus package



Source: HSBC, 2009

Many countries have incorporated 'green growth' elements into their economic rescue packages (Figure 4.7). These include retrofitting buildings to make them more energy efficient, expanding public transport and freight rail services, constructing 'smart' electrical grid management systems, investing in renewable energy (wind, solar, bioenergy), greening of living spaces, restoring rivers and forests, recycling wastes, and implementing GIS-based green information systems (Barbier, 2009). Many of these investments are concentrated in new kinds of urban infrastructure, thus reinforcing the significance of cities in managing the transition to 'green economies'.

4.2.1 Africa as a special case?

Growth rates in Africa in the 1980s averaged below 2%, but by the end of the 1990s were getting close to 3% and by 2005 were reaching 5%. However, these impressive growth rates declined after the collapse of commodity prices from 2008 onwards, mitigated only slightly in 2009 by the rising price of oil. This is indicative of the structural weaknesses of the African growth model.

In 2000, the export of primary natural resources accounted for nearly 80% of all exports from Africa. This is much higher than for the rest of the world (see Figure 4.1). According to the UN Conference on Trade and Development, **in 2003 many African countries were highly dependent on the export of a single resource** – for example, crude oil (Angola, Congo, Gabon, Nigeria, Equatorial Guinea), copper (Zambia), coffee (Burundi, Ethiopia, Uganda), tobacco (Malawi) or uranium (Niger) (Oxfam, 2005). Many more were dependent on the export of just two or three primary products.

The World Bank has estimated the 'real wealth' of countries by calculating 'genuine savings', by adjusting the gross savings component of the Gross National Income (GNI) as follows: first, depreciation of fixed capital was deducted to create a figure for 'net savings'; to this was added expenditures on education (deemed to be an investment in human capital); then the value of the depletion of natural capital and of pollution was deducted in order to arrive at the figure for Genuine Savings (World Bank, 2006). Because most African countries are exporters of primary resources, the result of this study was that most African countries had a net negative rate of Genuine Savings relative to Gross National Income. The fact that the

Genuine Savings for sub-Saharan Africa hover around zero is an important explanation for why poverty almost doubled between 1981 and 2005 (World Bank, 2006, p.42).

However, whereas countries with relatively diverse economies, like Kenya, Tanzania and South Africa, have positive genuine savings rates, resource-dependent countries like Nigeria and Angola have genuine savings rates that decline to -30. The countries with the highest resource dependence and lowest capital accumulation included some of the largest resource exporters, namely Nigeria, Zambia, Mauritania, Gabon, and Congo. Unfortunately, raising resource prices in absence of appropriate regulatory arrangements and good governance could exacerbate what Sachs and Warner (2001) called the **'resource curse'**, a way to explain why countries with substantial resource endowments end up poor. They suggest that over-dependence on export income removes the incentive to invest in the human resources and innovations required for growth through economic diversification. Instead of funding institutional and human capital resources to benefit the majority, resource rents bolster the power and prestige of elites. It follows that any strategy to increase resource rents for resource-rich resource-exporting economies will need to be coupled to a 'good governance' strategy aimed primarily at strengthening democratic institutions and accountability (Evans, 2006).

The above-cited World Bank report comes after more than 20 years of trade liberalization. African governments have lifted protective tariffs, thus undercutting local industries that were unable to compete with prices of imported goods. In the name of increasing trade, the opposite was achieved. According to Christian Aid, "[t]rade liberalization has cost sub-Saharan Africa US$272 billion over the past 20 years. Overall, local producers are selling less than they were before trade was liberalized" (Christian Aid, 2005, p.3).

Despite increased demand for primary resources from the emerging economies such as China and India, **the value of Africa's primary resource exports are generally falling.** This is particularly true for agricultural products that declined in absolute value from US$15 billion in 1987 to US$13 billion in 2000. According to Aksoy and Beghin (cited in Bond, 2006, p.61), non-oil exporting sub-Saharan countries suffered from declining terms of trade for the period 1970–1997 resulting in a cumulative reduction in revenue levels that amounted to 119% of their total actual GDP for the period. In other words, if the terms of trade had remained stable, the combined GDP of these countries for the period 1970–1997 would have been more than double what it was, with all the attendant potential development benefits (Bond, 2006, pp. 60–63).

Remaining so dependent on the export of primary resources does not make economic sense for any resource-rich resource-exporting countries. What will make a difference in Africa are substantial investments in the development of indigenous innovation capacity and governance systems that make it possible to **capture resource rents for re-investing in human capital development, infrastructure and technological innovation.** An ideal model that may have some lessons is Norway's approach to investing its resource rents generated from oil in ways that will continue to be economically productive after the decline of oil revenues.

4.3 Decoupling and the rebound effect

This paper has shown that both resource decoupling (achieving the same or greater output with fewer inputs) and impact decoupling (doing less environmental harm

© Bbbar/Dreamstime

per unit of output) are feasible, and indeed are taking place (driven largely by market forces). It logically follows from this that any innovation that results in less inputs/impacts per unit of output will contribute to decoupling. In practice, however, other factors come into play. This is the problem that has come to be known as the 'rebound effect' (otherwise known as Jevon's Paradox). **The rebound effect is the quantitative difference between the projected savings of resources that should have been derived from a given set of technological changes and the actual savings derived in practice**, measured in percentage terms. It determines the actual level of decoupling that can be achieved by a given set of sustainability innovations.

Jevon's Paradox in its original form claimed that "with fixed real energy prices, energy efficiency gains will increase energy consumption above what it would be without these gains" (Saunders, 1992). Under the condition of constant prices, the rebound effect can amount to more than 100% of the savings achieved by the original innovation.

Various efforts have been made to classify rebound effects (Greening & Greene, 1997; Sorrell, 2007). A common classification is into *micro effects* (or direct rebound) and *macro effects* (indirect rebound). *Micro effects* occur at the consumer level: even though the final price of a product is not determined entirely by the resource price, in general if a consumer saves money on a commodity because it has been produced with less resources and therefore possibly at lower cost, he may consume more of this commodity, or spend his money saved on something else that again consumes resources. *Macro effects* occur at the level of national economies, are more long term and more difficult to assess. How these direct and indirect effects may be distinguished from the effects of economic growth in general depends on the respective theory of economic growth. For some, this is possible (Sorrell, 2007), but others contend that rebound effects are a

necessary outcome of economic growth and therefore cannot be distinguished from growth (Ayres and Warr, 2005).

Research on **micro level** rebound effects has, in general, concluded that across time and across products, the rebound effect is not a major problem and does not undermine the case for investing in resource efficiency or productivity (Greening *et al.*, 2000; Herring, 2004; Berkhout *et al.*, 2000; Schipper, 2000). In most cases, the direct rebounds range from 0% to 40% (Sorrell, 2007). The size of direct rebound effects depends on income: the richer the consumer, the greater the likelihood that he will not buy more of the same if it gets cheaper, and the resource savings will be achieved. The poorer the consumer, the more likely he will redirect his savings into more or other consumption that will reduce the resource gains. This way, however, the rebound effect actually allows for improvements in material welfare. Research on rural electrification in India, for example, shows that a rebound effect of at least 50% could be observed, but thereby allowed for meeting basic needs that could not be met prior to electrification (Roy, 2000).

However, when it comes to the **macro-economic level** the implications of the rebound effect are much less clear, and are potentially problematic from a decoupling perspective. The macro-level rebound effect does not adequately address the divergence between projected efficiency gains and actual efficiency gains. Where efficiency increases, the divergence is in the level of economic activity which, in theory, should be higher with efficiency gains than without. It is very difficult to verify this empirically, especially for efficiency increases that are the result of government policy. This is clearly an issue for further research, with some plausible support for this proposition (Ayres and Warr, 2005; Ayres and van den Bergh, 2005) but no definite proof of a direct link between increases in energy efficiency and economic growth.

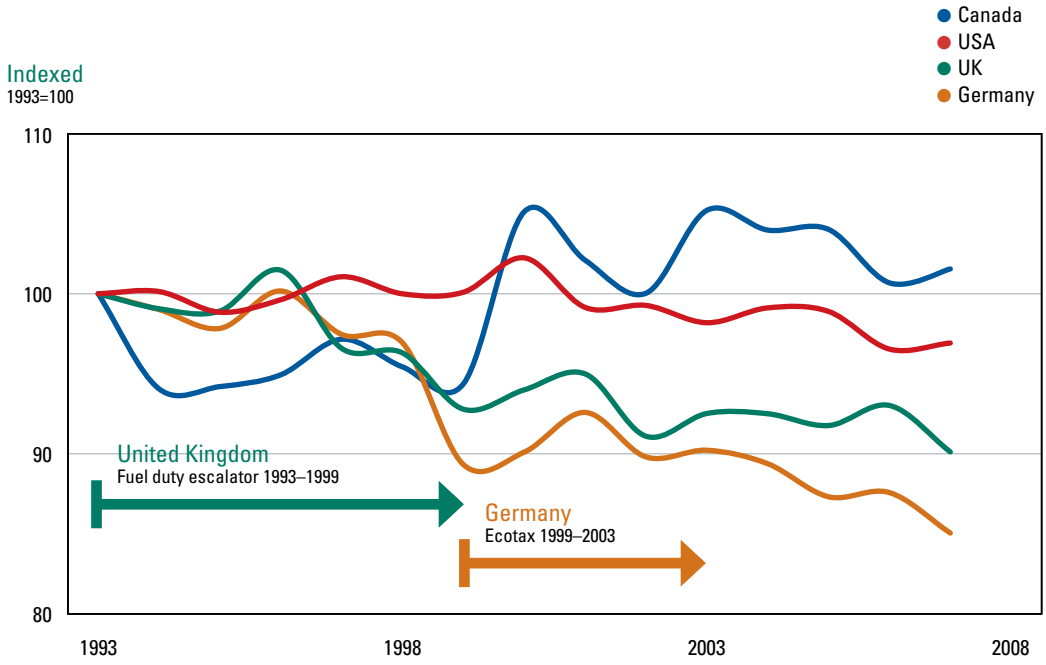
4.4 Prices and resource productivity

The size of rebound effects depends at least partly on the trajectory of prices. In a context of constant or sinking price levels, rebound effects tend to become larger. This issue will be dealt with in more detail in the Second Report of the Decoupling Working Group that will focus on specific applications of decoupling across a range of sectors.

Figure 2.4 showed that the long-term historical trajectory of real resource prices has been downward in the 20th century, with some periods of soaring resource prices. Since the turn of the Millennium, many have argued that now, finally, resource prices will continuously rise. The surge of oil, gas and other mineral resource prices until the economic crisis in 2008 was triggered by steeply rising demand from the rapidly developing Asian economies, led by China, following standard economic theory of supply and demand. But **the economic interpretation that declining price levels are a correct market indicator for resources not becoming scarcer is risky:** one may find the opposite when it is already too late to take corrective measures (see discussion in De Bruyn *et al.*, 2009).

In the context of the climate debate, where agreements have been achieved about limits not of resource use, but of the absorption capacity of the atmosphere, policy interventions into the price system seem inevitable. Trading permits for CO_2 emissions will – indirectly – raise prices for energy use from fossil fuels. Various instruments are available – the cap and trade regime, feebates, fees and charges – and various command and control instruments steering technologies have direct and indirect effects on prices. Another major instrument for influencing prices is a tax escalator regime, used in Britain and Germany since the 1990s. The 'escalator' idea is to add small annual

Figure 4.8. CO_2 emissions from fossil fuel consumption



Source: UNEP, 2011. The UNEP GEO Data Portal, as compiled from Carbon Dioxide Information Analysis Center (CDIAC). United Nations Environment Programme, http://geodata.grid.unep.ch.

price signals that are agreed for many years in advance.

These two historical examples of fuel tax escalators can be seen as proof of effectiveness. The British escalator on petrol taxes was introduced in 1993, and the German ecotax reform came six years later. In both cases the fiscal duty increased year by year by very small amounts, which by itself would have hardly any steering effect. But **the certainty of future steps to come had a major effect on customer behaviour.** Families would buy more fuel-efficient cars, travelling by rail and other public transport enjoyed some renaissance, and unnecessary trips were reduced. Figure 4.8 shows the effects on CO_2 emissions from fuel consumption per capita and year. It shows that German petrol consumption falls before the ecotax escalator began were also caused by fuel taxes, which were raised three times by the previous government since 1991 for purely fiscal reasons to pay for costs of the German unification.

Figure 4.8 contrasts the British and German experiences with those of Canada and the US. In the latter two countries, the increasing efficiency of compact cars was more than compensated by the introduction of tax breaks for sport utility vehicles (SUV's) and small trucks and by added miles driven; no signs of recovery can be seen in the mostly outdated and inefficient railway systems in the North American countries.

If climate protection policies are going to be taken seriously worldwide and it is agreed that a strong downward trajectory of CO_2 emissions needs to be achieved, policy interventions directly or indirectly into the price of fossil fuel will be required, and this is likely to increase the price level of all raw materials. In the way this transition is planned now (Stern, 2007; Edenhofer *et al.*, 2008), it might transfer some of the income achieved into developing countries where an increase in material welfare is highly warranted.

5 Conclusions and major policy challenges

5.1 Conclusions

This report has sought to clarify the concept of decoupling as applied to sustainable development. This concept provides a basis for enhancing human well-being while reducing the intensity of resources being used in economic activities (resource decoupling) and reducing negative environmental impacts from any use of natural resources (impact decoupling). Resource decoupling leads to increasing efficiency with which resources are used, sometimes called 'dematerialization.' Impact decoupling means using resources better, more wisely, or more cleanly, but does not necessarily reduce the amount of resources used, or the cost of production.

The report's focus has been on material resources: construction materials; ores and industrial minerals; fossil fuels; and biomass. These natural resources have been harvested at increasing rates over the past century, helping to support increasingly rapid growth in GDP (Figure 2.1). They may gradually approach limits of production, as their prices in recent years are showing increasing volatility after a long-term decline of about 30% during the 20th century. Increasing

© Eugene Hoshiko/Pool /Reuters

demand for resources, declining grades of several key ores, and increasing environmental impacts associated with resource use suggest that decoupling could be a timely policy response.

Other categories of resources are also important and would benefit from decoupling (such as water, soils and land), but these are being addressed elsewhere, including by other working groups of the International Resource Panel (IRP).

The report has built on several fundamental concepts:

- A distinction between **relative decoupling** (in which the growth rate of resources used is lower than the growth rate of GDP, though resource use continues to grow) and **absolute reductions** of resource use. Absolute reductions are rare, as they require resource productivity to grow faster than GDP.

- A focus on **material resources**, characterized by qualities that render them useful for certain applications, and get lost (or diminished) by use. They are natural assets deliberately extracted by human activity for their utility to create economic value; they can be measured in both physical units and monetary terms.

- A **life cycle perspective** on resource use, showing that resource use implies a series of transformations. While each of the four classes of material resources are different in many ways, generally speaking, their life cycle begins with extraction of the resource, then transport to a processing plant, combustion or conversion into a commodity, contribution to a manufactured product, transport to consumers, consumption, and finally disposal or recycling. Each part of the life cycle can take place in various parts of a country or even different parts of the world, with the costs and benefits widely distributed. Decoupling can contribute to resource efficiency at many parts of the life cycle, with different actors responsible for the decoupling and different policies required for supporting decoupling at the different stages of the life cycle.

- Resources can be accounted for as total global or national amounts annually used, and as individual metabolic rates, which is the amount of resources consumed by an average person on the entire globe or a particular country. **Metabolic rates** are a relatively objective way of comparing how resource consumption is changing over time, or for comparing countries with each other. The average global metabolic rate doubled from 4.6 tons per capita in 1900 to 8–9 tons per capita at the beginning of the 21st century. Metabolic rates vary widely among countries, an indicator of inequity, though it appears that densely populated areas and regions need fewer resources per capita for the same standard of living and material comfort.

- A distinction between **economic growth** (defined as the added monetary value of all final goods and services produced within a country in a given period of time) and **physical growth** (defined as the growth of physical throughput in the economy). It is physical growth that is coupled to environmental pressures and resource depletion.

International trade is a critical issue in decoupling, given that some 20% of the consumption of the resource categories addressed in this report is traded internationally, and CO_2 emissions embodied in internationally traded products accounted for 27% of the total energy-related CO_2 emissions in 2005, up from 22% in 1995 (Bruckner *et al.*, 2010). Environmental pressures directly and indirectly linked to international trade thus make up a significant share of total environmental pressures. Internationally traded materials increased from about

5.4 billion tons (5.4 Gt) in 1970 to 19 billion tons (19 Gt) in 2005, an indication of the challenge of trying to assign responsibility for decoupling along the value chain from original extraction to ultimate disposal.

The report was nourished by the detailed **case studies** from China, Japan, Germany, and South Africa, all of which have experienced the long-term consequences of resource depletion and negative environmental impacts, and responded by adopting policies that include decoupling.

While some decoupling has occurred 'spontaneously' (for example, GDP grew at a considerably faster rate than material extraction or metabolic rates during the 20th century, as shown in Figures 2.1 and 2.2, respectively), much more is needed if society is to be sustainable over the longer run, as resources come under more pressure with population growth and increasing GDP.

This need is indicated by considering several **scenarios** for the future. *Business as usual* would triple global annual resource extraction by 2050, compared to 2000, amounting to some 140 billion tons (140 Gt) – far beyond what is likely to be sustainable. *Moderate contraction and convergence* would require industrialized countries to reduce their per capita resource consumption by half the rate for the year 2000 while developing countries reach the metabolic rate of the industrialized countries by 2050 – this would lead to a global annual resource use of 70 billion tons (70 Gt). *Tough contraction and convergence* would keep global resource consumption at its 2000 level, but redistribute the resources so all countries achieve roughly the same per capita metabolic rate; this would be unlikely to be politically acceptable. Even the last scenario would not lead to an actual global reduction in resource use.

The report finds that **innovation**, even radical innovation, will be required to achieve resource and impact decoupling. Some of this will need to be economic innovation, for example UNEP's Green Economy Initiative, which seeks to couple a revived world economy with reducing ecosystem degradation, water scarcity, and carbon dependence. Other forms of innovation will be based on new knowledge and ways of managing information, leading to technological, institutional and relational innovations.

An especially promising source of innovation could be **cities**, where more than half the world's population lives. People are attracted to cities for jobs, education, shelter, protection, access to information, and cultural diversity. Cities usually have a lower metabolic rate than rural areas, though richer cities have higher metabolic rates. But cities also concentrate the knowledge, financial, social and institutional resources needed for sustainability innovations. While cities drive unsustainable use of resources, they can also provide the greatest potential for sustainability innovations.

Ultimately, one main objective of the IRP is to provide information about how to reduce the consumption of resources required to support well-being for all people. **Non-material economic growth** has been proposed as one means of doing so. Decoupling is seen as a major conceptual basis for helping to achieve this, but many challenges remain. This report has identified some of the major challenges and suggested possible approaches to addressing them.

Many governments have adopted 'green growth' as an important part of their economic development, as the overall material intensity of the global economy declined from 2.1 tons per US$1,000 in 1980 to 1.6 tons in 2002, requiring some 25% less material input in 2002 compared to 1980 to produce one unit of real GDP (Behrens *et al.*, 2007).

© Eric Gevaert/Dreamstime

In summary, resource and impact decoupling are already taking place, though at a rate that is insufficient to meet the needs of an equitable and sustainable society. Far greater efforts will be required in the coming years to accelerate decoupling and avoiding any rebound effect, and the report has identified some key challenges that the IRP will address in the coming years. Success in meeting these challenges will contribute to meeting the needs of a growing population, reduce poverty, and support economic development without threatening the ecosystem services upon which human well-being depends.

5.2 Major policy challenges

This report has provided evidence that it is time to recognize the limits to the natural resources available to support human development and economic growth. **Growing resource constraints will not affect everyone equally.** The world's poorest people will be deprived of opportunities to develop, even though they are minor consumers of most materials covered in this report. At the same time, the world's richest nations will find it increasingly difficult to enjoy their current levels of consumption and the fruits of a stable world if resource depletion continues and resource prices increase. The optimal solution for all countries is to make sustainable resource management a central focus of global policy frameworks for growth and development. As a contribution to what this means in practice, this report has shown how decoupling of resource consumption and environmental impacts from economic growth could provide a policy tool for calibrating the shifts required over time to manage the transition to a more sustainable global economy.

To make the transition to a more sustainable global economy, sustainable resource management strategies will be required that promote resource *and* impact decoupling, with an emphasis on absolute resource use reductions in developed economies and relative decoupling in developing economies (up to a certain point

after which they must also shift into an absolute reduction mode).

This approach to decoupling poses at least the following major challenges:

- How can global resource flows and their associated environmental impacts be integrated with efforts to deal with problems such as climate change, degradation of ecosystem services, and pollution?
- How can policymakers (and the public) be convinced of the reality of physical limits to the quantity of natural resources available for human use and that the negative environmental impacts of economic activities also have limits?
- What are the economic factors driving the decoupling that is already taking place, and how can these be mobilized more effectively to enhance escalations in investments in innovations and technologies that can accelerate decoupling?
- How can market signals generate increases in innovation for resource productivity? How can international trade best incorporate the concepts of resource decoupling to support equitable conditions of trade in natural resources?
- How can the current economic growth model be modified to realize the aims of 'non-material growth' through sustainable resource management?
- Given that the multiple challenges of economic growth, sustainable resource management and ending poverty take place in the midst of the 'second wave of urbanization', how can cities become the spaces where ingenuity, resources and communities come together to generate in practice what decoupling means in the way cities produce and consume?
- How can decoupling be demonstrated as a necessary precondition for reducing the levels of global inequality and eventually eradicating poverty? In particular, how can developing countries find a growth and development strategy that eradicates poverty by increasing resource productivity and restoring ecosystem services?

The IRP intends to seek answers to such questions in its future work.

Country case studies

What follows are four case studies of countries that have in one way or another started to address the challenge of decoupling. The countries studied are Germany, China, South Africa and Japan. Each case is structured in accordance with the following headings:

- **Recognizing limits:** this section addresses whether the country has experienced and recognized resource constraints and limits;
- **Policy responses:** the various policy responses are then assessed in order to show how the country understands the challenge and the related responses (mainly at the level of intent);
- **Decoupling:** whether there is evidence of decoupling, both empirically and at the level of policy intent;
- **Conclusion and outlook:** key challenges going forward.

6 Germany[1]

Addressing overall resource productivity as a key element of sustainable production and consumption only very recently came into the focus of the Federal Government of Germany with the formulation of a National Strategy for Sustainable Development (NSSD) in 2002. The government's goal to double resource productivity by 2020 evolved as a key indicator to evaluate policy progress in the process of formulating the NSSD. 'Governance by evaluation, integration and coordination' is how Zieschank (2006) labels the use of an indicator set in the NSSD. This is, however, quite an uncommon practice in German policymaking. The new government, in place since 2009, reconfirmed this policy line and established a national resource efficiency programme, serving as an input to the Rio+20 UN Conference.

6.1 Recognizing limits

Germany is often described as an early front-runner in environmental policymaking. Recognition of natural limits to resource use – albeit more biased to impacts – was already apparent in the early 1970s when the basis for successful reduction of air and water pollution and for a proper system of waste disposal and handling was laid (Andersen and Liefferink, 1997). In its 1971 Environmental Programme the Brandt government of Social Democrats and Liberals adopted a strategic planning approach and attempted to treat environmental protection in an integrated manner. The programme formulated ambitious long-term targets for air pollution control and water protection, described nearly 150 concrete policy measures, and set up guiding principles of environmental policy. New institutional arrangements[2] were established, leaving the Ministry of the Interior in charge of environmental policy.[3] Despite formal adoption of environmental policy as a cross-sectional task and formal continuation of the Environmental Programme by the federal government in 1976, the integrated and strategic planning approach in the late 1970s and early 1980s gave way to a medium-term approach relying heavily on detailed command-and-control regulations to control emissions at the source. Federal environmental policy thus became increasingly focused on key resource carriers such as air, water and soil, with pollution addressed in most cases by means of 'best available technology'. Though the Kohl Conservative-Liberal government after 1982 halted further progress in environmental policy, advances continued to be made in the 1980s and early 1990s with respect to air pollution, water protection and waste disposal and management. By the middle of the 1990s, however, the former front-runner had turned laggard as the Kohl government failed to formulate an integrated approach to the concept of

1 The main text of this case study was completed in January, 2009. A few factual amendments were added in December, 2010.

2 In 1972 the Environmental Expert Council (SRU) was established, as well as Cabinet Committees and Standing Committees of Federal executives; two years later the Federal Environmental Agency (*UBA*) was set up.

3 The Federal Ministry for the Environment was established later in 1986.

sustainable development conceptualized by the 1987 Brundtland Report and the 1992 UNCED in Rio. It may be worth mentioning, though, that in 1998, the then environment minister Dr. Angela Merkel, who later became chancellor, issued a comprehensive policy paper on sustainable development[4] intended to answer the challenges from Rio de Janeiro. But in the 1998 elections, three months later, political majorities changed, and the government of Social Democrats and Greens (1998–2005) set out on another, yet more proactive agenda.

6.2 National Strategy for Sustainable Development

The call to develop a National Strategy for Sustainable Development (NSSD) was raised by think-tanks (BUND/MISEREOR, 1996) and in the Bundestag, the federal parliament. The work of two successive parliamentary committees of enquiry[5] finally led to the Bundestag asking the federal government to elaborate a NSSD and to establish a sustainable development council.[6] After the election in 1998 a new government coalition of Social Democrats and Greens transposed this decision into its coalition agreement: a NSSD with concrete objectives should be elaborated by the new government and be prepared by 2002. In 2000 the government decided on the institutional framework for a NSSD. Its main feature is a strong role for the Chancellor's Office (Bundeskanzleramt); its mandate is to horizontally coordinate the work of the federal ministries involved in the NSSD through a Committee for Sustainable Development at the level of permanent secretaries.[7] An inter-ministerial working group at the level of sub-directors prepares the meetings of the Committee. Other important institutional innovations were the establishment of the German Council for Sustainable Development (RNE) in 2001 and a new Committee for Sustainable Development in the Bundestag in 2004. The RNE significantly contributed to the NSSD that was finally endorsed by the government in 2002.

Recalling the patterns of environmental policymaking in Germany as described above, it is no small achievement that the NSSD was developed and that its institutional setting was established. The NSSD can be seen as a remarkable policy innovation – whether it proves to be a long-term success remains open as the structural conditions of integrated policy-formulation and policymaking continue to be unfavourable.

The German NSSD comprises strategic, mostly quantitative, trend objectives and indicators – all in all a set of 21 indicators grouped under the headings 'intergenerational equity' (including indicators for natural resource use, state budget, innovation and education), 'quality of life' (including indicators for economic prosperity, quality of the environment, mobility, nutrition, health and crime), 'social cohesion' (including indicators for employment, equal opportunities and families) and 'international responsibility' (including indicators for expenditure for development aid and opening EU markets). In the context of this report, Indicator 1 ('resource conservation') is the most important, as it includes sub-Indicators 1a 'energy productivity' and 1b 'resource productivity'. The NSSD goal is to double both energy productivity (base year 1990) and resource productivity by 2020 (base year 1994). The 'resource productivity' indicator includes all used abiotic raw material extracted in Germany as well as abiotic imports. Biotic raw material, though, is not included, which constitutes a grave problem as will be discussed later. A different indicator

4 Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), 1998. Entwurf für ein umweltpolitisches Schwerpunktprogramm. Bonn: BMU.
5 Cp. Deutscher Bundestag, 1998.
6 This decision in 1998 was made using a wide cross-party consensus.
7 This Committee was called "Green Cabinet" under the Schröder government; after the election of 2005 this name was dropped.

© Martin Roeder/Dreamstime

(Indicator 4 'land use') calls for the reduction of the daily increase in land use (daily increase reduced from 120ha to 30ha by 2020).

The NSSD is subject to regular review and some indicators were revised in 2006 (though none referring to resource use). Why each of the 21 indicators was chosen is not always easy to comprehend. As Jänicke (Jänicke *et al.*, 2001) points out, there is a fundamental lack of agreement in the federal administration on how to define sustainability. Be that as it may, the NSSD doubling resource productivity by 2020 became the official goal of the federal government. This goal was affirmed by the new Merkel government after 2005 and can now be considered as the cornerstone of the government's position on resource use. The Chancellor's political commitment to the goals of the NSSD should be seen as an important prerequisite for the continuing efforts towards implementing sustainable patterns of consumption and production in Germany.

6.3 A feasible vision? The '2000 Watt/cap society'

The feasibility of raising energy efficiency by a factor of four (at least) has been demonstrated for many specific examples and with national and global scenarios.[8] In particular, the Swiss concept of a '2000 Watt per capita society'[9] is interesting, because it includes a vision for the combination of energy efficiency with material efficiency as a goal, though the mutual reinforcing effects have not been quantified in integrated scenarios up to now.

Meanwhile, the concept is debated in Germany as well: decoupling, leapfrogging and socio-technical innovations are the basic rationale behind the concept of the '2000 Watt per capita society' for OECD

8 Compare Weizsäcker *et al.*, 1998 and Lovins & Hennicke, 1999. WBGU 2003 and Ecofys/ DLR *et al.*, 2007 and 2008.

9 The 2000-watt society is a vision, originated by the Swiss Federal Institute of Technology in Zürich at the end of 1998, in which each person in the developed world would cut their overall rate of energy use to an average of no more than 2,000 watts (i.e. 17,520 kilowatt-hours per year of all energy use, not only electrical) by the year 2050, without lowering their standard of living.

countries. 2000W/cap (= 65 GJ/cap) corresponds to one third of today's European per capita energy use. Enabling a GDP/cap growth of two thirds by 2050, the '2000 Watt per capita society' implies a factor 4 to 5 increase in energy efficiency. Swiss research institutes have been working on this concept for many years demonstrating the technical feasibility of this challenging vision. As the world average energy consumption in the last two decades has been 70 GJ/cap, one of the Swiss report's hypotheses is that 65–70 GJ/cap could even be a future convergence value for a sustainable world energy system.

Thus, an ambitious increase in energy and material productivity, a complete change of the innovation systems, the exploitation of long re-investment cycles and gradual structural change to more sustainable patterns of consumption and production are important preconditions for establishing a '2000 Watt per capita world society'.

It should be added that by reducing the gigantic losses of existing energy systems[10] and by raising the share of renewables (as decided for EU-27 and especially for Germany) the vision of 'a sustainable energy society' could even today be taken as guidance for concrete implementation steps. Meanwhile, for Germany very sophisticated databases and dozens of medium-term (2020) and long-term (2050) scenarios are available that demonstrate the feasibility of a sustainable German energy system.

6.4 The key to sustainable energy: efficiency increase by a Factor x

Up to now, the debate on resource efficiency has focused on energy. Many detailed databases and sophisticated scenarios are available, especially for Germany. But no fully integrated scenario analysis of strategies to foster the combined increase of material and energy productivity for Germany or other countries exists.

A detailed, but again only energy-related analysis of the feasibility of a sustainable energy system was presented for Germany in 2008[11] in the so-called 'BMU Leitszenario',[12] serving as an orientation for energy, climate and resource policies advocated by the German Ministry of Environment. This scenario demonstrates that the phase-out of nuclear power (by 2023 as decided), the reduction of CO_2 by 80% (by 2050), a moderate 1.2% annual (green?) increase of GDP-growth and additional job creation are technically feasible and cost-effective in the long run: the moderate additional societal costs for the energy system up to 2030 will be more than compensated for by the benefits by 2050. One crucial assumption is that (besides an ambitious increase in the share of renewables in all sectors) energy productivity increases at least by a factor of 4 – in other words, a fourfold increase in the efficiency with which energy is used.

With the so-called Integrated Energy and Climate Programme (IECP, 2007/2008) the German government adopted two dozen policies and measures whose collective aim by 2020 is to raise the share of renewables for electricity to 30%, for heat to 14%, the share of Combined Heat Power (CHP) for electricity to 25% and to save energy in all sectors. With the help of the IECP and additional measures it is expected that at least a 30% CO_2-reduction by 2020 (and 40% reduction conditioned to ambitious goals of the EU27) can be reached.

While not fully convincing with regard to implementation (e.g. too moderate goals for new coal power plants and efficiency standards for the car industry) the IECP nevertheless is one important step forward

10 On average only about 30% useful energy is derived from 100% primary energy inputs in the worldwide energy system and in most national energy systems; see Jochem, 2004.

11 Sustainable world energy scenarios with comparable goals and results have been developed by Lovins/Hennicke, 1999; WBGU, 2003; and Ecofys/ DLR *et al.*, 2007 and 2008.

12 See BMU, 2008a.

in the direction of the new Ecological Industrial Policy of the Ministry of Environment.[13] The key to this new strategy is to foster an increase in resource productivity (e.g. the integrated increase of energy and material productivity) and development of 'lead markets' e.g. for sustainable energy and mobility systems, for renewables, for recycling technologies and for sustainable water and waste management.[14] It has been calculated that the world 'market' (profitable potential)[15] for GreenTech adds up to €1000 billion (2005) with the prospect to more than double by 2020.

In September 2010[16] the Christian Democratic and Free Democratic coalition government (in power since October 2009), mostly reconfirmed these approaches but modified the position on nuclear power, allowing for an extended time frame for the phase-out of nuclear reactors.

6.5 Integrating material and energy efficiency strategies

Up to now, strategies to foster energy efficiency and climate/resource protection have been separated from activities to develop and disseminate material-efficient production processes, products and services. Within enterprises an integrated accounting of energy and material flows is still an exception. But from the cost perspective of enterprises as well as for the national economy there are close inter-linkages if energy and material productivity is stepped up in an integrated way. In general, addressing resource productivity increases as a top priority seems to be a promising strategy for decoupling added value and economic growth from resource use and to create structural changes to new green patterns of growth.

To make it happen, technology and resource prices will become the key instrument for driving the eco-efficiency revolution. However, this will need to be accompanied by a discourse and policies on more environmentally-viable lifestyles and on new patterns of sustainable consumption and production. In that case, the technological efficiency revolution helps to gain time and may support a structural change to new models of wealth.

According to official statistics, material throughput accounts for more than 40% of total cost of production in the German processing industry. This is more than twice the labour cost share. The share of energy cost in the processing industry lies on average only at about 2%. Thus, the 'material' cost factor is more important for competitiveness of the economy and of enterprises than labour costs.[17] The same order of magnitude applies to other OECD countries.

On the other hand raw material and energy prices (oil, gas) are mostly determined by the world market and thus will influence competitors all over the world in a more general and equalized way than domestic wages. Furthermore, concerning material and energy costs there are specific market failures and obstacles – even in the period of rapidly growing raw material and energy prices up to summer 2008 – that make SMEs especially reluctant to exercise even very cost-effective options for cost reduction. The lists of obstacles to realize cost-effective energy-efficiency potentials is long (e.g. deficits of awareness, information, market transparency and capital availability, missing life cycle-cost calculations, asymmetric payback expectations split incentives, etc.) and will be certainly even longer and more complex

13 See BMU 2008b.
14 See BMU/ UBA 2007.
15 Though the study speaks of "markets", the formulation "profitable options" is preferred. Because of market failures and obstacles, it requires incentives, guidelines and a new policy mix to convert these gigantic profitable options into self-sustained markets.
16 See BMWi/BMU, 2010.

17 Engaging in resource strategies on the enterprise level is in the interest of German Trade Unions (especially IG Metall), as it would lower pressure on labour costs; see BMU/IGM/WI, 2006.

when it comes to material efficiency.[18] The huge variety of raw materials, substances, composites, etc. and of substitution or recycling options is the main reason why without the help of a new policy mix (e.g. external experts, networking, information programmes and incentives) highly cost-effective potentials are not realized.

In this respect, it makes sense to ask how to jointly increase material and energy efficiency in practice by an integrated strategy and how to create positive incentives especially for small and medium enterprises. The management consultancy Arthur D. Little (AdL) assumes that by consulting external experts companies can regularly reduce their material throughput costs. Experience shows that an annual cost reduction of 20% can be achieved by non-recurrent expenditure that has an average payback of 12 months.[19]

18 See Bleischwitz *et al.*, 2008.
19 See AdL/ISI/ WI, 2006.

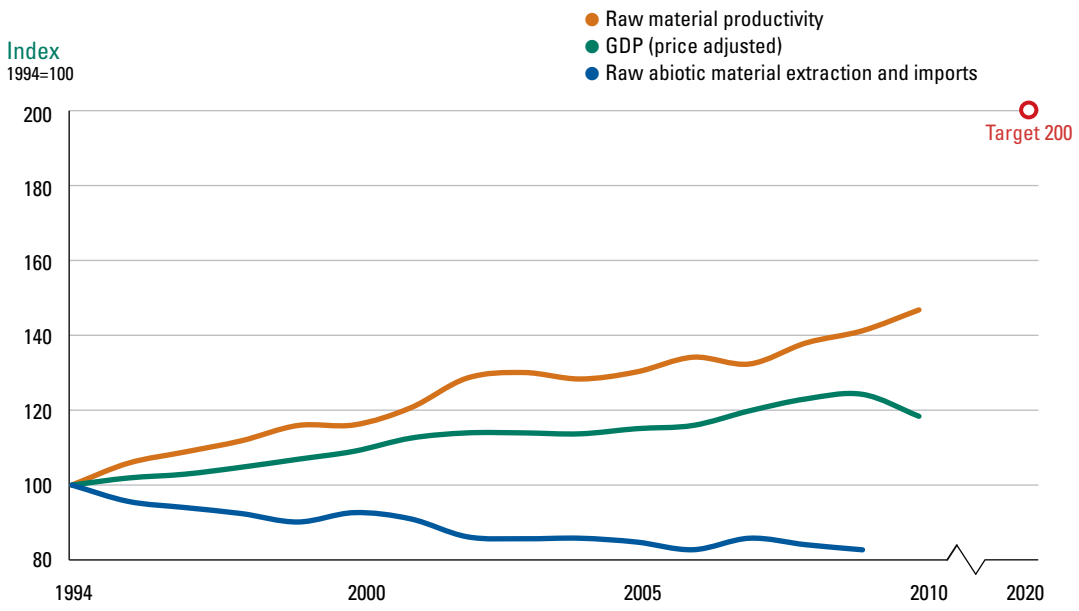
6.6 Decoupling – empirical evidence and strategic actions

Empirical evidence suggests that between 1994 and 2007 a seemingly impressive absolute (resource) decoupling of GDP growth and raw material inputs[20] occurred in Germany. While resource productivity (raw materials) rose by 35.4% and GDP by 22.3%, raw material input decreased by -9.7% (see Figure 6.1).

But the average annual increase of about 2% from 1994–2007 must more than double if the official NSSD goal is to be achieved. While there is some evidence that this goal is still within reach, scaling up existing successful programmes and accelerating the rate of increase of resource productivity will require ambitious new initiatives especially from the German government

20 This includes all used abiotic raw material extracted in Germany as well as imported abiotic materials.

Figure 6.1. Resource productivity and GDP growth



Source: DESTATIS, 2008, http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/EN/Content/Publikationen/SpecializedPublications/EnvironmentEconomicAccounting/Statement2010,property=file.pdf

and from industry. Furthermore, the German raw materials concept does not include **biotic** raw materials,[21] i.e. it ignores the very important trade-off between biomass and fossil fuels or between biotic and abiotic raw materials as inputs for industry. Also not included are the economically not used primary material extracted in Germany and all indirect requirements associated with imported goods. These 'ecological rucksacks' and international side effects of the domestic use of resources are therefore neglected in these metrics.

At the EU-15[22] level there is clear empirical evidence that the burden of growing resource extraction is shifting to the outside world, especially to developing countries. While domestic Total Material Requirement (TMR)[23] between 1980 and 1997 absolutely decoupled from GDP growth, the foreign TMR increased (Moll *et al.*, 2005). The problematic substitution of fossil fuels by biodiesel encouraged by tax exemptions and later by a mandatory blending of fossil-based diesel (Beimischungsgebot) and the general increase in energy use from imported and domestic biomass (mostly not certified from sustainable production) is also not covered by the German raw materials indicator.

6.7 Impulse programme for material efficiency (2005–2009)

A macroeconomic analysis for German industry (see Box) demonstrates that even if only half of the existing material efficiency potentials were realized, there would still be an increase in gross national product, and creation of new business areas and of employment. These macro-economic effects seem to justify a long-term modernization and innovation policy for reducing material costs, growth and employment. A feasibility study by AdL and others (Jochem *et al.*, 2005) identified a first mix of instruments and measures to address and overcome prevailing barriers.

The Aachener Modell

Results of the Aachener Modell
(reducing material costs for German industry by 10%)

At the end of the simulation period (2020):

- Additional employment:
  + 1,000,000 jobs
- Additional business revenues:
  + €120 billion
- Additional increase of economic growth:
  + 1% per year
- Harvesting first mover advantages of competitiveness
- Reducing import dependency of strategic resources
- Contributing to geostrategic risk minimization
- Approaching the official German goal ("doubling resource productivity in 2020")

Source: Aachener Stiftung, Kathy Beys, 2005

Based on the encouraging results of these studies, the German Government in 2005 initiated a pilot phase for an Impulse Programme for Material Efficiency to test instruments and create pilot projects and networks for SMEs and public enterprises. The overall economic goal is to reduce material and energy costs in the manufacturing industry and public sector. Minimization of resource use, residues, waste and emissions are expected to yield cost savings, identify new business fields, and increase employment and competitiveness. A pre-feasibility study identified potentials and priority sectors for pilots.[24] The programme offers financial support for audits (VerMat) and for establishing networks (NeMat) for SMEs.

21 See UBA, 2008.
22 EU-15 includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.
23 Total Material Requirement (TMR) measures total primary material requirements of production and consumption. It comprises the domestic and foreign share and the used and unused extraction of resources.

24 See: www.wupperinst.org

A German Material Efficiency Agency (DEMEA) has been established.

By September 2008, DEMEA had successfully supported in-depth audits for more than 236 projects. On average, cost savings of €229,000 (2.5% of revenues) with a payback time of less than 6 months were demonstrated. Additionally, about 40 SME networks for raising material efficiency were established.

In North Rhine Westfalia the Efficiency Agency (EFA, established in 2000) has supported more than 700 projects in collaboration with five affiliates across the region. A balance sheet of 140 completed projects concludes that a €27.8 million investment in resource efficiency technologies has yielded an annual cost reduction of €8.7 million (average payback time of about 3 years) has been achieved.

6.8 Research on integrated strategies (Ecological Industrial Policy)

Based on scientific research results and successful practical examples the German Ministry of Environment and the German Environment Agency launched an ambitious four-year research project on material efficiency and resource conservation (MaRess)[25]. Coordinated by the Wuppertal Institute in cooperation with a consortium of 30 partners from research institutes, universities and industry, MaRess is expected to define a new policy mix for increasing resource productivity as a key strategy of a new Ecological Industrial Policy. The project structure is summarized in Figure 6.2.

The Wuppertal Institute has also proposed an Innovation Programme for Resource Efficiency to form part of a comprehensive German 'Konjunkturprogramm' to mitigate the economic crisis.[26] By scaling up existing experiences of the DEMEA and EFA (see above) with a total amount of €10 billion from the federal budget for the SME-sector, its aim would be to foster ecological modernization, and create new employment and business fields for GreenTech. It would be operated by a lean federal Resource Agency together with a network of regional and local partners. Support for SMEs would comprise a mixture of impulse and in-depth audits combined with investment subsidies. The key rationale for this programme is a threefold integration:

1. Integration of five key thematic strategies

- create sustainable markets, give innovations a direction
- establish strong institutions, build partnerships and networks to foster the diffusion of existing GreenTech
- develop sustainable products ('cradle to cradle-approach')
- use the market power of the state as a consumer
- create new thinking through training and education (e.g. 'Resource University')

2. Integration of sectoral policies

- harmonize overlapping and target oriented policies - at least the Ministry of Economics, Ministry of Science and Education, Ministry of Transport and Buildings, and Ministry of Environment should cooperate

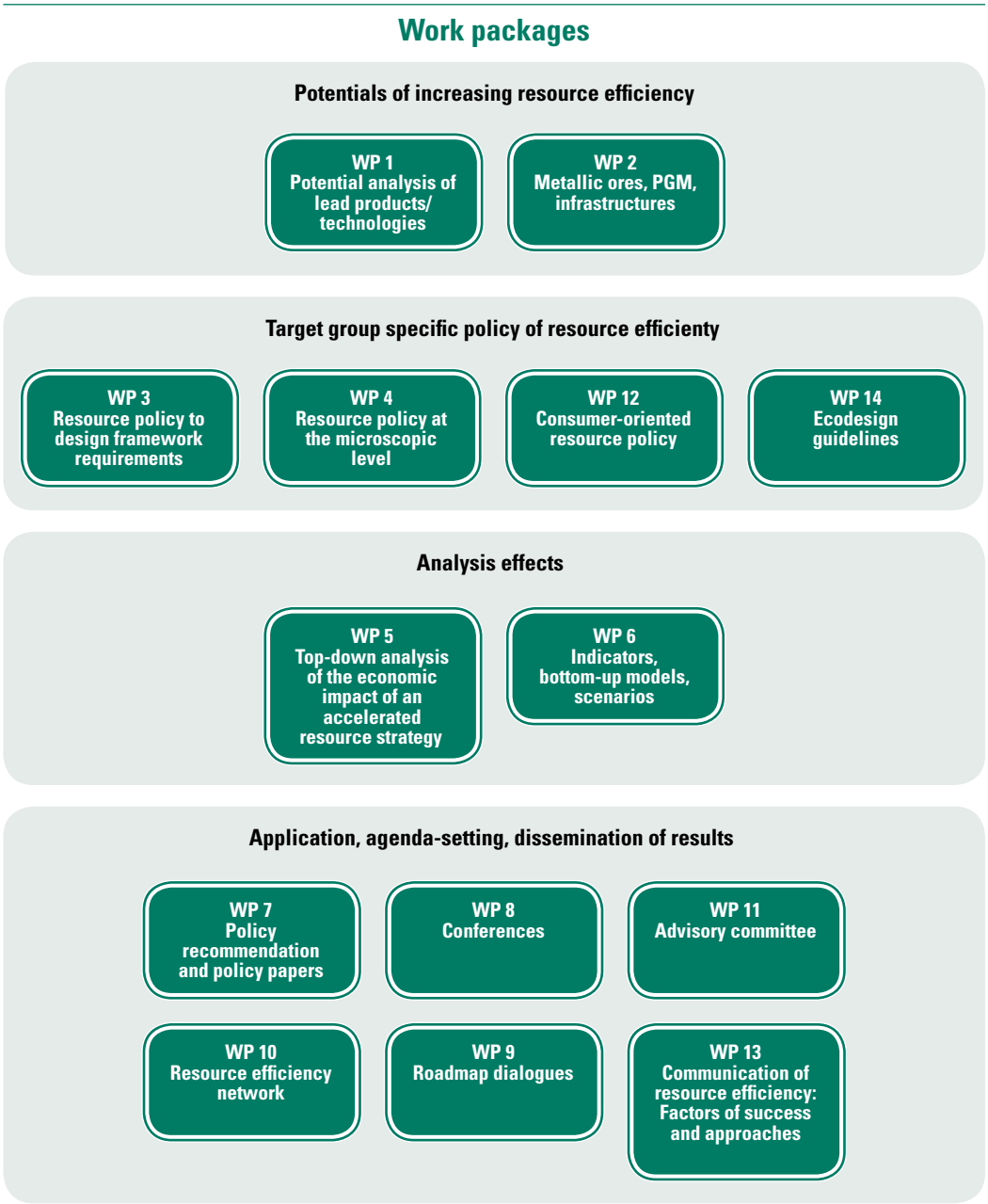
3. Integration across technology and product-development cycles

- integrate target oriented R&D to raise material and energy efficiency with Demonstration, Pilots and Market Aggregation (fostering diffusion)

It is estimated that (especially through this integrated approach) the programme would have a high self-financing effect for the federal budget and would contribute towards defending and extending the world market position of German GreenTech industries.

25 See www.wupperinst.org
26 See Hennicke & Kristof, 2008.

Figure 6.2. Structure of the project MaRess



Source: Wuppertal Institute, http://ressourcen.wupperinst.org/en/project/index.html

Successful implementation of this programme will depend on many factors, including a convincing demonstration of the economic benefits, effective scaling up of the German innovation system, mitigation of rebound and counterproductive growth effects, development of an effective communications strategy and – in general – acceptance by the target group and the voting public.

6.9 Institutional context for decoupling: selected problems

Integrated environmental policymaking, understood in its full meaning as sustainable development, proves difficult in the institutional context of the Federal Republic of Germany. The federal structure leads to an asymmetrical allocation of environmental competencies between the federal and *Länder* level. Moreover, Germany is a strong example of a consensus democracy (Lijphart, 1999), its constellation of veto players leading to incremental policy evolution or, even worse, deadlock in times of opposed majorities in both chambers of parliament. The electoral system creates coalition governments, normally comprised of a big (Social Democrats or Conservatives) and a small (Liberals or Greens) party, with considerable ideological heterogeneity of the actors involved. Coalition governments of the German kind tend to view their coalition agreements as binding contracts, making the formulation of new policies not agreed upon in the original agreement very difficult (Martin, 2004). This held true especially for the 2005–2009 'Grand Coalition' between Conservatives and Social Democrats. Although the Chancellor has the power to specify the overall direction of government policies (Richtlinienkompetenz), the administrative structure of the federal government is, in general, not favourable for integrated policy approaches and horizontal coordination as ministers have strong positions, leading their ministries under their own or their parties' responsibility, respectively. Finally, Germany is usually described as a 'high regulatory state', meaning that the body of environmental laws and regulation is dense and policies are, overall, geared towards top-down approaches. The use of new instruments of environmental governance, such as market-based instruments (eco-taxes, tradable permits, etc.) was only reluctantly introduced in the repertoire, none of them addressing the issue of sustainable production directly. On the other hand, (legally non-binding) voluntary agreements between government and industry were used quite often in the context of sustainable production, e.g. leading to the phasing-out of the use of harmful substances such as lead in petrol (Wurzel *et al.*, 2003). In the field of waste policy, however, instruments were implemented to influence product design at an early stage. The principle of producer's product responsibility was introduced with the Waste Management Act of 1986 and reconfirmed in the Cyclic Economy and Waste Act in 1996. This approach was quite successful with regard to packing materials for household products and batteries (Müller, 2002).

6.10 Conclusion and outlook

On the one hand there are still numerous problems to be solved and obstacles to be overcome for a 'decoupling policy' in Germany. Successful implementation of a new resource policy would certainly accelerate the ongoing structural change as well as the eco-efficiency revolution in Germany. In every period of rapid structural change there will be winners and losers, which raises specific challenges for the willingness and capabilities of governments and politics to take the lead. On the other hand, for Germany there is much evidence that in the long run raising resource productivity is a win-win-win option, leading to (net) benefits for the private sector, creating new 'green' business fields and jobs, and reducing environmental impacts and social tensions from resource extraction.

Over the long term, a new resource policy will need to aim to change the direction of technical progress, fostering resource productivity at least with the same intensity as that of the growth in labour productivity. The ultimate socio-economic goal should be a new labour-augmenting and nature-saving pattern of social and technological progress on the way to sustainable development.

7 South Africa[1]

South Africa has only recently emerged from a colonial and apartheid history spanning four centuries of racially-based dispossession and disenfranchisement, and which produced widespread, systemic poverty. The 1994 democratic transition heralded unprecedented change. Virtually every facet of policy and practice in the emergent democratic state was reviewed and revised. A Bill of Rights forms part of the new Constitution and specifically guarantees the right of all South Africans to have the environment protected for the benefit of present and future generations. But reconciling complex and sometimes conflicting relationships between poverty, economic development and protection of environmental assets is a major challenge. In particular, the dominant economic growth and development paradigm fails to address a wide range of underlying resource constraints that can rapidly undermine the preconditions for the kind of developmental growth that is required.

1 This case study is based on a report entitled Growth, Sustainability and Dematerialisation: Resource Use Options for South Africa, by Mark Swilling, commissioned by The Presidency, South African Government, presented at the Workshop on Scenarios for South Africa in 2019, The Presidency, Pretoria, July 2007 (Swilling, 2007).

© Henner Frankenfeld/VISUM/Still Pictures

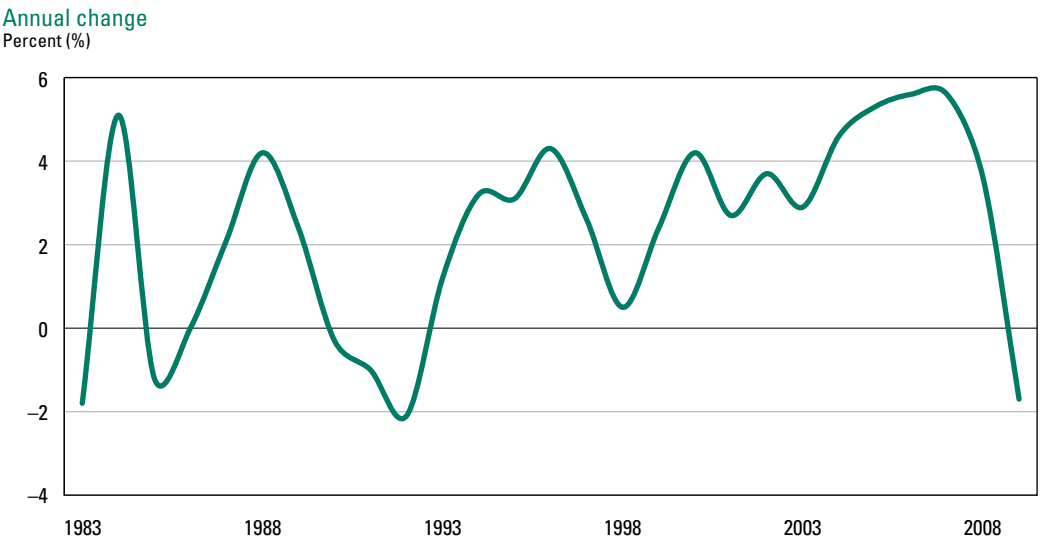
7.1 Recognizing limits[2]

It is becoming increasingly apparent that key ecological thresholds in South Africa are being breached by its prevailing approach to growth and development, and that this is resulting in dysfunctional economic costs. This condition of rising costs caused by a new set of material, ecologically-driven constraints sets the context for new ways of thinking about the country's economic growth model and poverty reduction strategies. Since the first democratic elections in 1994, South Africa has experienced an unprecedented growth period that came to an end towards the end of 2008. As a resource-rich resource-exporting country, South Africa benefited from the rise in commodity prices over the past decade, but suffered as they collapsed during 2008 as a result of the global financial crisis. Figure 7.1 and Figure 7.2 demonstrate this growth period, and how economic growth has correlated with employment growth, which is a key strategy to reduce poverty.

South African economic growth has been driven by a combination of expanded domestic consumption financed by rising levels of household debt, which in turn is securitized against residential properties, and exports of primary resources. The manufacturing sector has, unfortunately, declined in response to a vigorous strategy to lower import tariffs and liberalize the capital markets (thus favouring investments in liquid assets rather than long-term fixed investments). Figure 7.3 and Figure 7.4 reveal the rise in consumption spending and the decline in manufacturing.

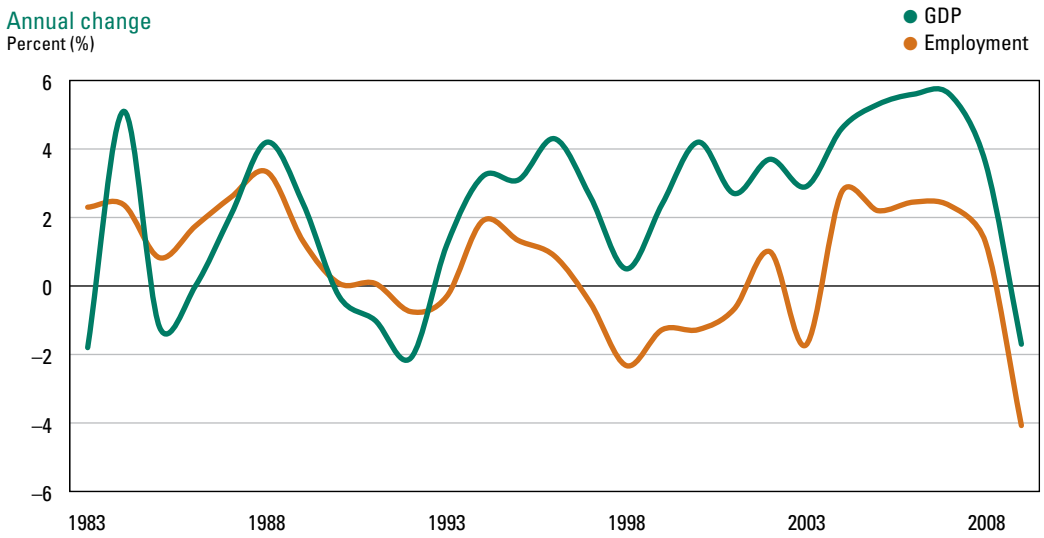
2 This section is based primarily, but not exclusively, on background research materials commissioned to inform development of the National Framework for Sustainable Development. The materials were circulated publicly and most are available on www.deat.gov.za. The commissioned research papers are referenced in the sub-headings that follow, and additional research integrated where necessary. Because this section relies quite heavily on these papers, they are not specifically referenced. The supporting research and backup references can be found in these commissioned papers.

Figure 7.1. Real GDP growth 1983–2004



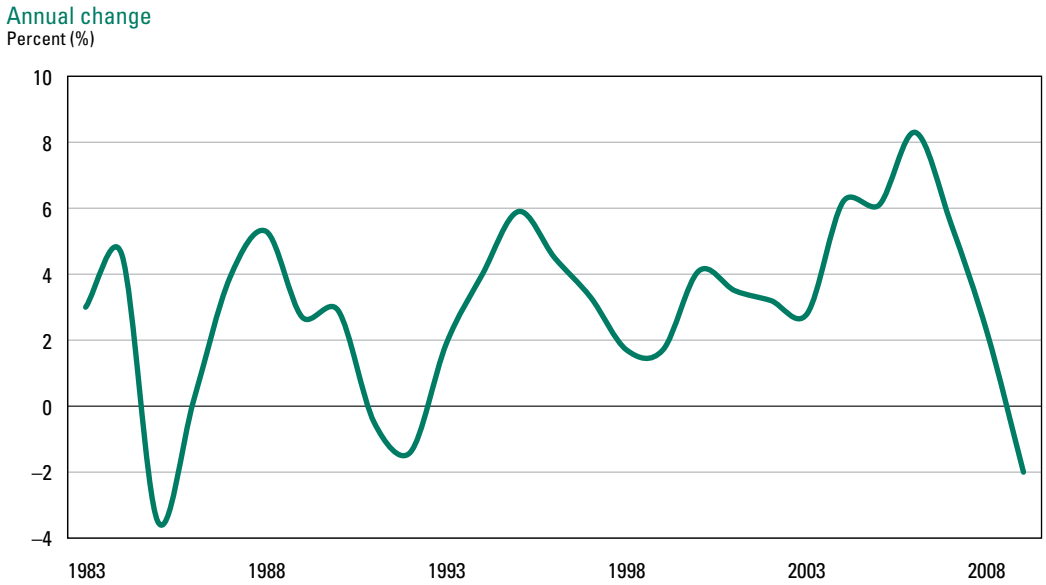
Source: South African Reserve Bank. Data cited in Quantec, 2010

Figure 7.2. GDP and employment change 1983–2004 (non-agricultural sectors)



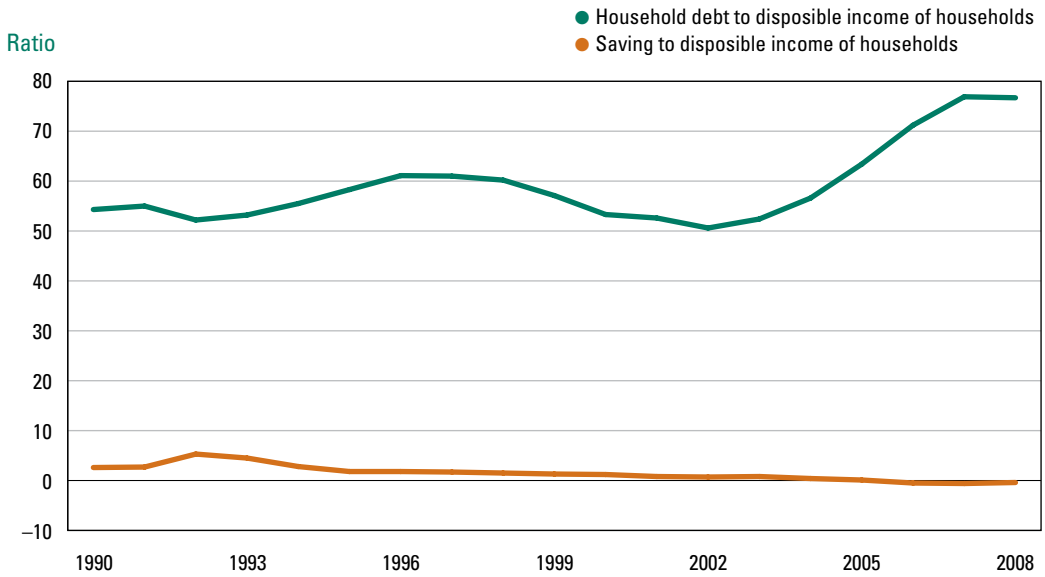
Source: South African Reserve Bank. Data cited in Quantec, 2010

Figure 7.3. Final consumption expenditure by households



Source: South African Reserve Bank. Data cited in Quantec, 2010

Figure 7.4. Percentage of household saving and debt 1970–2006



Source: South African Reserve Bank. Data cited in Quantec, 2010

The growth in final real demand is shown in Table 5.6, but when read against rising debt levels and decline in the manufacturing sector in the figures that follow, it is clear that debt-financed consumption has been the driver of consumer demand for an increasing quantity of imported products. The balance of payments pressures this created was at first mitigated by the beneficial impacts of rising commodity prices. But with the global economic crisis, both easy credit to drive consumption and high commodity prices came to an end.

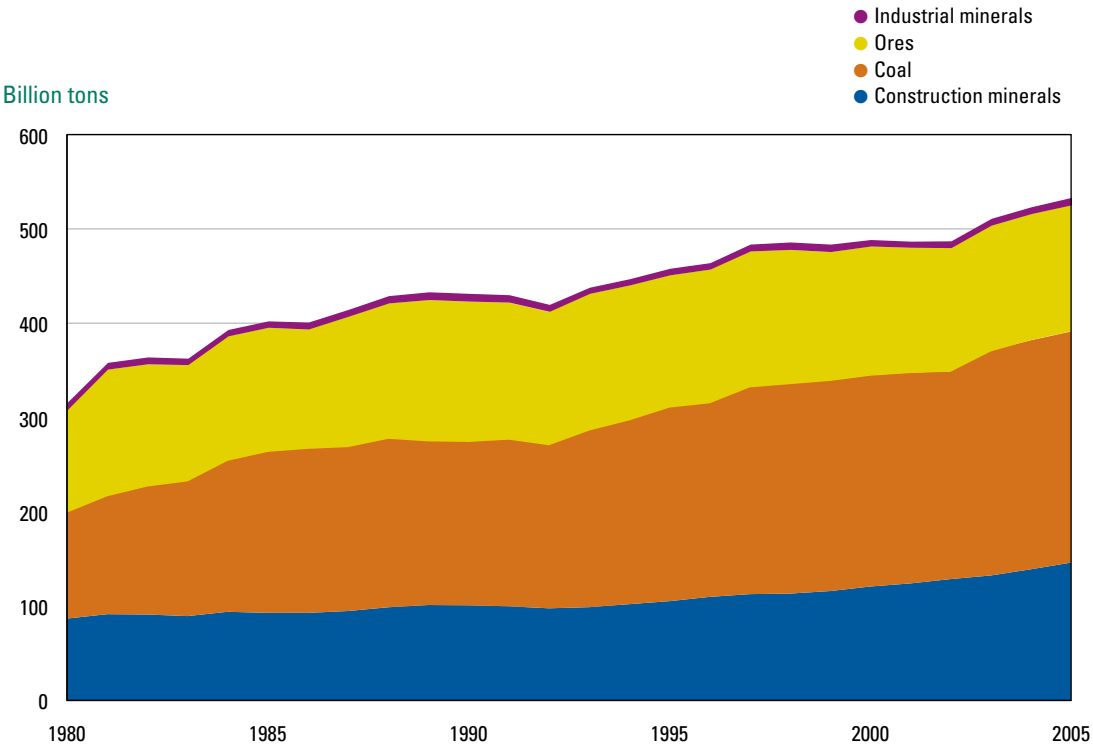
South Africa's dependence on its rich endowment of natural wealth is reflected in Figure 7.5. It reveals the significance of ore extraction, although it has declined since 1980. At the same time, coal extraction has increased to fuel the coal-based electricity generation industry which supplies the cheapest electricity in the world to South Africa's economy. The low-price coal and mineral policy has resulted in limited diversification of the economy and high levels of inefficiency.

Despite the dependence on ore and coal extraction, there is also evidence of decoupling in the 20 years leading up to 2000 as revealed in Figure 7.6. Although based on a limited study, Figure 7.6 does suggest that a relatively minor level of decoupling is taking place – domestic material consumption (DMC) of primary materials[3] has declined while population growth and GDP have grown. However, this may be misleading because the calculation of DMC excludes exported materials, with dramatic increases in the export of ores and coal as a key driver of GDP growth (see Figure 7.7).

In short, South Africa is a good example of an economy caught up in the financialization of a globalized economy. This has undermined manufacturing as tariff barriers have been lowered and cheap imports from Asia have risen. It has also resulted in debt-financed consumption spending, and increased dependence on revenues from exported primary resources

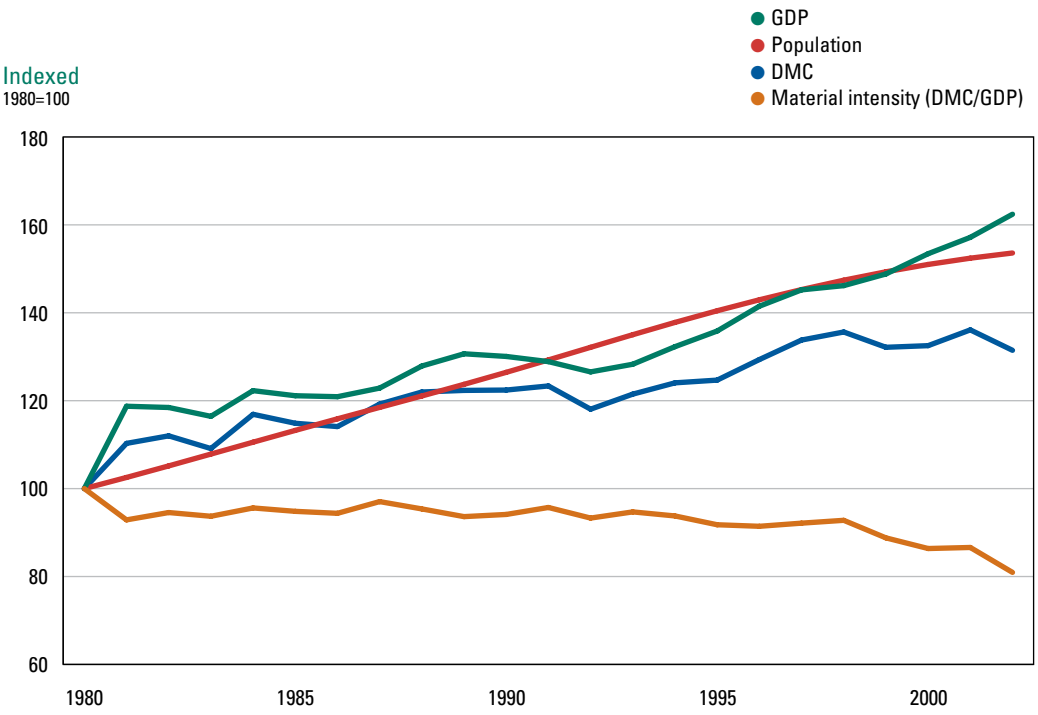
3 Domestic material consumption is the sum of domestic extraction of primary resources, plus imported primary resources, minus exported primary resources.

Figure 7.5. Domestic extraction



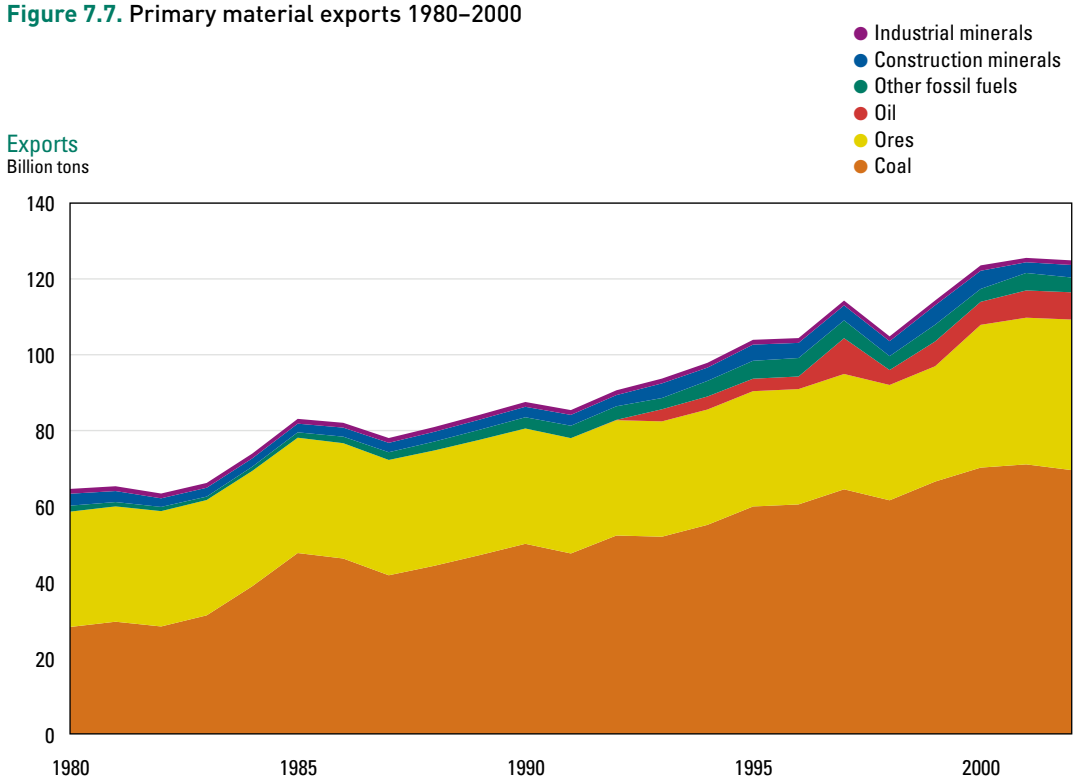
Source: Social Ecology Database (SEC database, http://www.uniklu.ac.at/soc ec/inhalt/3812.htm) and SERI (www.materialflows.net)

Figure 7.6. Material efficiency 1980–2000



Source: Social Ecology Database (SEC database, http://www.uni-klu.ac.at/socec/inhalt/3812.htm) and SERI (www.materialflows.net)

Figure 7.7. Primary material exports 1980–2000



Source: Social Ecology Database (SEC database, http://www.uni-klu.ac.at/socec/inhalt/3812.htm) and SERI (www.materialflows.net)

at low prices. The unsustainability of this is recognized by the government and key stakeholders and various interventions are being made.

However, South Africa is a robust constitutional democracy with three layers of government (National, Regional, Local) that are, in turn, independent from one another. This has resulted in very low levels of intra-governmental coordination. Each sector responds to the sustainability challenges in its own way, but what is lacking is a government-wide approach that connects industrial policy, environmental policy, and resource management strategies. These sectoral responses are discussed further below.

7.2 Climate change[4]

Using the Global Climate Models the following changes to the South African climate within the next 50 years were predicted, with drastic impacts on national water availability, food and biomass production capacity, incidence of disease and the country's unique biodiversity:

- continental warming of between 1 and 3°C;
- broad reductions of approximately 5 to 10 % of current rainfall;
- increased summer rainfall in the northeast and southwest, but reduced duration of summer rains in the northeast;

4 Based on the work of the Scenario Building Team 2007, Department of Environmental Affairs and Tourism, 2005a.

Table 7.1. Comparative carbon emissions 2004

	Population (million)	GDP per capita US$	Carbon footprint (CO_2 emissions per capita (tons))	Carbon intensity (CO_2 emissions per unit of GDP)
South Africa	46.6	10,715	9.8	0.99
Sub-Saharan Africa	781.3	1,945	1.0	0.57
USA	293.6	40,971	20.6	0.57
OECD	1160.5	28,642	11.5	0.45
World	6389.3	9,348	4.5	0.55

Source: UNDP, 2007

- nominal increases in rainfall in the northeast during winter season;
- increased daily maximum temperatures in summer and autumn in the western half of the country;
- extension of the summer season characteristics.

CO_2 is South Africa's most significant greenhouse gas (GHG), contributing more than 80% of its total GHG emissions for both 1990 and 1994. The main source of CO_2 emissions was from the energy sector, which generated 89.7% of total CO_2 in 1990 and 91.1% in 1994. These high emission levels relate to the high energy intensity of the South African economy, which depends on large-scale primary extraction and processing, particularly in the mining and minerals beneficiation industries. Although still a developing economy, its energy intensive nature and its dependence on coal-driven energy sources results in an extremely high carbon emission level per unit of GDP compared to the rest of the world (see Table 7.1).

A Long Term Mitigation Scenario (LTMS) exercise (see next page) produced two primary scenarios, namely the Growth without Constraints Scenario and the Required by Science Scenario. The first models long-term implications of current economic policy, and concludes that emissions will grow from 440 megatons of CO_2-equivalent in 2004 to 1600 megatons of CO_2-equivalent by 2050. This would involve fuel consumption rising by 500%, building seven new coal-fired power plants or 68 Integrated Gassification plants, constructing nine conventional nuclear and 12 Pebble Bed Modular Reactor (PBMR) plants, and introducing five new oil refineries. Renewable energy will play a negligible role. The Required by Science Scenario envisages very radical interventions to position South Africa in a post-carbon world. The result would be a 30–40% reduction of CO_2-equivalent emissions by 2050 from 2004 levels. The scenario views this ambitious programme of extreme decoupling as necessary, but admits it cannot be reliably costed as the required technologies must still mature. The LTMS document was adopted by the South African Cabinet in July 2008, with a commitment to the Required by Science Scenario as the preferred option. This has major implications for economic and development policy.

7.3 Oil resources[5]

Imported oil meets approximately 16–20% of South Africa's energy needs. Table 7.2 illustrates that if demand for liquid fuels in South Africa (essentially the hydrocarbons petrol, diesel and jet fuel) is driven by current transport demand patterns and transport modes, even modest growth rates of 3% and 6% per year would lead to increases of 1.8 and 3.2 times the present (2004) volumes.

5 Based on the work by Jeremy Wakeford (Wakeford, 2007).

Table 7.2. Past and projected consumption of transportation fuels (million litres/year)

											Low growth rate (3%)	High growth rate (6%)
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2024	2024
Petrol	10,153	10,566	10,798	10,883	10,861	10,396	10,340	10,335	10,667	10,985	19,840	35,230
Diesel	5,432	5,759	5,875	5,959	5,993	6,254	6,488	6,831	7,263	7,679	13,869	24,628
Jet fuel	1,368	1,601	1,777	1,877	1,995	2,020	1,924	1,967	2,099	2,076	3,749	6,658

Source: Cairncross, 2005

Current macro-economic policy documents do not address the challenge of peak oil. There is no estimate of the rate of increase of the oil price, nor is there an assessment of the potential impact if oil prices continue to rise, as they inevitably will. The combination of growing demand and rising prices will severely undermine economic growth and poverty reduction measures. It follows that either growth rates must be revised downwards, or massive investments are required to substantially reduce consumption of imported hydrocarbons.

7.4 Energy[6]

Just over 70% of South Africa's energy is derived from coal. This is a long-term trend and will more than likely continue well into the future. The remaining 30% is derived from oil (20%), gas (1.5%), nuclear (3%) and biomass (5.1%). Significantly, coal-to-liquid and gas-to-liquid technologies account for 30% and 8% respectively of the total liquid fuel supply.

Cheap energy (possibly the cheapest in the world) and abundant coal supplies have made it possible to build an energy-intensive economy. Table 7.3 reveals how resource intensive the South African economy is compared to other parts of the world.

The biggest future challenge for the energy sector is the steady growth in electricity demand without a clear plan to increase generation capacity. Expanding access to electricity by poor households and the imperatives of a growing economy put increasing pressure on supply. In 2006–07 rolling blackouts across the country took place because reserve margins dropped below a safe level of 15% exacerbated by inefficient management of coal supply and maintenance regimes.

To date policymakers have paid little attention to large-scale energy efficiency (EE) and renewable energy (RE) interventions. The White Paper on Renewable Energy (November 2003) identified a RE target of 4% by 2013 and a 12% reduction in energy intensity by 2014. Scenario-building exercises have provided evidence that up to 50% of South Africa's future energy supply could come from RE by 2050. However, for this to be realized, planning and investments need to proactively focus on this long-term trend. In other words, there is agreement that the energy sector must be dematerialized, but no agreement on how far this should go or on the balance between RE and EE.

In the short term, immediate electricity generation needs will be met by re-commissioning old coal-fired power stations. The long-term financial viability and security of nuclear power remains uncertain. Short-term high-impact investments in proven wind and solar power technologies could rapidly create the basis for a long-term supply of renewable energy.

6 Based on AGAMA Energy, 2005.

Table 7.3. Energy intensities

	TPES/capita	TPES/GDP	TPES/GDP	Elec. consumption per capita (national average)
	Toe/capita	Toe/ 000 1995 US$	Toe/ 000 PPP 1995 US$	kWh/capita
South Africa	2.51	0.63	0.29	4,533
Africa	0.64	0.86	0.32	503
South Korea	4.10	0.31	0.30	5,901
Indonesia	0.69	0.70	0.25	390
Non-OECD	0.96	0.74	0.28	1,028
OECD	4.78	0.19	0.22	8,090
World	1.67	0.30	0.24	2,343

Key: TPES = total primary energy supply, toe = tons of oil equivalent, PPP = purchasing power parity (i.e. adjusted to remove distortions of exchange rates), GDP = Gross domestic product.
Source: SARB Quarterly Bulletin

7.5 Water and sanitation[7]

With an average annual rainfall of 497mm South Africa is a dry country. And, 98% of available water resources have already been allocated. This means that "South Africa simply has no more surplus water and all future economic development (and thus social well-being) will be constrained by this one fundamental fact that few have as yet grasped" (Turton, 2008,p.3). The country therefore has no further 'dilution capacity' when it comes to absorbing effluents in its water bodies. The Johannesburg-Pretoria complex – South Africa's most significant urban-economic conurbation – is located on a watershed which means that outflows of wastewater pollute the water resources this conurbation depends on. The result is that after China, South Africa's national water resources contain some of the highest toxin levels, in particular mycrocystin for which no solution currently exists. Cyanobacteria blooms, caused by end-of-pipe NPK loads, threaten national water security. Inter-basin water transfers have degraded the ecological integrity of aquatic systems, and radionuclides, heavy metals and sulphates from mining activities have polluted valuable water resources. In short, the combination of low average rainfall, overexploitation and re-engineered spatial flows have led South Africa to an imminent water crisis in quantity as well as quality.

According to the Department of Water Affairs, in 2000 there was still surplus capacity of around 1.4%. Recent models indicate that very serious water shortages can be expected by as early as 2013. Significantly, it is the urban and domestic sector where consumption increases are set to triple:

Table 7.4. Historical water consumption (1996) and projected water demand (2030) by sector

	m³/year	
Sector	1996	2030
Urban and domestic	2,171	6,936
Mining and industrial	1,598	3,380
Irrigation and afforestation	12,344	15,874
Environmental	3,932	4,225
Total	20,045	30,415

Table 7.4 graphically represents the resource use crisis that will be generated by economic growth and poverty

7 This section relies on the following documents: Turton, 2008; Department of Water Affairs and Forestry, 2006; Republic of South Africa, Department of Water Affairs and Forestry, 2004; Republic of South Africa, Department of Water Affairs and Forestry, 2002; Ashton & Turton, 2008).

eradication if existing water management systems and processes remain unchanged.

There is scope for major water saving in two sectors – urban and domestic use, and the agricultural sector. Recycling urban wastewater is an urgent priority. For example, between 40% and 50% of all water piped into households is used to flush toilets. Yet it is technically possible to flush toilets from on-site grey water flows (in particular for large middle class homes), or via neighbourhood-level closed loop systems that recycle water back to households. Rainwater harvesting and grey water supplies for irrigation also have potential. The second major water-saving priority is in agriculture, especially in combination with organic farming methods that simultaneously rebuild the biological capacity of soils and moisture retention capacity in the top layers.

The government is aware of these severe water supply constraints. In her 2007 Budget Speech, the Minister of Water Affairs and Forestry dedicated considerable space to her water efficiency campaign, with apparent emphasis on regulations and tighter controls. But unless more immediate and drastic action is taken, economic growth will soon be undermined by water shortages and related dysfunctionalities (like salinization of aquifers, etc,). The research results are clear: available physical extra capacity in 2000 was at most 1.7% higher than existing requirements, while growth in water demand could be as much as 25% higher than available yield by 2025. Even if demand only increases by 1% per year, by 2014 the economy will already be facing severe shortages on a number of fronts. By 2019, water shortages will have pulled the economy into a downward spiral of low growth and growing socio-economic inequalities, with associated mini-'resource wars' over water supplies.

Sophisticated modelling work by University of Pretoria researchers shows that a combination of physical, fiscal, institutional and technological interventions could turn this potential disaster into a major opportunity for effective sustainable resource use (Blignaut, 2006). However, for this to occur, water resources need to be seen as a 'binding constraint', and the government must seriously invest in the sustainable resource use approach advocated by all leading researchers and policy managers in the water resource sector.

7.6 Solid waste[8]

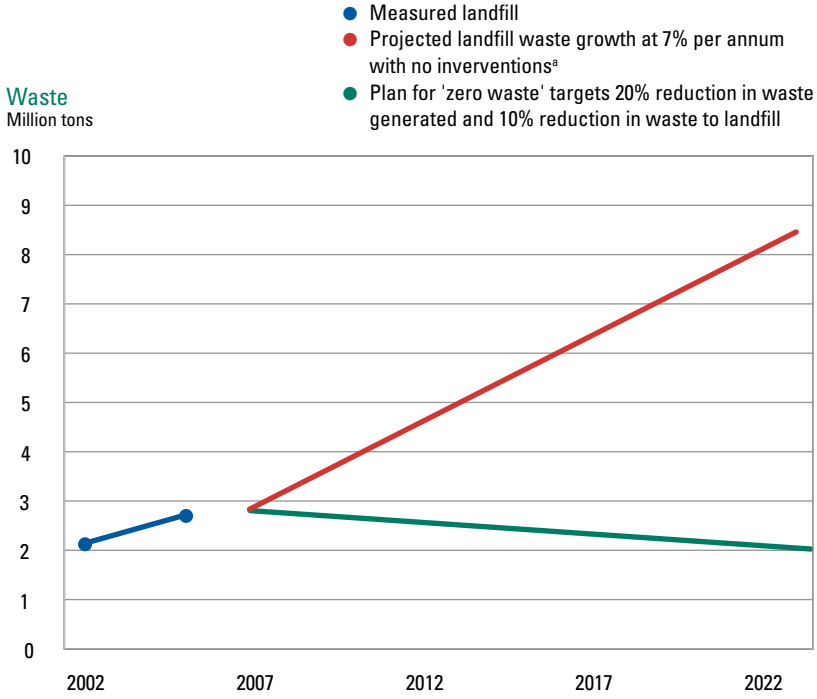
Solid waste includes all municipal and industrial waste. As of 2005, the solid waste system managed the disposal of 20 Mt[9] of municipal solid waste (MSW), 450 Mt of mining-related wastes and 30 Mt of power station ashes.

MSW quantities are growing faster than the economy in many cities.[10] The typical daily average of 2kg/person is 3–4 times that in many European cities. Both the quantity and nature of solid waste differs considerably across the socio-economic spectrum. People in informal settlements generate on average 0.16kg per day, whereas over 2kg per day is not unusual in affluent areas. Food and green waste make up 35% of waste in affluent households, compared with 20% for poor households. In Cape Town 60% of industrial waste is recycled, compared to only 6.5% of residential and commercial waste (among the lowest in the world). There is no reason to believe that the situation is very different in other South African cities.

While many countries have moved away from 'disposal-to-landfill' as the primary means of solid waste management, in South Africa the large bulk of MSW is disposed of in landfill sites spread out across the country. Although national costs

8 Based on Von Blottnitz, 2005.
9 Mt =1 million metric tonnes or 1 billion kg.
10 For example, in Cape Town MSW is growing by 7% per year.

Figure 7.8. Solid waste disposal in millions of tons in Cape Town, 2002–2027



a Excludes effect of tourism and industry growth
Note: Effect/implications of waste minimization: Roll-out/implementation must create infrastructure, educate and make all aware, encourage public/industry participation, facilitate creation of recycling market through partnerships (industry, NGOs, CBOs), enable job creation through recycling rather than clean-ups, and enforce stricter standards.
Source: Adapted from City of Cape Town, 2007

have not been calculated, they are probably similar to those in Cape Town where the cost of managing landfills – and related dumping – doubled between 2000 and 2004.

Growth in the minerals and coal-based energy sector directly leads to increased industrial wastes with limited productive recycling and reuse – a clear example of the way unsustainable resource use is coupled to growth and poverty reduction. Yet technologies and processes for decoupling waste from growth and poverty eradication are simple, low cost and extensively used throughout the world.

Waste recycling represents one of the most immediate, tangible and low-cost investments in dematerialization available. It saves on capital costs, creates jobs, and forces the middle classes to take greater responsibility for the resources they throw away. It is also normally a highly competitive sector, with sophisticated value chains with respect to resources like used engine oil, used vegetable oils, a wide range of plastics, building rubble, organic matter for composting, glass, cans, paper, etc. Numerous studies confirm that recycling has very positive economic benefits with respect to job creation, manufacturing and technology and innovation. Furthermore, waste recycling also has significant export potential.

The National Integrated Waste Management Act adopted by Parliament in 2009 will force every local government authority to prepare an Integrated Waste Management Plan with defined targets for recycling, thus paving the way for a recycling revolution in South African cities. The stage is now set to move South Africa decisively into a post-disposal approach with respect to MSW, with a special focus

on middle and high income consumers. The Mineral and Petroleum Resources Development Act (2002) makes specific provision for waste management and pollution control in the mining sector. This Act, together with the emerging MSW approach, provides the basis for the emergence of a vast decentralized network of market-driven and community-based recycling businesses. In addition the National Cleaner Production Strategy is being beefed up, establishing incentives and legal requirements to stimulate cleaner production systems (CPS) in the business sector – particularly mining and construction – with a special focus on investments in recycling enterprises.

7.7 Soils[11]

South Africa falls within the so-called 'third major soil region' typical in mid-latitudes on both sides of the equator. The result is that South Africa is dominated by very shallow sandy soils with severe inherent limitations for agriculture. Only 13% of the land is arable and just 3% high potential land. The result is overexploitation and the use of inappropriate farming methods, as the nation tries to exceed its soils' capacity to meet growing food requirements. All this has resulted in far-reaching nationwide soil degradation.

Water erosion remains the biggest problem, responsible for the loss of an estimated 25% of the nation's topsoil in the past century and continuing still. Other factors include: wind erosion affecting 25% of soils; soil compaction due to intensive mechanized agriculture; soil crusting caused by overhead irrigation systems; acidification of more than 5 million hectares of arable land, caused by poor farming practices particularly incorrect fertilizer and inadequate lime applications; soil fertility degradation resulting from annual net losses of the three main plant nutrients (Nitrogen, Phosphorous and Potassium); soil pollution caused by various human practices; urbanization

11 Based on Laker, 2005.

often spreading across high-value arable land on the outskirts of cities.

Once degraded, there is little potential for recovery. Areas where degradation is limited must be prioritized so that efforts can be focused on prevention via appropriate farming practices. Reversing the above trends will require locally trained soil scientists who recognize that soil conditions are unique (because they are 'third major soil region' soils) and that therefore the nation cannot copy solutions generated in countries with a different soil profile. Location-specific technical solutions are required as blanket solutions have proven unworkable. Locally trained soil scientists must work together with local leader farmers via horizontal learning practices. This has worked in India, Cuba and many other places in the developing world and is urgently required in South Africa.

7.8 Biodiversity[12]

South Africa is globally recognized as the third most biologically diverse country in the world, yet this diversity is one of the most threatened on the planet. Significantly, this concerns not just the prevalence of plant and animal species, but also critical ecosystems that provide vital services to human society.

Although South Africa has invested enormous public, private and community resources in the expansion of protected areas, conservation areas and reserves, in the future, the innovative partnerships will be required to ensure that the burden for all this is not carried entirely by the fiscus. To this end the Protected Areas Act offers a unique opportunity. It provides for any land, including private or communal, to be declared a formal protected area, co-managed by the landowner(s) or any suitable person or organization. This means that formal protected area status is not limited to state-owned land, and that government agencies are not the only organizations that can manage protected areas, opening the way for a range of innovative arrangements not previously possible. A related challenge is to make the links between protected area development, sustainable tourism, and benefits to surrounding communities who should be key stakeholders in protected areas.

The National Environmental Management Act provides for a comprehensive regulatory framework for protecting key environmental resources. The core instrument used to give effect to this Act is Environmental Impact Assessment (EIA). Although development projects must be subjected to an EIA, the focus is on costs of pollution and environmental impacts, and not resource inputs and prices. This does not provide a sufficient basis for decoupling over the long run.

12 Based on Driver *et al.*, 2005.

Table 7.5. Key threats to South Africa's ecosystems

	Officially classified as threatened	Main issues and causes
Terrestrial ecosystems	**34%**	degradation of habitat, invasion by alien species
Freshwater ecosystems • Wetlands destroyed • Fish threatened	**82%** 50% 36%	pollution, over-abstraction of water, poor water course condition
Marine ecosystems • Estuaries endangered	**65%** 62%	climate change, unsustainable marine harvesting, seabed destruction by trawling, coastline urbanisation, marine pollution

Source: Driver *et al.*, 2005

7.9 Policy responses

Recent years have witnessed an emerging trend in South Africa's national policy discourse calling for more responsible use of natural resources. Growing numbers of policy statements acknowledge that the country's economic growth and development path is too resource-intensive and that this needs to change. However, this way of thinking is by no means a dominant paradigm in policymaking circles. Section 24(b) of South Africa's new Constitution commits the state to "secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development". This provides the point of departure for the National Framework for Sustainable Development (NFSD) adopted in June 2008 (Republic of South Africa, Department of Environmental Affairs and Tourism, 2007). However, key macro-economic policy documents make no reference to this constitutional provision.

7.9.1 Macroeconomic policy versus Section 24(b) of the Constitution

In line with an ideological shift since 2002 away from neo-liberalism towards a more 'developmental state' approach, the Accelerated and Shared Growth Initiative for South Africa (ASGI-SA) was adopted in 2006 as the official economic policy framework. Its focus is on specific 'binding constraints' that must be dealt with via concerted state-coordinated interventions that run contrary to traditional neo-liberal prescriptions. ASGI-SA lists the following binding constraints: currency volatility; cost, efficiency and capacity of the logistics and transport system; shortage of skilled labour; barriers to entry and limits to competition; regulatory environment; and state capacity.

In 2007, the cabinet adopted the National Industrial Policy Framework (NIPF) (Republic of South Africa, Department of Trade and Industry, 2007). The NIPF lists four preconditions for effective industrialization through industrial sector interventions:

- stable and supportive macroeconomic environment
- adequate skilled labour supply supported by appropriate education infrastructure
- existence of traditional and modern infrastructure[13]
- innovation capabilities to foster development of domestic technologies and systems.

Neither ASGI-SA nor NIPF make any reference to Section 24(b) of the Constitution. Natural resources and ecosystem services are not identified as 'binding constraints' suggesting that no action is required to prevent further degradation. A viable set of ecosystems and long-term supply of natural resources are not regarded as preconditions for successful industrialization. The implicit assumption appears to be that natural systems, within which the socio-economic system is embedded, are intact and durable.

7.9.2 National Framework for Sustainable Development

The NFSD was adopted by the cabinet in June 2008. In sharp contrast to macroeconomic policy, it explicitly acknowledges the growing stress on environmental systems and natural resources from economic growth and development strategies, and maps out a vision and five 'pathways' to a more sustainable future:

- enhancing systems for integrated planning and implementation

13 Traditional infrastructure includes transport, electricity, water, while modern infrastructure refers to wireless, satellite, broadband, fixed line and mobile telecommunication networks.

- sustaining our ecosystems and using resources sustainably
- investing in sustainable economic development and infrastructure
- creating sustainable human settlements
- responding appropriately to emerging human development, economic and environmental challenges.

The NFSD commits South Africa to a long-term programme of resource and impact decoupling. The Government has resolved that the NFSD will be converted into a full-blown National *Strategy* for Sustainable Development by the end of 2009 that will include specific targets, commitments and budget allocations.

7.9.3 Growing influence of sustainability thinking

In July 2008, the South African cabinet endorsed the outcomes of the Long Term Mitigation Scenario (LTMS) process, which explored options for climate change mitigation in a multi-stakeholder exercise. Reinforcing the NFSD, the LMTS recommended the Required by Science Scenario that envisages a 30–40% reduction in South Africa's emissions by 2050.

In April 2006 the National Treasury published for comment a remarkable document entitled *A Framework for Considering Market-Based Instruments to Support Environmental Fiscal Reform in South Africa.* The document defines an environmental tax as a *"tax on an environmentally-harmful tax base"* (Republic of South Africa, National Treasury, 2006ii (emphasis in original)) and examines all existing environmental taxes, charges and levies,[14] which combined account for approximately 2% of GDP and just under 10% of total tax revenue. The report suggests that in light of the sustainable development challenge, tax shifting is required so that taxes levied on 'bads' (such as pollution) can be increased and taxes on 'goods' (such as labour) reduced. This, the report argues, is the 'double-dividend hypothesis' – "minimising the burden of environmentally-related taxes on the affected sectors, whilst creating the required behavioural incentives to achieve certain environmental outcomes" (Republic of South Africa, National Treasury, 2006v). Put differently, taxes from unsustainable practices should increase, and be re-invested in more sustainable practices.

It is noteworthy that the National Treasury perspective described above is effectively a command-and-control perspective focused on impacts. This is different to 'upstream' interventions that focus on primary resource inputs and prices. Nevertheless, this report, plus the gathering influence of the NFSD, did lead to the following statement by the Minister of Finance during his Budget Vote speech in 2008:

> *"We have an opportunity over the decade ahead to shift the structure of our economy towards greater energy efficiency, and more responsible use of our natural resources and relevant resource-based knowledge and expertise. Our economic growth over the next decade and beyond cannot be built on the same principles and technologies, the same energy systems and the same transport modes, that we are familiar with today."*

The above quote is the clearest and most radical statement by a senior South African politician to date about the need for far-reaching measures to decouple rates of growth from rates of resource consumption. Nevertheless, there are other Ministers who have responded to resource constraints in their respective sectors by emphasizing the need for

14 Transport fuel levies (General Fuel Levy, Road Accident Fund Levy, Equalisation Fund Levy, Customs and Excise Levy); Vehicle Taxation (Ad Valorem Customs and Excise Duty, Road Licensing Fees); Aviation Taxes (Aviation Fuel Levy, Airport Charges, Air Passenger Departure Tax); Product Taxes (Plastic shopping bags levy); Electricity (NER Electricity Levy; Local Government Electricity Surplus); Water (Water Resource Management Charge, Water Resource Development and use of Water Works Charge, Water Research Fund Levy), and Wastewater (Wastewater Discharge Charge System - proposed).

sustainable resource use approaches. These include the Minister of Water Affairs and Forestry who has admitted that by 2013 South Africa will face severe water shortages if alternatives are not implemented; the Minister of Minerals and Energy who has finally acknowledged that South Africa needs a rapidly expanding renewable energy sector;[15] and the Minister of Housing who wants to see all low-income housing settlements subsidized by government to include sustainable design elements such as correct orientation, insulation, public transport links, recycling, energy efficiency and renewable energy supply. Significantly, the Minister of Science and Technology has called for a ten-year science investment plan that will include a strong focus on innovations for sustainability, with decoupling referred to as a specific goal for innovation research and incentives. The Department of Environmental Affairs and Tourism has completed the National Cleaner Production Strategy. This document lays down the framework through which different stakeholders (government, industry and civil society) will participate in ensuring that South Africa achieves her goals on sustainable production and consumption (DEAT, 2005b).

7.10 Decoupling – opportunities for action

Perhaps the most significant prospect for decoupling in South Africa is the massive injection of public and private investment funds to drive a vast multi-year infrastructure investment programme worth nearly R800 billion. A cornerstone of the government's long-term growth strategy, this national programme offers a unique opportunity to advance towards a more sustainable future. There is no doubt that public investment in infrastructure is a powerful way to ensure that growth sets up the conditions for meaningful poverty reduction. But there are two key questions.

The first is whether these investments address the challenges discussed above. There are some obvious positive investments, such as in public transport, upgrading of the rail infrastructure, and sustainable approaches to housing. These are already government priorities. There are also some obvious gaps, e.g. investments in soil rehabilitation, water and sanitation, air quality and renewable energy on scale.

The second question is less about *what* is being built, but rather about *how* it will be built. There is an enormous opportunity to design and build low-carbon infrastructures and buildings that could contribute significantly to decoupling. Furthermore, the way infrastructures and buildings are developed on scale could be the single biggest catalyst ever available to drive a long-term commitment to sustainable resource use that, in turn, frees up resources for poverty eradication. Finally, doing things in new ways opens up a wide range of new value chains that could be exploited by new entrants into the sector with major employment creation opportunities. In its response to the global economic crisis, the government has accepted that 'green collar jobs' will play a role. The box, opposite, provides an overview of feasible and affordable strategic measures, following priority headings used in the ASGI-SA policy document to prioritize investment focus areas.

7.10.1 Decoupling opportunities

The summary below is an elaboration of the national economic development priorities of the country aimed at demonstrating what the decoupling opportunities are. They do not have official status, but many are already being considered or could be considered with relatively minor shifts in policy.

15 A renewable Energy Feed-In Tariff was introduced in 2009, as well as a new Air Quality Management Act.

Energy

- Increase Energy Efficiency by 20-30%: boost Demand-Side Management fund, remove it from ESKOM control, establish efficient decision-making system
- Increase Renewable Energy supply to 30% of national requirements from large-scale wind, solar, wave and biomass plants by Independent Power Producers using Feed-In Tariffs, and incorporate solar energy into all residential developments
- Promote solar roof tops: co-finance one million new houses with solar roof tiles and water heaters
- Create financial incentives and terminate disincentives via price-mechanisms for investment in energy efficiency innovations

Water and sanitation

- Switch from building dams to sustainable ground-water exploitation and management (including storage and aquifer replenishment)
- Invest in reducing water loss from leakages to below 10%
- Reduce domestic water consumption by 40% via mandatory use of water efficient household fittings, grey water recycling and rainwater harvesting
- Build neighbourhood-level plants that recycle grey water for toilet flushing, capture methane gas for energy generation and capture nutrients for reuse in food production and greening
- Invest in technology innovations to reverse the qualitative degradation of national water resources

Transport and logistics

- Increase investments in urban public transportation systems, especially Bus-Rail-Transit
- Shift long distance freight transport from road to rail
- Reduce dependence on oil via a shift to electric cars, hydrogen and ecologically sustainable biofuels

Housing and social infrastructure

- Eliminate housing backlog through construction of 5 million low-income houses with sustainable design and close to centres of employment
- Increase densities from 15-20 dwelling units/hectare to a minimum of 35-45 dwelling units/hectare via smaller plot sizes, multi-story living, and neighbourhood designs that minimize private vehicle transportation
- Implement municipal 'green house' regulations governing all private, public and social infrastructure

Local Economic Development (LED) infrastructure

- Substantial investment in institutional development for LED as envisioned in the LED Framework for South Africa (2006)

7.11 Conclusion

The dominant economic paradigm in post-apartheid South Africa has to date failed to recognize and address a wide range of underlying resource constraints that will almost certainly undermine many preconditions for growth and development. This case study demonstrates that growth and poverty eradication strategies are not decoupling from unsustainable natural resource use and exploitation. Reversing this trend will require policy frameworks and interventions that are currently absent from national economic policy documents.

There is broad consensus around two economic and social challenges for South Africa's second decade of democracy:

- how to boost growth to 6% and ensure a more equitable distribution of wealth;
- how to eradicate poverty, with special reference to the Millennium Development Goals.

The sustainability perspective means there now is a third challenge, and due to the adoption of the NFSD and LTMS, this is being recognized:

- how to decouple growth rates and poverty eradication from rising levels of natural resource use and waste (commonly referred to as 'dematerialization').

Many of South Africa's leading scientists have for some time been saying that economic growth policies are premised on incorrect assumptions about the health and durability of its natural resources and ecosystem services. Aligning economic policy with Section 24 (b) of the Constitution is not simply about preserving the environment. As other countries have experienced, it is also about preventing wasteful expenditures on avoidable system failures. But above all, it can also be about the creation of new opportunities for driving non-material forms of growth that improve quality of life for all, forever.

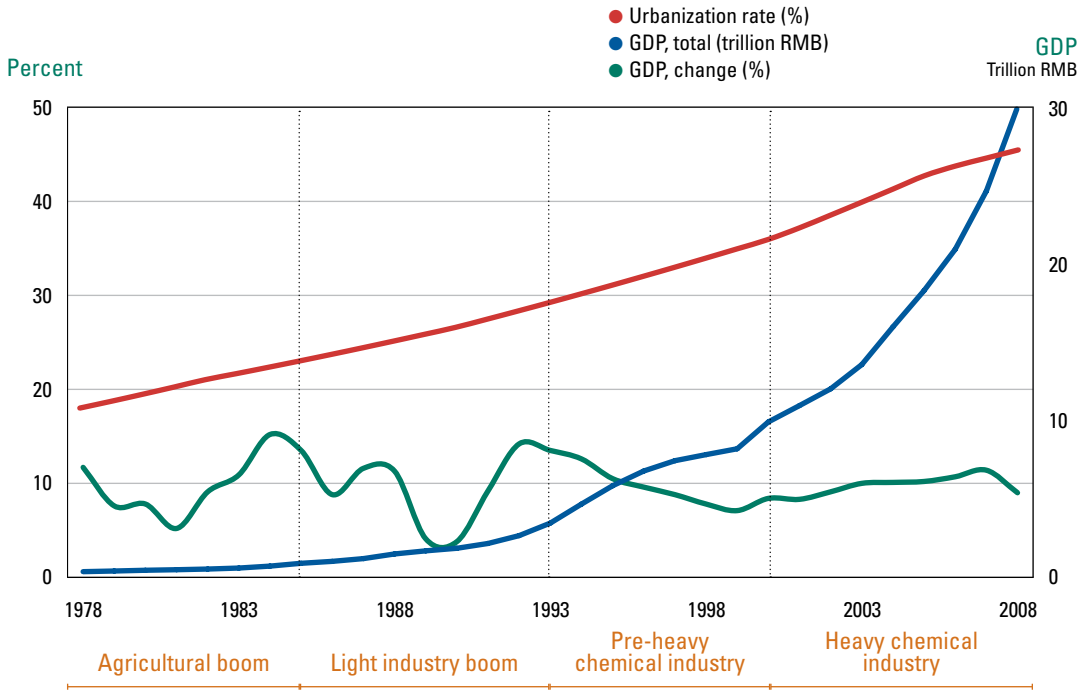
8 China

Four decisive factors determine China's environmental and ecological status. First, the country's highly diverse but generally fragile ecological systems: one third of its land is arid or drought-prone, and one fifth is considered ecologically fragile (SEPA, 2004). Second, its huge population: currently at 1.3 billion, projected to reach 1.5–1.6 billion by 2030, stabilizing at around 1.4 billion by 2050 (He Juhuang, 2001). Third, its limited natural endowment on a per capita basis compared to world averages.[1] Fourth, its economic growth path: given the first three factors, China's pattern and pace of growth has become the most critical variable in relation to its environment.

Since the launch of reform 30 years ago, China has gone through four stages of economic development (Figure 8.1) (Wang Mengkui, 2005). The first was characterized by economic recovery featuring rural reform and rapid agricultural development. The second, from the mid-1980s, witnessed the rise of non-agricultural industries especially textile and light industries. In the third stage, the output of the heavy-chemical industry began to overtake that of

1 In per capita terms, China's mineral resources are 58% of the world average; its water resources 25%; its arable land 33%; its forest cover just 21% (http://zhidao.baidu.com/question/19598240.html?fr=qrl3).

Figure 8.1. The process of economic development in China since 1978



Source: China Statistics Yearbooks, 1979–2009, the People's Republic of China

light industry. The fastest growing sectors were in energy and raw materials, such as oil and natural gas; infrastructure such as roads, ports and power; and household appliances. This period was accompanied by rapid urbanization. In the fourth stage, post-2000, the heavy-chemical industry became the major driver for growth.

Heavy-chemical industries are major consumers of energy and resources, and significant polluters. Starting in the late 1990s, therefore, China entered an era of tremendous environmental challenges. Furthermore, China's industrialization is taking place in a highly compressed and accelerated timeframe when compared to that of Europe, North America and even Japan. While this has brought about fast-growing material wealth for Chinese people, it also means that China faces a rapid accumulation of serious environmental problems.

8.1 Recognizing limits

Calculated in contemporary prices and current exchange rates,[2] over the 30 years from 1978 to 2008, China's GDP has expanded by an annual average of 9.8% to US$4.4 trillion (PRC, 1979; 2009). This growth has been non-linear with an accelerated rate of growth in later years accompanied by massive discharge and emission of pollutants. China is now the world's second largest CO_2 emitter, and may top the world in SO_2 emissions and Chemical Oxygen Demand (COD) discharge. COD discharge in China has exceeded the environmental carrying capacity by 80% and the picture of SO_2 emissions is similarly grave (CCICED, 2007a; MEPC, 2009). On the resource input side, resource intensity[3] per unit of GDP is about 90% higher than the world average (Chinese Academy of Sciences, 2006), while energy efficiency is 10% below that of the developed world. The Chinese government acknowledges that the resource and environmental cost of economic growth has been excessive (CPC, 2007).

While globalization has brought tangible benefits to China, it has also introduced a serious challenge of transferred emissions as a result of international trade in goods. As the world's manufacturer, China has become a net exporter of embodied energy.[4] CCICED estimates suggest that, from 2002 to 2006, China's net export of embodied energy jumped from 240 million tons of standard coal equivalent (TCE) to 630 million tons, and the proportion of exported embodied energy in China's overall primary energy consumption increased from 16% to 26% (CCICED, 2007a). This translates into 1,109 billion tons CO_2 emissions, accounting for 23% of its total annual emissions (2005), or equivalent to the current total emissions of Japan. The percentage of SO_2 emissions, COD discharge and water consumption embodied in net goods exports were 38%, 18% and 12% respectively (CCICED, 2007a and 2007b; Wu Yuping *et al.*, 2008 cited in Ren Yong, 2009).

8.2 Policy responses

Recognizing these various resource and environmental constraints as a major bottleneck for achieving its social and economic strategies, the Chinese government in 2007 put resource and environmental concerns at the top of its list of priority problems to be resolved in its development path, thereby fundamentally altering its development philosophy. The 11th Five-Year Plan for Economic and Social Development (2006–2010) will go down as a landmark in the history of reconciling environment and economy. The plan sets 22 quantitative indicators of which eight are

2 US$1 against RMB 6.8337 in February 2009.
3 Including freshwater, primary energy, steel, cement and common non-ferrous metals.

4 Embodied energy refers to the energy consumed in the production of goods. When goods are exported, their embodied energy is also exported while pollution is left in the producer country; when a country exports more goods than it imports, it may become a net exporter of embodied energy, or from the perspective of pollution trade, it suffers from an ecological deficit.

mandatory targets, five of them related to environment and resources. The most pivotal and challenging targets are a 20% reduction of GDP energy intensity, and a 10% drop in SO_2 emissions and COD discharge by 2010 (from 2005 levels). To ensure achievement of these targets, the State Council of China established the Leading Group on Energy Conservation and Pollution Reduction as well as Climate Change, headed by Premier Wen Jiabao, and issued the Action Plan for Energy Conservation and Pollution Reduction. An intensive programme was launched across the country, and significant progress has been made. By the end of 2008, the GDP energy intensity had reduced by 10.08%, and SO_2 emissions and COD discharge had dropped by 8.98% and 6.61% respectively (PRC, 2009a).

8.3 Towards an 'ecological civilization'

The concept of 'ecological civilization' was put forward by the government in 2007. From a long-term strategic perspective, the idea of ecological civilization elevates respect for nature and environmental protection to the level of concerns for human civilization. It illustrates a Chinese vision for green and harmonious development that is different from its current development path which is characterized by 'black pollution' associated with industrialization. In the short run, the idea of ecological civilization is to foster a common public consensus surrounding the value of environmental protection. The building of a resource-efficient and environment-friendly society is the mid-to-long term goal. In order to materialize this goal, the Chinese government has taken large-scale and pragmatic actions. For example, since 2006, it has launched nationwide mandatory energy saving and pollution reduction programmes to address low resource efficiency and high intensity of pollution; to address the linear process from primary resources to products and further to post-consumption wastes, it has promoted circular economy policies; in response to climate change, the National Action Plan on Climate Change was introduced in 2007. Also, in order to provide sufficient economic incentives to control pollution, the government started to introduce a systematic package of economic instruments in 2007.

8.4 The circular economy

China has placed great stock in the concept of a circular economy, with particular focus on the 3R principles[5] (Ren Yong *et al.*, 2005). An official decision was made to incorporate the circular economy into the 11th Five-Year Plan on Social and Economic Development. In addition, the State Council promulgated Several Opinions of the State Council on Speeding up the Development of Circular Economy. This was followed by expeditious circular economy policy pilot projects throughout China in 2006. So far, 27 provinces and municipalities, 29 recycling-oriented industrial parks and/or enterprises, 89 companies, four townships, and 44 industrial parks have become involved in these pilot activities under the oversight of the central government. In October 2008, China enacted the Circular Economy Promotion Law, the first of its kind in the world. The Law entered into force in January 2009, ushering in a new phase for the circular economy.

Additional specialized policy frameworks on the circular economy include the following:

- The Law on Cleaner Production Promotion;
- Management and taxation policies for comprehensive utilization of wastes and used resources;

5 Reduction, reuse and recyling activities in the processes of resources exploitation, production, distribution and consumption.

- Assessment Standards to evaluate eco-industrial parks and set out codes for their establishment;
- Green procurement by governmental agencies and public institutions;
- Investment policies for piloting the circular economy – a special fund to support pilot projects.

8.5 Environmental economic instruments

China generally relies on a command-and-control approach to addressing managerial issues of various kinds. There is however growing recognition that this approach is far from adequate to solve the serious environmental pollution problems and non-compliance behaviour with environmental laws. Shortcomings include the absence of incentives and flexibility for business to control its own pollution, as well as negative impacts on social justice arising from law enforcement activities. This has led the state to introduce a system of economic instruments that provide incentive mechanisms for resource conservation and pollution abatement, as well as end-of-pipe pollution treatment. These instruments fall into the following categories:

1. **Natural resource prices and environmental fees** – this includes reform of natural resource and energy pricing, paid use of environmental services, and fees for pollutants emission/discharge, sewage treatment and waste disposal.

   Most natural resources in China are priced by market supply and demand. Government-guided pricing with some basis in market conditions is applied to a few strategic resources, such as electricity, petroleum and coal for power generation. In both cases, the

biggest challenge in pricing is the failure to internalize environmental externalities of resource and energy consumption. Efforts to reform these pricing mechanisms are inevitably time-consuming and complicated. Pollution fees have been imposed on industry for over 20 years; fees for sewage and garbage disposal have been in place for nearly 10 years. Reforms of such fee policies are now targeting levy increases and focusing on widening the range of regulated entities. A further policy concept currently under discussion is one whereby any acquisition of environmental resources must not be undertaken without purchasing the initial right of use.

2. **Resources, energy and environmental taxation** – this refers to all types of taxes aimed at internalizing the external 'diseconomy'. It includes taxes on resources, energy and the environment, as well as consumption taxes and preferential tax policies applicable to resource conservation and environmental protection.

   Since 2006 China has significantly increased tax rates for several mineral resources such as gold, petroleum, and coal. A consumption tax for fuel was introduced in January 2009. Taxes on CO_2 and SO_2 as well as on pollution-intensive products are currently under study. Consumption taxes on large engine vehicles, disposable wooden chopsticks, and timber floor boards have been in place since 2006. The policy on mandatory payments for plastic bags has also been enforced. Preferential taxation policies to encourage investment in reuse and recycling facilities and pollution treatment have been expanding in scope and scale. Since 2007, China has imposed a differentiated electricity price policy that works against energy and pollution-intensive industries. This has led to more widespread adoption of flue-gas desulphurization (FGD).

3. **Green trade policy** – mainly targeting product export and import tariffs. In order to fulfil the mandatory targets of energy conservation and pollution reduction in the 11th Five-Year Planning Period and reduce the trade surplus at the same time, tariffs on a considerable number of products have been adjusted since 2007. For instance, higher export tariffs have been imposed on 142 energy and pollution-intensive commodities; export tariffs on over 80 types of iron and steel products will be further increased by 5–10%. Export rebates were removed from 553 energy-and-pollution intensive products, including endangered fauna and flora. Exports of energy and pollution-intensive products reduced by as much as 40% by the end of 2007 as a result of these various tariff adjustments.

4. **Emissions trading** – Collaborative research with the United States Environmental Protection Agency on emissions trading since mid-1990s has involved pilot activities in a number of Chinese cities. SO_2 emissions trading markets have been established in some cities in Jiangsu and Zhejiang Provinces. The Ministry of Environmental Protection is studying a programme of SO_2 emissions trading in the power sector.

5. **Green consumption policy** – this includes green governmental procurement and other policies associated with consumption that benefits resource conservation and environmental protection. In October 2006, the former SEPA and the Ministry of Finance jointly promulgated Opinions on the Implementation of Governmental Procurement of Environmentally Labelled Products, requiring public organizations to give preference to products with environmental and energy-saving labels when undertaking procurement paid for from fiscal resources. Following that, both agencies

promulgated the List of Environmentally Labelled Products for Governmental Procurement.

6. **Eco-compensation** – also known as payments for ecological services. In China two types of environment-related behaviour are not effectively regulated by market-based instruments: (a) ecological damage and environmental pollution from mining; and (b) economic activities in the upper reaches of river basins normally restricted by regulations for water source conservation. In the early 1990s, China began to study eco-compensation as a solution to both types of problems. The basic idea is twofold: using the Damager Pays Principle, mineral product producers are requested to pay; likewise, following the User Pays Principle, the region along the lower reaches of the river basin and others benefiting from the eco-services are requested to compensate those in the upper reaches for their conservation efforts (Ren Yong *et al.*, 2008). A large number of local governments are actively undertaking pilot activities on eco-compensation, with guidance provided by relevant government agencies. A harmonized national policy is expected to be promulgated in the near future.

7. **Green fiscal policy** – such as investment in environmental protection, research and development of environment-friendly technologies and products.

   Consistent with the 11th Five-Year Plan for Environmental Protection, government investment in environmental protection from 2006 to 2010 is expected to reach 1.3% of GDP, representing a substantial increase. The economic stimulus package launched at the end of 2008 in response to the financial crisis earmarks 5% for direct investment in environmental protection. The proportion could be much higher, taking into account the indirect benefits arising from 'green elements' of investments in other sectors.

8. **Green Finance** – green credit, environmental liability insurance, and environmental requirements for security financing are possibly the most important innovation since the Chinese government began formulating a new incentives system for the purpose of environmental protection.

   For example, under new protocols banks may deny a loan application, suspend or withdraw a loan, or provide a loan with prudence, based on borrowers' significant environmental risks or environmental non-compliance. Green credit policy has been implemented in the majority of China's provinces and cities, and is now developing in line with the Equator Principles.[6] Similarly, the government established a corporate environmental performance review system for companies entering the securities market, along with a requirement for information disclosure at the time of a company's listing. And, although still in its infancy, an insurance system on environmental liabilities is being advocated, with pilots particularly targeting industrial sectors with a record of significant pollution accidents.

8.6 Decoupling – evidence and strategic actions

The metrics of decoupling

The distinction between absolute and relative decoupling has been made earlier in this report. But measuring the degree of decoupling in an economy remains a thorny issue. The OECD has published a set of 31 indicators covering a broad range of

6 The Equator Principles (EP) are a set of environmental and social benchmarks for managing environmental and social issues in development project finance globally. Once adopted by banks and other financial institutions, the Equator Principles commit the adoptees to refrain from financing projects that fail to follow the processes defined by the Principles. (http://en.wikipedia.org/wiki/Equator_Principles).

environmental issues (OECD, 2002a). This case study attempts to define a 'Decoupling Index', a single indicator to help depict the degree of decoupling.

The **Decoupling Index** (DI) refers to the ratio of (1) change in the rate of consumption of a given resource (e.g. water), or in the rate of production of a given pollutant emission (e.g. SO_2); to (2) change in the rate of economic growth (GDP) within a certain time period (typically one year). For example, if we define

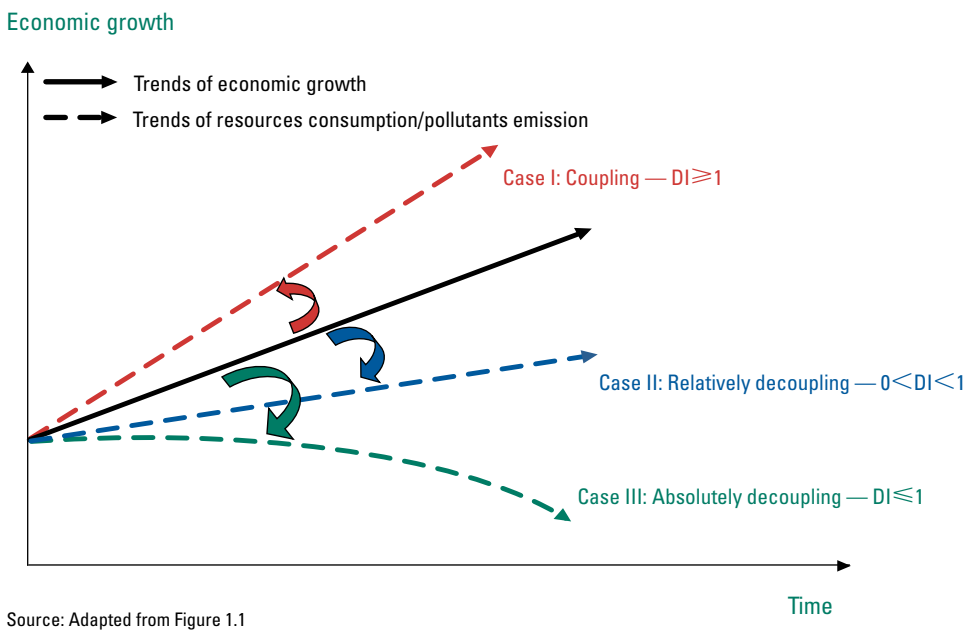
- change in the rate of resources consumption or pollution emission between year t and year t-1 as $\triangle P_t = \frac{(P_t - P_{t-1})}{P_{t-1}}$
- change in the rate of economic growth as $\triangle Y_t = \frac{(Y_t - Y_{t-1})}{Y_{t-1}}$
- then the Decoupling Index in year t, $DI_t = \frac{\triangle P_t}{\triangle Y_t}$

In the case of continued economic growth, namely $\triangle Y_t > 0$, the Decoupling Index (DI) may imply one of three scenarios as follows:

1. When DI≥1, it means the increasing rate of resource consumption or pollutant emissions[7] keeps pace with or is higher than economic growth (see Case I in Figure 8.2). In this case, no decoupling is taking place. In other words, as the economy grows, resource consumption and environmental degradation increase rapidly. This is the first half of the Kuznets Curve, or 'climbing stage' (Area A in Figure 8.3). When DI equals 1, it is the turning point between absolute coupling and relative decoupling. In the stage of absolute coupling, a higher DI value means higher dependence on resources by economic growth, lower resource efficiency and heavier environmental pollution.

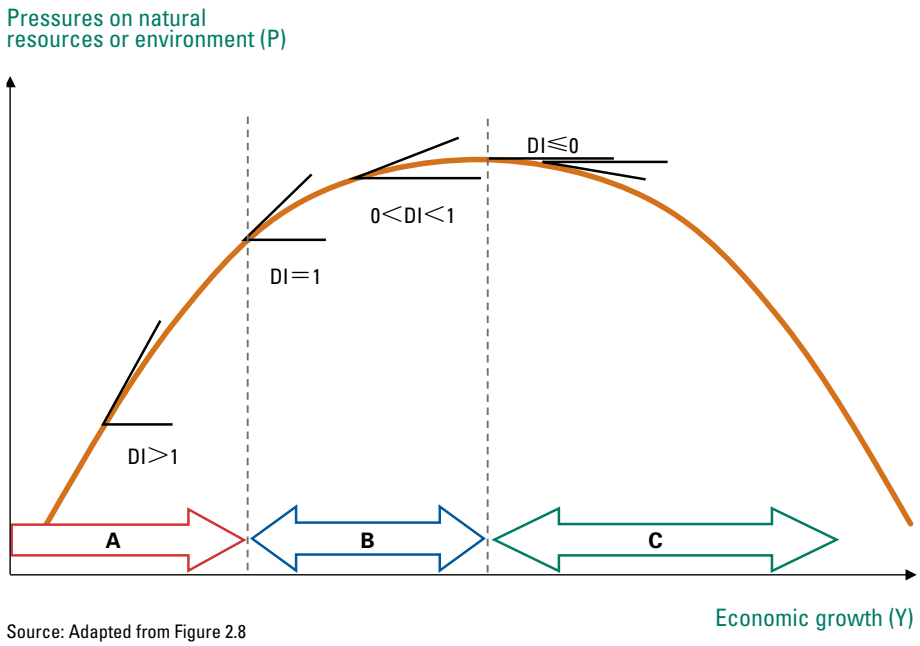
7 Since pollution emission/discharge is related to not only production and consumption activities, but also pollution treatment activities, in this case it refers to pollutants production. But certainly in case studies, pollutants emission/discharge is normally applicable.

Figure 8.2. Scenarios for economic growth and its pressures on environment and resources



Source: Adapted from Figure 1.1

Figure 8.3. Three stages of economic growth and pressures on environment and resources



Source: Adapted from Figure 2.8

2. When 0<DI<1, it means the rate of growth in resource consumption or pollutant emissions falls short of that of economic growth. In this case, relative decoupling is taking place (Case II in Figure 8.2 and Area B in Figure 8.3). When DI ranges from 0 to 1, lower DI means higher resource efficiency and lower dependence on resources.

3. When DI=0, it means the economy is growing while resource consumption remains constant. In other words, when the economy grows continuously, the amount of pollutants does not increase. When resource consumption or pollutant emissions/discharge decreases while the economy keeps growing, then DI<0 (Case III in Figure 8.2). Here the relationship between environment and economy can be described as the 'declining stage' of the Kuznets Curve (Area C in Figure 8.3), namely, absolutely decoupling.

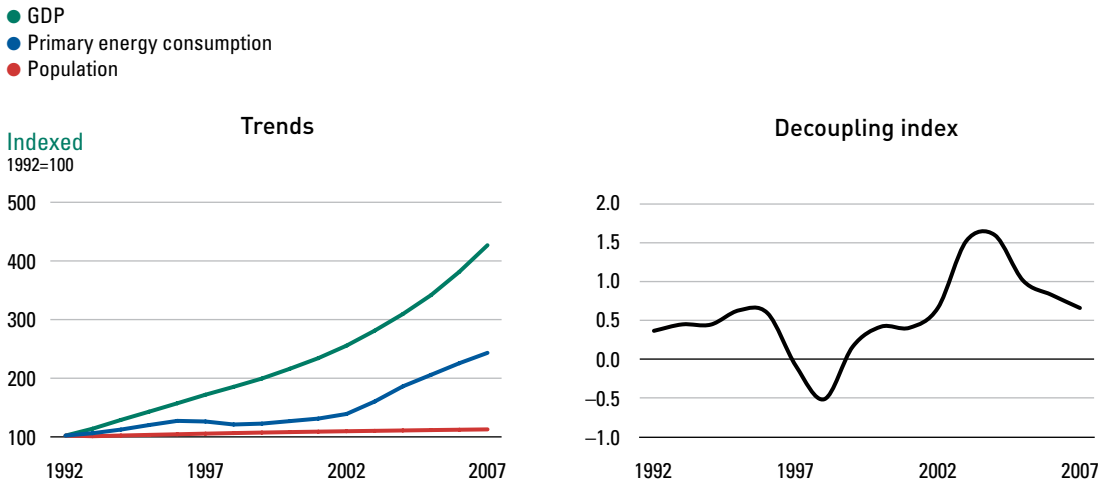
8.7 Decoupling trends in China[8]

By applying the DI metric to a number of resource input and impact variables, the following picture emerges. With respect to primary energy consumption since 1992, there is evidence of relative decoupling (Figure 8.4). During the Asian financial crisis, GDP growth rate fell to 7.1% in 1999 from over 10% before 1996, while total energy consumption dropped slightly from 13.89 trillion TCE to 13.38 trillion TCE. As a result, DI in 1997 and 1998 stood at -0.1 and -0.5 respectively, representing absolute decoupling. From 2002, GDP growth climbed back to over 10% underpinned by massive growth in the heavy-chemical industry.

As a result, DI in 2003, 2004 and 2005 reached 1.5, 1.6 and 1.0 respectively, representing re-coupling of energy

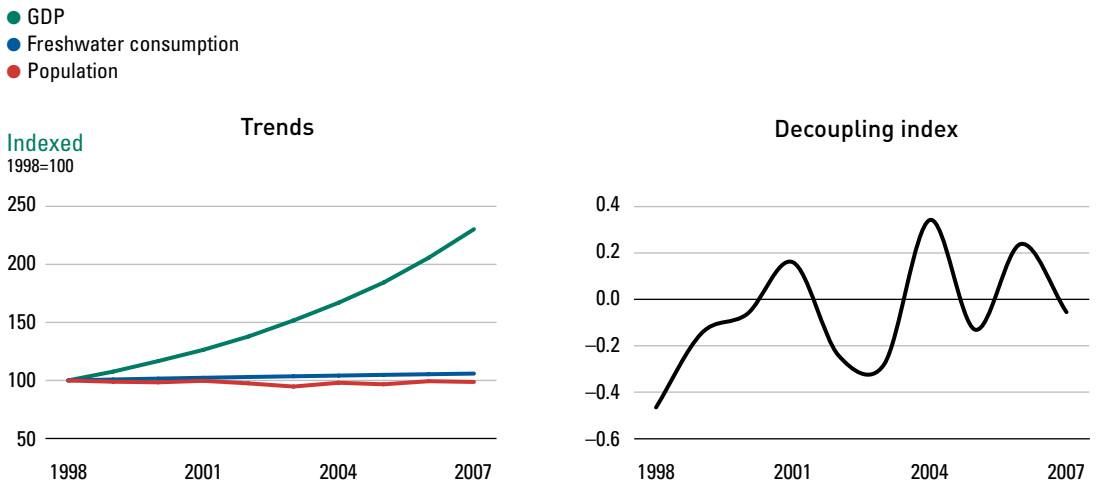
8 Data sources of all figures in this section include: *China Statistics Yearbook 1990–2007, China Environmental Statistics Yearbook 1990–2007, China Water Resources Statistics Yearbook 1998–2008.*

Figure 8.4. Trends (left) of energy, GDP and population and the decoupling index (right) of primary energy consumption to GDP growth



Source: China Statistics Yearbooks, 1993–2008, the People's Republic of China

Figure 8.5. Trends (left) of fresh water consumption, GDP and population and the decoupling index (right) of fresh water consumption to GDP growth



Source: China Water Resources Statistics Yearbooks, 1999–2008, the People's Republic of China

consumption and economic growth. In 2006, following the launch of a massive energy saving and pollution reduction programme, energy consumption began to relatively decouple from economic growth.

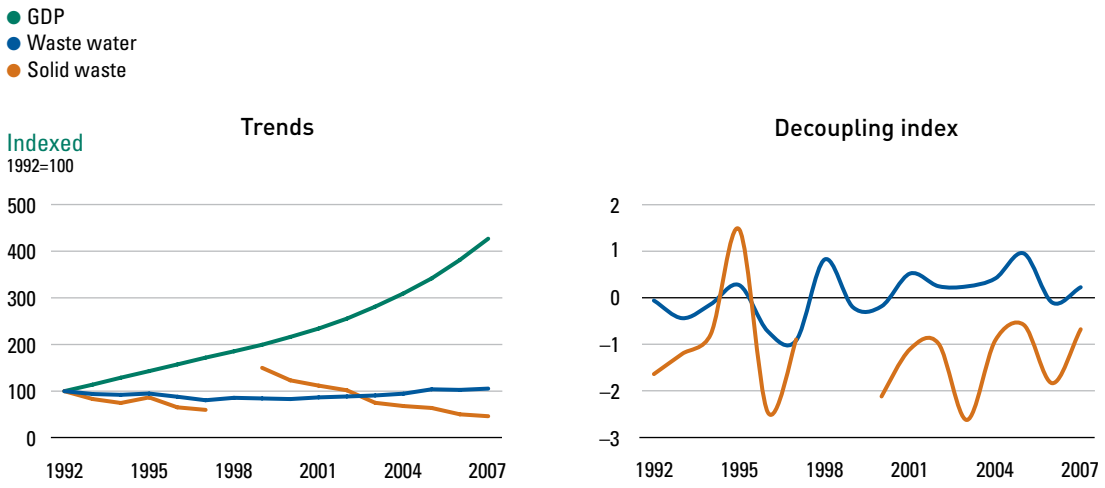
A more remarkable trend can be observed in freshwater (Figure 8.5). For most of the last 10 years, China achieved absolute decoupling between freshwater consumption and economic growth. During 1998–2007, total freshwater consumption varied within a small range between 290.1 and 306.2 billion m^3. But in terms of mineral consumption China faces huge challenges. For instance, the country's steel consumption jumped nearly tenfold from 53 million tons in 1990 to 520 million tons in 2007, and steel consumption per unit of GDP increased at a rate higher than

GDP growth (China Statistics Yearbook 1990–2007, cited in Ren Yong, 2000).

On the impact side, the emission/discharge of a number of pollutants began to decouple from economic growth in the early 1990s. Since 1992, industrial wastewater discharge and solid waste discharge have absolutely decoupled in a number of years, with the DI of solid waste falling below -1 several times (Figure 8.6).[9] Progress in this area owes much to the improved recycling rate and proper disposal of industrial solid waste.

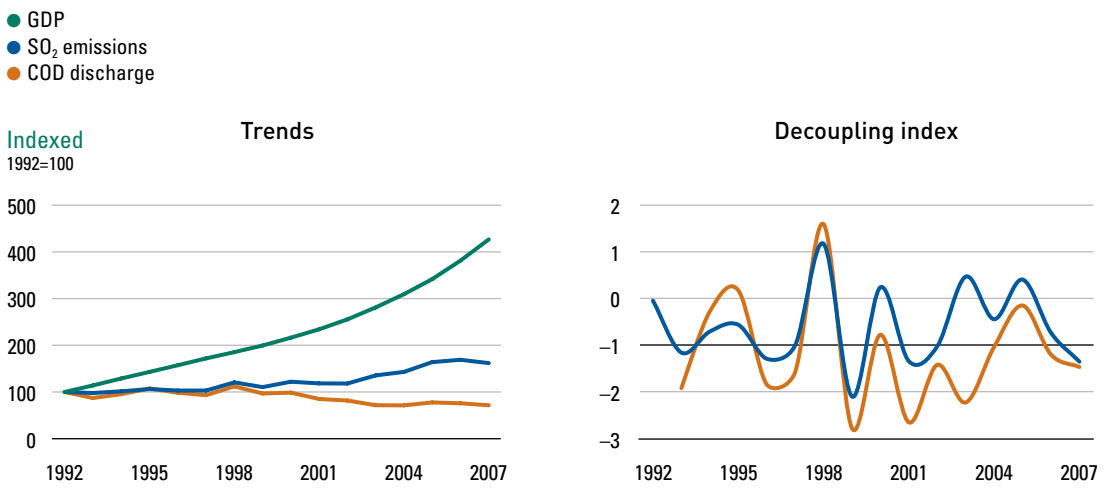
9 China made an adjustment to the scale of data collection for a number of pollutants in 1998, causing irregularities in indicators of industrial solid waste, COD, SO_2 and so on. This report therefore does not take into account the statistics in 1998, resulting in broken curves in relevant charts. However, this would not affect the analysis result as a whole.

Figure 8.6. Trends (left) of industrial waste water and solid waste discharge and GDP and the decoupling index (right) of industrial waste water and solid waste discharge to GDP



Source: China Environmental Statistics Yearbooks, 1993–2008, the People's Republic of China

Figure 8.7. Trends (left) of COD discharge, SO_2 emission and GDP and the decoupling index (right) of SO_2 emission and COD discharge to GDP



Source: China Environmental Statistics Yearbooks, 1993–2008, the People's Republic of China

In most years since 1992, there has been absolute decoupling of COD discharge (indicator for water pollution) and relative decoupling of SO_2 emissions (indicator for air polluttion) (Figure 8.7). These results are in part linked to China's total volume control programme for pollutants launched back in 1996. However, a new stage of rapid economic growth and industrialization since 2002 has seen a re-coupling of SO_2 emissions and economic growth.

Finally, it should be noted that the decoupling of certain pollutant emissions/discharge does not necessarily mean that environmental quality has improved. In fact, despite the decrease of total volume of some pollutants, their emissions/discharge still far exceeds the self-purification capacity of the environment. Given historical accumulation, environmental quality may further deteriorate in China.

8.8 Actions towards decoupling

Following adoption of the 11th Five-Year Plan, the Chinese government has pursued a three-pronged strategy to raise energy efficiency and reduce pollution:

1. **Industrial restructuring.** The main approach here is the phasing out of outdated production capacity. In the Action Plan for Energy Conservation and Pollution Reduction, the State Council of China set detailed targets for phasing out outdated production capacity of 12 energy-intensive and heavily-polluting industrial sectors.[10] This work is ahead of schedule and has so far played an essential role in energy conservation and pollution reduction.

2. **Energy conservation programmes and construction of pollution treatment facilities.** The following programmes are ahead of schedule in terms of their respective targets:

   - 10 national energy conservation programmes in energy-intensive industrial sectors aimed at conserving an equivalent of 240 million TCE.

   - Wastewater treatment facilities aimed at increasing daily urban sewerage treatment capacity by 45 million tons and daily usage of recycled water by 6.8 million tons.

   - Installation of desulphurization facilities (FGD) for coal power plants, aimed at reaching 0.355 billion Kilowatts.

3. **Strengthened environmental management.** Specific measures include:

   - Making better use of environmental impact assessment (EIA) mechanisms and raising environmental benchmarks to stop the access of energy-intensive and heavily-polluting industrial sectors.

   - Strengthening environmental supervision and inspection, and strict application of the 'regional environmental approval suspension'[11] on serious breaches of environmental laws and regulations.

   - Setting up a complete system of statistics, monitoring and reviewing for pollution reduction; incorporating pollution reduction indicators into the performance review system for local governments and their main leaders; and establishing an accountability system.

10 Power, iron, steel, electrolytic aluminium, iron alloy, calcium carbide, coke, cement, glass, paper, alcohol, and citric acid.

11 If environmental laws and regulations are seriously breached in a specific jurisdiction, MEP will suspend environmental approval for all new projects within this region.

- Setting up a special fiscal fund for energy conservation and pollution reduction.

- Introducing market-based and fiscal-oriented incentive instruments.

Circular economy activities involving all stages in the economic cycle – resource exploitation, production, distribution, and consumption – are being implemented at three levels:

- *enterprises* – focusing on cleaner production and raw materials' recycling, thus raising resource efficiency and reducing pollution, or even achieving zero emission;

- *industrial parks* – restructuring existing parks and organizing new industrial parks in line with 3R principles, focusing on building eco-chains and shared infrastructure systems for water and energy supply and centralized waste treatment;

- *regional (e.g. city, province)* – using a dual approach: (a) establishing a reuse and recycle industry, and (b) among consumers, advocating resource and energy conservation, rational and environmentally-friendly lifestyles, green governmental procurement, energy efficiency certification and environmental product labelling.

The circular economy in China is at an early stage of development, and no systematic analysis of its effectiveness has yet been published. However, some preliminary findings indicate that the energy efficiency and pollution intensity in the pilot entities are superior to those in other areas (NDRC, 2008).

8.9 One world, one dream – the Green Olympics

In 2002, Beijing Municipality formulated its Olympic Action Plan with an Environmental and Ecosystem Protection Plan as an integral part of it. In the following seven years, over 160 specific programmes were implemented, resulting in significant improvements of air quality and the environment of the entire city.

8.10 Conclusion

This case study demonstrates that through concerted efforts, resource and impact decoupling can be achieved. Resources and energy efficiencies in China have been increasing, and both intensities and volumes of major pollutant emissions have been falling. Since the early 1990s, a relative decoupling between primary energy consumption and economic growth has taken place, and there has been an absolute decoupling of freshwater consumption throughout most of the past decade. Since 1992, industrial wastewater discharge and SO_2 emissions have relatively decoupled, and COD and industrial solid waste discharges have absolutely decoupled in most years. And, through a strong commitment to the 2008 Green Olympic Games, industrial wastewater and COD discharges and SO_2 and NO_x emissions in Beijing all absolutely decoupled from the city's rapid GDP growth since the end of last century. Environmental quality in the city has been greatly improved.

However, many challenges for China's decoupling ambitions are evident. They include a huge population; an extensive pattern of economic growth with a legacy of low resource efficiency and high intensity of pollution emissions centred on heavy-chemical industrial sectors; rapid

How Beijing fulfilled its commitments to Green Olympics

1. Air pollution control measures

Restructuring Energy Components: Natural gas supply increased from 1.4 billion m^3 in 2001 to 4.7 billion m^3 in 2007. A total of 16,000 coal boilers below 14MW and 44,000 coal cooking facilities were converted to natural gas. Renewable energies such as biomass, ground thermal and solar energy were promoted; the ratio of cleaner energy in total energy consumption increased from 45.4% in 2001 to 62% in 2007.

Vehicle Emission Control: (a) More stringent standards: Euro II, Euro III, and Euro IV Vehicle Emission Standards and relevant standards on vehicle fuels were introduced in succession. (b) Green Public Bus Fleet: over 10,000 old polluting public buses and 50,000 aged taxis were replaced. By the time of the games, all 20,000 public buses met Euro III emission standards, with 4,000 natural gas buses, the largest fleet of its kind in the world. (c) VOC control: all gas stations, oil tankers and depots in Beijing conducted oil and gas recovery renovation to reduce pollution generated in the fuel storage and refilling process. (d) Building attractive public transport: public bus and metro fares were reduced to attract the public; total mileage of the metro was extended from 40km in 2001 to 200km in 2008; 60km of surface BRT system is now in operation.

Industrial Restructuring: The economy was restructured and the regional development layout readjusted. Processes and enterprises with high energy consumption and heavy pollution were phased out. High-end industries such as new hi-tech industries and modern service industries have been promoted and the ratio of tertiary industries is now over 70% of total GDP. From 2000 to 2007, 200 polluting enterprises were closed, converted to other production or resettled. Beijing's large-scale coal-fired power plants underwent desulphurization, dust-removal and de-nitrification renovation, making their emission performance levels among the best in the world.

2. Eco-conservation

Three green eco-shelter-belts have been established in the mountainous areas, plains, and urban areas, with forest coverage at 51.6%, the urban green coverage at 43% and per capita green area of $48m^2$.

3. Water environment

16.1 billion Yuan were invested in protection of drinking water sources, wastewater treatment and rehabilitation of urban water courses. With the completion of 9 sewage treatment plants, the sewage treatment rate reached 92% in 2007. There are 11 recycling water plants in operation, and 57% of urban water is reused.

4. Solid waste management

Sorted collection of urban waste is promoted. Some 23 environmentally-safe disposal facilities have been completed. The waste collection rate in urban districts is 99.9% compared to 80% in suburban areas. Around 96.47% of industrial solid wastes are reused and recycled.

5. Regional cooperation

Temporary measures were developed and implemented in cooperation with neighbouring cities and provinces to guarantee good air quality for the Olympic Games. Good air quality was maintained during the Olympic Games fortnight.

Source: Beijing Municipal EPB

urbanization and associated changes in consumption patterns; environmental impacts induced by globalization and China's status as the 'world's manufacturing centre'.

Addressing these challenges requires a complex combination of consolidated political willingness, scientific strategies, and pragmatic and intensive actions. With the birth of the Scientific Outlook for Development in 2003 as a milestone, China has moved into a strategy transformation period of restructuring the relationship between environment and society, and gradually drawn up a visible roadmap for reconciling the environment and socio-economic development. Continuous, focused and intensive actions such as energy conservation and pollution abatement, the circular economy, the national climate change programme, introduction of environmental economic instruments and so on, are vital steps towards China's vision of absolutely decoupling after 2030.

9 Japan

The Japanese economy is very dependent on imports of natural resources, such as energy, food and other raw materials. This geopolitical fact of life means that its use of primary materials is to a large extent separated from the ecological impacts at the point of their extraction. Yet even in Japan there are visible problems associated with the increasing volume and diversified nature of solid wastes (such as a shortage of disposal sites, risk of environmental pollution by waste treatment facilities, illegal dumping, and rising costs).

The spirit of 'Mottainai' is a long-established Japanese concept meaning that it is a shame for something to go to waste without having made use of its potential in full. The expression incorporates a respect for the environment that has been handed down through the ages, and constitutes a societal value that is essential to the nation's efforts to become a 'Sustainable Society' as signalled by a Cabinet decision on 1 June 2007.[1] This is finding expression in policy frameworks and innovations that are uniquely Japanese.

1 See www.env.go.jp/en/focus/070606.html.

© Marian Mocanu/Dreamstime

9.1 Recognizing limits

9.1.1 Limits of resources – lessons learned from oil crises

In the beginning of the 1970s, Japan's dependency rate on imported oil was more than three quarters of Total Primary Energy Requirement (TPER). Two world oil crises in 1973 and 1979 caused significant shocks to the Japanese economy and society. Prices of goods soared and nervous consumers rushed into the market to secure daily necessities. Such reactions caused a vicious circle of rising prices and shortages of commodities. In this sense, it could be said that Japanese consumers did recognize the 'limits' of an oil-dependent economy, though some of the short-term chaotic situations in the market were obviously a function of incomplete information.

Industries reacted to the crises by investing large amounts of money to save energy and improve energy efficiency. There were significant levels of decoupling between energy consumption and economic production by manufacturing industries during the late 1970s and early 1980s. While oil dependency of national primary energy supply has decreased gradually to less than half, it is still higher than that of other developed economies. Energy saving and fuel switching as a reaction to the oil crises generated favourable side effects with respect to air pollution abatement. For the reduction of SO_x emissions, it is true that impact decoupling such as flue gas desulfurization was successful. In addition, reduction of oil consumption through energy-efficiency improvements and fuel switching to natural gas and other primary energy sources also significantly contributed to SO_x reductions (Ministry of the Environment, Government of Japan, 1992). These successes can be taken as an example of the combination of resource and impact decoupling.

9.1.2 Limits at the end-of-pipe

The amount of solid waste generation is sometimes regarded as a proxy of an affluent lifestyle, which implies high levels of resource consumption that ends up as waste products. Because of its high population density, Japan has been facing shortages of landfill capacity. To reduce waste volumes going to landfill, incineration has increased significantly. In the late 1980's, the increase in municipal solid waste generation was obvious, apparently coupled to economic growth. However public concern over risks of environmental pollution associated with waste treatment processes has made it more difficult to expand the capacity of waste treatment facilities. Large investments were made to replace old incinerators with state-of-the-art facilities that successfully decoupled dioxin emissions from the voluminous waste incineration. Moreover, in parallel with these efforts at impact decoupling, the government began to take measures for decoupling waste generation from economic growth. The recognition of limits of resources was not the direct, primary driving force behind waste prevention, but it has been advocated and recognized, including through the *Mottainai* spirit, that waste prevention and recycling contributes to resource saving.

The Japanese government has been submitting annual Quality of the Environment reports (State of the Environment Report) to the Diet since 1969. In its prologue to the 1998 annual report (GoJ, 1998), 'limits' to resources was explicitly mentioned, including a reference to ancient civilizations. Roughly translated, the essence of the message was as follows:

> *"Many ancient civilizations developed utilizing their rich forest resources, but as development proceeded and human populations increased, the resources were depleted and the civilizations in turn declined and perished.*
>
> *"Unlike the ancient civilizations, the environmental impacts of which were limited to certain areas on earth, our*

society (civilization) of the present day stands at a point of no return. The reason for this situation is that in a very short period of time we have been consuming natural resources, including fossil fuels, which have been generated and stored over millions, if not billions, of years.

"At the same time we have been disposing of great quantities of wastes. These have exceeded the natural capacity of ecosystems to break down waste and have thus placed, and continue to place, huge pressure on the environment.

"In order to avoid such environmental load, it is necessary first to properly control and circulate substances generated by human activities and to reduce the burden on the environment. Secondly, by understanding the underlying mechanisms of nature which are the foundations upon which all human activities depend, it is necessary to transform our society, establishing an economic and social system that is based on the principles of 'circularity' and 'coexistence', wherein human activities can be harmoniously adjusted to suit the mechanisms of nature ."

Based on this recognition of limits, policies for transition to a Sound Material Cycle Society have been formulated.

9.2 Policy responses

Inspired by the Earth Summit in Rio (UNCED 1992), the Japanese government enacted the Basic Environment Law in 1993. This was followed by adoption of the Basic Environment Plan in December 1994. This plan outlines the overall and long-term policies of the government in environmental conservation. In its foreword, the plan recognized mainstream socio-economic activities as a common driving force behind various environmental problems:

"There is a growing need to reconsider our values placing too much emphasis on the pursuit of material wealth, and the prevailing socio-economic activities and lifestyles marked by mass-production, mass-consumption, and mass-disposal."

It went on to affirm that Japanese society must change to a sustainable one that generates little burden on the environment, while at the same time promoting international activities for conserving the global environment (GoJ, 1994).

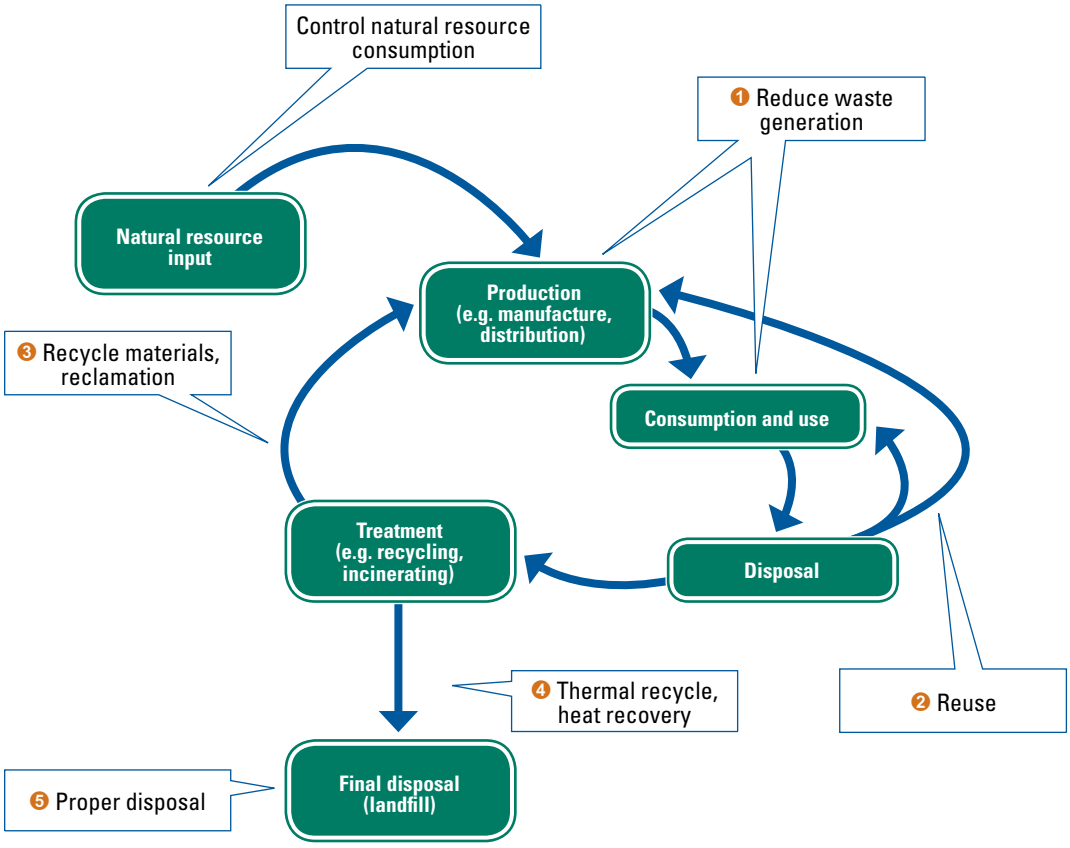
However, a review conducted by the OECD pointed out that despite quite advanced and sometimes exemplary policies, the decoupling achieved in the 1990s had not been sufficient (OECD, 2002). CO_2 emissions continued to increase as did a number of pollution trends, most notably those related to traffic and energy use. Remaining waste disposal capacity was also reaching a critical point. This led the government to take firmer steps towards establishing a sound material cycle society (SMC). While its conceptual linkage with the policies for a low carbon society was made at later stage, reduction of CO_2 has yet to be sufficient compared to the target of Kyoto Protocol. This case study does not undertake further analysis of energy and CO_2 issues, but focuses on material cycles. An exception is the so-called 'top runner' approach for energy consumption by electrical appliances.

9.2.1 Towards a sound material cycle society

The term 'Junkan-gata-shakai' (Sound Material Cycle Society) was first coined in 1991 by an expert committee of the Japan Environment Agency (Moriguchi, 2008). The concept of a SMC is firmly rooted in 3R principles.[2] Japan's commitment to a 3R policy is premised on a growing recognition of two factors – first, that the increase in waste generation and waste not treated in an environmentally-sound manner is contributing to worsening environmental

2 Reduce, reuse and recycle.

Figure 9.1. Scheme of a sound material cycle society (SMC)



Source: Ministry of the Environment, Government of Japan, 2009

pollution worldwide including air, soil and water pollution as well as greenhouse gas emissions; and second, that the quantity of raw materials wasted as a result of inefficient resource and waste management worldwide is immense.

Thus, the SMC society is one in which measures such as reduced waste generation and reduced extraction of resources, reuse, recycling, and appropriate disposal have been advanced in a balanced manner (Figure 9.1). The first step in building an SMC society is, therefore, to understand the flows of materials in the economic sector, in terms of the resources extracted, consumed and disposed of. This would not only enable reduced generation and cyclical use of wastes, but also generate knowledge to promote the efficient use of all material inputs to the economy and to inform future policy. Material Flow Accounts (MFA) have therefore become an integral feature in Japanese environmental policy, identifying the whole system of material flows in the national economy and providing itemized overviews for such flows. This enables the government to set numerical targets for so-called material flow indicators, as follows (GoJ, 2009):

- *resource productivity* = GDP/Direct Material Input; target value: Yen 420,000/ton (60% improvement compared to the year 2000)

- *cyclical use rate* = cyclical use amount/ (natural resources input + cyclical use amount); target value: 14 to 15% (40 to 50 % improvement compared to the year 2000)

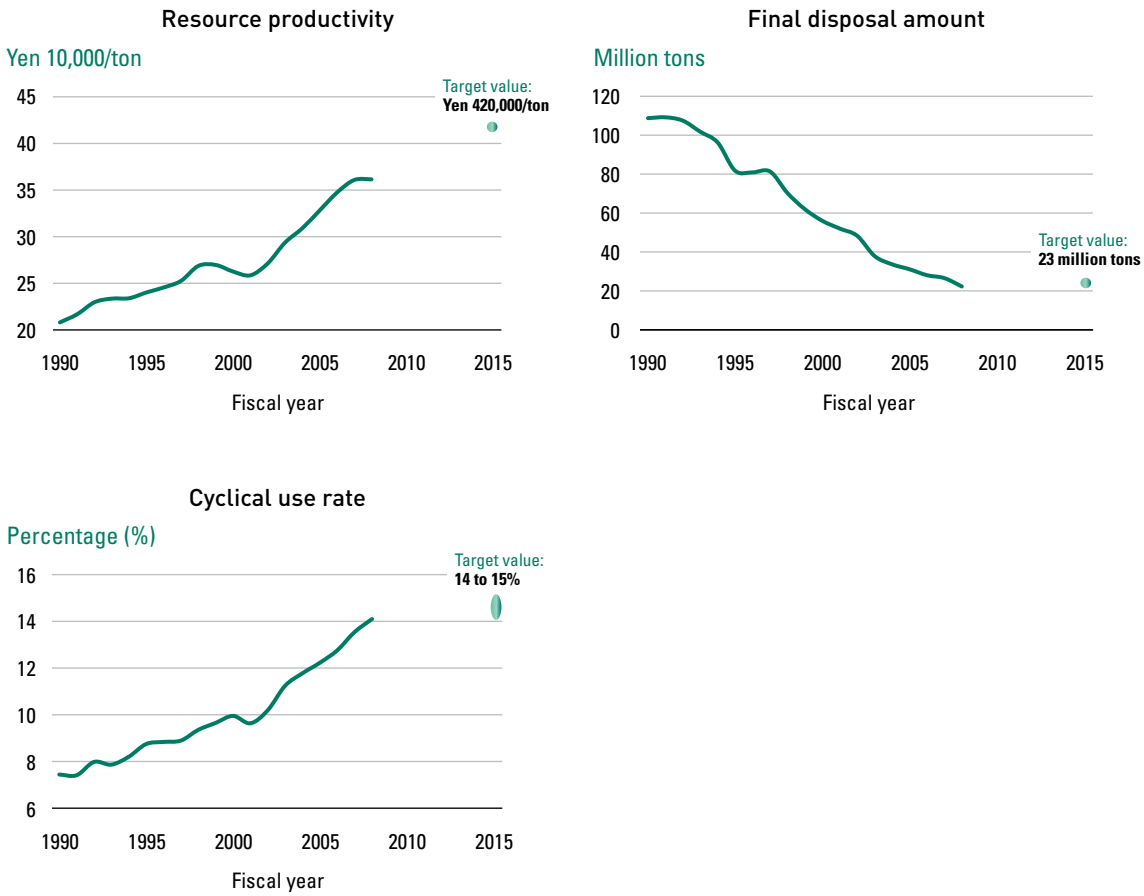
- *final disposal amount* = sum of general wastes and industrial waste; target value: 23 million tons (60% reduction compared to the year 2000)

There are successful trends towards the attainment of these targets, as shown in Figure 9.2.

9.2.2 The Fundamental Law and Plan

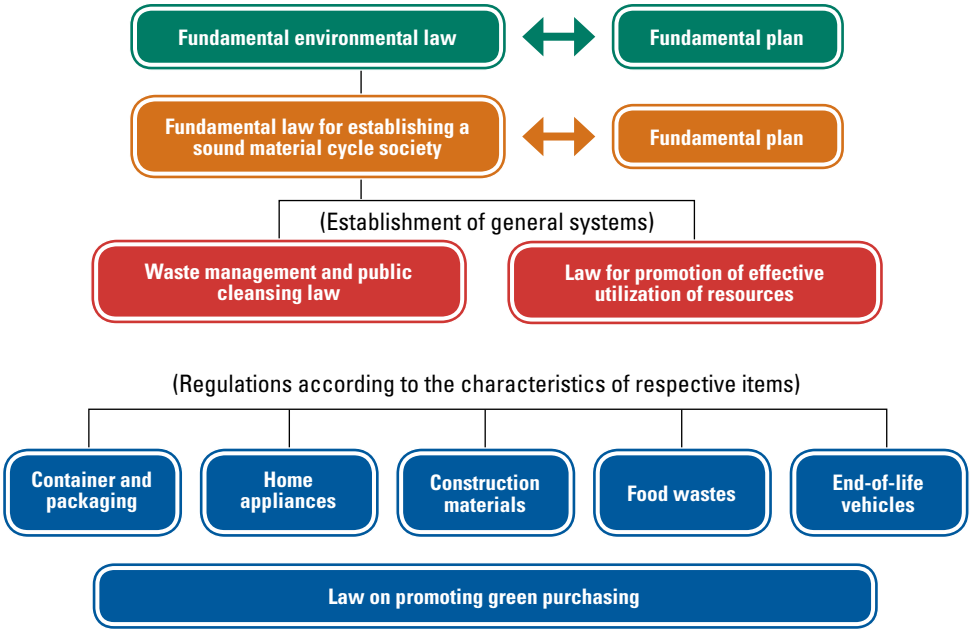
A Fundamental Law for Establishing a Sound Material Cycle Society has been in place since 2000. The 1st Fundamental Plan for Establishing a Sound Material Cycle Society was adopted by the cabinet in 2003, and a revised 2nd Plan was adopted in 2008. These legal instruments provide the fundamental framework to integrate environmentally-sound management of wastes and efficient use of natural resources into Japan's mainstream economic processes. Several sectoral recycling laws for specific products and

Figure 9.2. Trends of material flow indicators



Source: Ministry of the Environment, Government of Japan, 2010

Figure 9.3. Legislative framework for sound material cycle policy



Source: Moriguchi, 2011

sectors have been enacted and revised to support the transition towards an SMC society. The Law on Promoting Green Purchasing supports demand-side of recycled products (Figure 9.3).

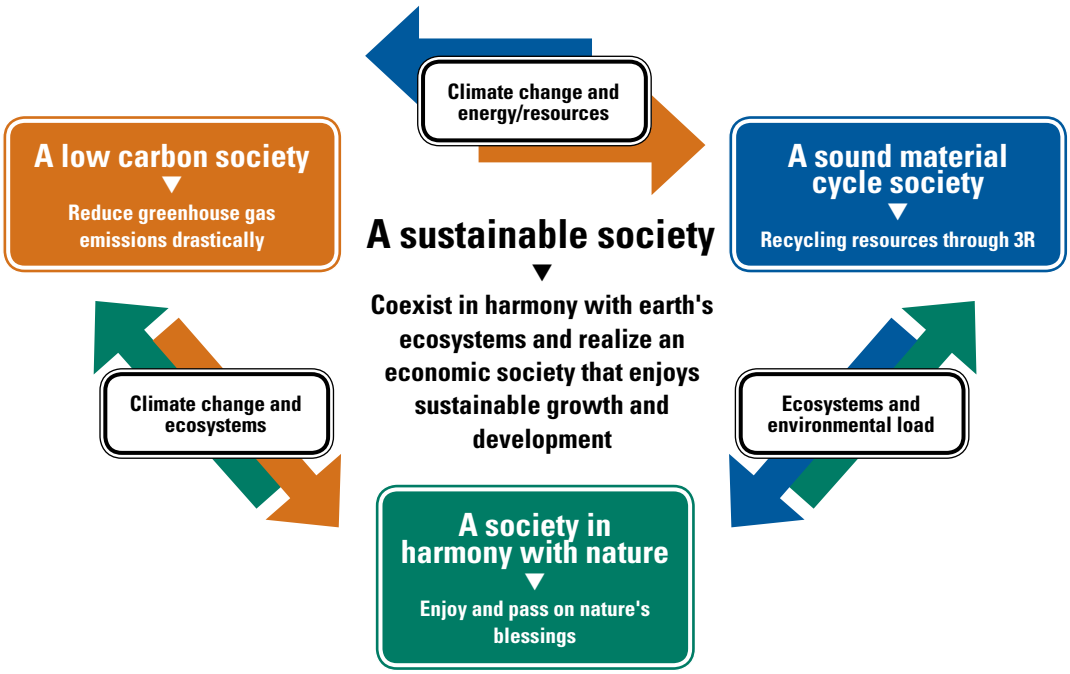
9.3 Contribution to international initiatives

In parallel with the enforcement of national 3R policies, the Japanese government has played an active role internationally to disseminate the concept and practical experiences of 3R, by proposing and implementing the '3R Initiative' at the G8. The G8 environment ministers adopted the Kobe 3R action plan in 2008 under the Japanese presidency of G8. The action plan referred explicitly to the need to support capacity developments in developing economies. The plan also encourages each country to set targets such as resource productivity.

9.4 Japan's strategy for a sustainable society

As shown in Figure 9.3, Japan's policy for SMC is positioned under the umbrella of overall environmental policy. Despite the fact that resource efficiency is closely interrelated with energy efficiency, SMC policy has not been directly linked to energy and GHG mitigation policies. Recently, a strategy with a more integrative view across energy, material and ecosystem resources was proposed. "Becoming a Leading Environmental Nation Strategy in the 21st Century – Japan's strategy for a Sustainable Society" was decided upon by the cabinet on 1 June 2007. The strategy proposes to build a sustainable society through comprehensive measures integrating the three aspects of the society, specifically, a low carbon society, a sound material cycle society and a society in harmony with nature, as shown in Figure 9.4.

Figure 9.4. Framework of Japan's strategy for a sustainable society



Source: Government of Japan, 2007

9.5 Decoupling – evidence and innovation

9.5.1 Voluntary actions by industries

The fundamental plan for SMC sets a national target of resource productivity and obligates the government itself to achieve it, but the plan does not set binding targets for industries. Nevertheless, voluntary efforts have been made to incorporate the Factor X concept into businesses. For example, as many as eight Japanese leading electronics companies (Fujitsu, Hitachi, Panasonic, Mitsubishi, NEC, Sanyo, Sharp and Toshiba) are collaborating to develop the guidance system for the Common Factor X approach:

"Eight major electronics companies in Japan have voluntarily agreed to develop the guidance for Common Factor X via Eco-Efficiency Evaluation to provide meaningful indicators as a powerful communications tool between manufacturers and consumers."

"The first step is for air conditioners, refrigerators, lamps and lighting apparatus, because these four products cover 60% of electricity consumption of households in Japan." (Shibaike et al., 2008)

Innovative efforts by individual companies were published as peer-reviewed journal papers (for the Panasonic case, see Aoe, 2007 and for Toshiba, see Kobayashi *et al.*, 2007).

As indicated by these example cases, manufacturing industries in Japan have been actively involved in research activities such as industrial ecology and cleaner production, and have applied this expertise to actual business practices. International conferences on eco-balance, eco-design, and eco-materials have been regularly organized during last decade with the participation of different industry sectors (Moriguchi, 2000). The most recent annual eco-products exhibition attracted as many as 174,000 visitors.

9.5.2 Actions by local authorities

In Japan, local governments are responsible for the management of municipal solid waste (MSW). Their efforts to reduce environmental and economic burdens associated with waste management vary significantly, according to their demographic, geographic, and industrial diversities. The following is just an example quoted from the recent Annual Report on the Environment and the Sound Material Cycle Society.

"With no incinerating facilities of its own, Shibushi City has to dispose of all its wastes in landfills. By means of the sorted collection of wastes into 28 categories, the city government has successfully reduced the amount of landfill wastes by 80% [as shown in Figure 9.5]. *To deal with kitchen garbage, the city also implements the 'Sun Sun Sunflower Plan', which produces sunflower oil from kitchen garbage as part of its efforts to achieve zero landfill wastes through regional collaboration."*

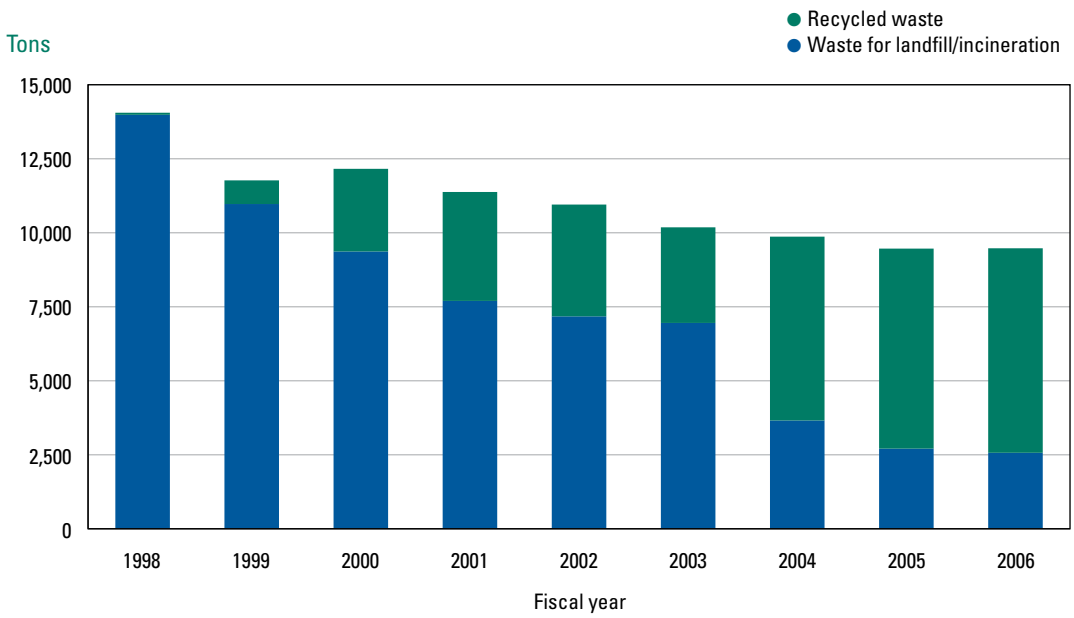
9.5.3 A Japanese approach to decoupling: the Top Runner Programme[3]

In many countries, the energy efficiency of electrical appliances is enhanced by Minimum Efficiency Performance Standards (MEPS). Japan followed a different strategy. Instead of setting a minimum efficiency standard, its Top Runner Programme searches for the most efficient model on the market and then stipulates that the efficiency of this **top runner model** should become the standard within a certain number of years. The Top Runner Programme applies to machinery and equipment in the residential, commercial, and transportation sectors.

The Top Runner Programme sets targets by product category.[4] In each category, the most efficient model currently on the

3 This section is largely based on an article by Bruno Wachter (2006).
4 Products currently covered are: passenger vehicles, freight vehicles, air conditioners, electric refrigerators, electric freezers, electric rice cookers, microwave ovens, fluorescent lights, electric toilet seats, TV sets, video cassette recorders, DVD recorders, computers, magnetic disk units, routers, switches, copying machines, space heaters, gas cooking appliances, gas water heaters, oil water heaters, vending machines, transformers (see http://www.eccj.or.jp/top_runner/index.html).

Figure 9.5. Waste management efforts in Shibushi City



Source: Ministry of the Environment, Government of Japan, 2008

market is used to set the standard to be attained by the rest of the industry within four to eight years. By the target year, each manufacturer must ensure that the weighted average of the efficiency of all its products in that particular category is at least equal to that of the top runner model. This approach eliminates the need to ban specific inefficient models from the market. At the same time, manufacturers are made accountable and, perhaps most importantly, they are stimulated to voluntarily develop products with an even higher efficiency than the top runner model.

The Top Runner standards are set by committees with representatives from the manufacturing industry, universities, trade unions, and consumer organizations. They follow well-defined procedures. An efficiency standard for a product category will rarely be a single numerical value. In most cases, it will vary according to a basic index, for instance, the weight of a car, the size of a TV screen, or the power of an air conditioner. If certain additional functions of a product correspond to a high market demand, but make it virtually impossible to achieve target values, a separate category may be created. If the pay-back ratio of newly developed products complying with the standard becomes too low, two separate categories may be created as well: one for the expensive, highly efficient models, and one for the reasonably priced, low-energy models. These kinds of flexible principles ensure that the Top Runner Programme does not limit the consumer's choice.

The programme has achieved good results (see Table 9.1), despite having relatively weak legal leverage. Prescribed under Section 6 of the Energy Conservation Law, it merely stipulates that manufacturers have 'the obligation to make efforts to achieve the target'. The real power of this programme lies in the fact that non-compliance puts the brand image of a company at risk. If a company is not able to meet targets or fails to make a good faith attempt at reaching the standard in spite of several warnings, this fact is publicized. Given the strong role that corporate pride plays in Japanese culture, this is something each company will make considerable efforts to avoid. Consumers, in turn, are also made to assume a certain level of responsibility through a labelling system. Individual products that do not meet the target are not withdrawn from the market, but they receive an orange label, in contrast to a green label for the models which do achieve the top runner standard.

Table 9.1. Top Runner Programme achievements

Product category	Energy efficiency improvement (actual result, %)	Energy efficiency improvement (initial expectation, %)
TV receivers	25.7	16.4
VCRs	73.6	58.7
Air conditioners	67.8	66.1
Electric refrigerators	55.2	30.5
Electric freezers	29.6	22.9
Gasoline passenger vehicles	22.8	22.8
Diesel freight vehicles	21.7	6.5
Vending machines	37.3	33.9
Computers	99.1	83.0
Magnetic disk units	98.2	78.0
Fluorescent lights	35.6	16.6

Source: ECCJ, 2008

9.6 Lessons from the use of resource productivity indicator

The Fundamental Plan for Establishing the Sound Material Cycle Society adopted a **resource productivity indicator** in its simplest form, i.e., GDP divided by DMI (Total weight of direct inputs of resources). This kind of simplicity was useful to demonstrate the concept of decoupling of economic growth from physical growth. However, experts have often debated whether or not these macroscopic material flow indicators are useful proxy indicators that properly represent both resource and environmental problems.

Since the adoption of the 1st Fundamental Plan in 2003, the performance of the Plan has been reviewed annually by the Central Environmental Council of Japan. The progress of material flow indicators toward numerical targets has also been reviewed. This review process revealed needs for improvement and further examination. For example, it was found that annual values of DMI were significantly influenced by fluctuations in construction material inputs. To lessen this influence, another resource productivity indicator, calculated as GDP divided by DMI minus inputs of construction minerals was introduced and the numerical target in the second Plan revised in 2008. Resource productivity in terms of fossil resources was also added to monitor trends. Compared to the recent steep upwards trend of the resource productivity indicator calculated as GDP/DMI, these two new indicators show more moderate trends, i.e. smaller improvements in resource productivity.

A decomposition analysis study was also undertaken (Hashimoto *et al.*, 2009) to elucidate in more detail what factors have changed Japanese Resource Productivity for the period 1995–2002. Effects of the following four factors were analysed: (1) Recycling factor, (2) Induced material-use intensity factor, (3) Demand structure factor, and (4) Average propensity to import

factor. The study concluded that changes in the demand structure (factor 3) produced the largest contribution to a reduction in resource-use intensity. The decline of final demand for construction materials resulted in the largest contribution to the decline in resource-use intensity (i.e. improvements in resource productivity). The study also found that the aggregate of the effect of improvements in induced material-use intensity of goods and services (factor 2) and the effect of the increase of recycled resource inputs (factor 1) contributed to the change in resource productivity as much as the effect of changes in demand structure.

9.7 Conclusion

In Japanese environmental policy, the limits of the current socio-economic system characterized by mass-production, mass-consumption and mass-disposal have been recognized since the 1990s. The geopolitical specificity of Japan which depends for most of its natural resource supply on imports and the spiritual tradition of 'Mottainai' explain this.

The case study revealed that the concept of 'decoupling' has been explicitly incorporated into Japanese national policy for establishing a sound material cycle (SMC) society, as represented by the adoption of material flow indicators, including resource productivity. While the direct driver of the SMC policy was a visible limit in solid waste management, it has been successfully coupled to resource input issues. 3R policies have been enforced by the national legislative framework and its concept and practical experiences have been disseminated internationally.

In contrast, though not directly reviewed in detail by this case study, decoupling of CO_2 emissions from economic growth has not been sufficient, as pointed out by the OECD's environmental performance review. While the top runner approach for electric appliances and the voluntary consorted efforts towards Factor X by electric companies shed light on these circumstances, further efficiency improvements are necessary to accomplish reductions in energy and resource consumption in absolute terms.

While the Resource Productivity indicator measured as GDP/DMI shows a successful trend towards the target, this is significantly influenced by a decline in final demand from the construction sector caused by recessionary conditions. The real challenge is to achieve reduction in inputs of valuable natural resources such as fossil fuels and metal ores, by integrating SMC policy with other major components of environmental policies such as those for a low carbon society.

References

Aachener Stiftung Kathy Beys (2005) Ressourcenproduktivität als Chance. Ein langfristiges Konjunkturprogramm für Deutschland. Norderstedt: Book available on request.

AdL/ISI/WI (2006) Arthur D. Little AdL; Fraunhofer-Institut für System- und Innovationsforschung ISI; Wuppertal Institut für Klima, Umwelt, Energie WI (Hrsg.): Studie zur Konzeption eines Programms für die Steigerung von Materialeffizienz in mittelständischen Unternehmen. Wuppertal u.a.: AdL/ ISI/ WI, 2006.

Adriaanse, A., Bringezu, S., Hammond, A., Moriguchi, Y., Rodenburg, E., Rogich, D. and Schütz, H. (1997) Resource Flows: The Material Basis of Industrial Economies. World Resources Institute, Washington, DC.

AGAMA Energy (2005) '*Every Decision is an Energy Decision': Sustainable Development's Hottest Topic*. Cape Town: Unpublished paper commissioned by the Department of Environmental Affairs and Tourism.

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

Alcamo, J. and Vörösmarty, C.J. (2005) A new assessment of world water resources and their ecosystem services. GWSP Newsletter No. 1, pp 1-3.

Aleklett, K., Höök, M., Jakobsson, K., Lardelli, M., Snowden, S. and Söderbergh, B. (2009) The Peak of the Oil Age – analyzing the world oil production Reference Scenario in World Energy Outlook 2008, *Energy Policy*, Volume 38, Issue 3, March 2010, Pages 1398-1414.

Andersen, M.S. and Liefferink, D. (1997) European Environmental Policy. The Pioneers. Manchester University Press, Manchester.

Aoe, T. (2007) Eco-efficiency and ecodesign in electrical and electronic products, Journal of Cleaner Production, 15, 1406-1414.

Ashton, P.J. and Turton, A.R. (2008) Water and Security in Sub-Saharan Africa: Emerging Concepts and their Implications for Effective Water Resource Management in the Southern African Region. In: H.G. Brauch, J. Grin, C. Mesjasz, H. Krummenacher, N.C. Behera, B. Chourou, U.O. Spring, P.H. Liotta and P. Kameri-Mbote (eds). Facing Global Environmental Change: Environmental, Human, Energy, Food, Health and Water Security Concepts – Volume IV. Springer-Verlag, Berlin.

Association for the Study of Peak Oil and Gas (ASPO) Newsletter No. 100 (2009) http://aspoireland.files.wordpress.com/2009/12/newsletter100_200904.pdf.

Australian Government (2009) Composition of Trade: 2008/2009. Department of Foreign Affairs and Trade, Canberra.

Ayres, R.U. (1994) Industrial metabolism: theory and policy. In B. R. Allenby & D. J. Richards (eds.), The Greening of Industrial Ecosystems: 23-37. Washington, DC: National Academy Press.

Ayres, R.U. and van den Bergh, J.C.M. (2005) A Theory of Economic Growth Material/Energy Resources and Dematerialization: Interaction with Three Growth Mechanisms. Ecological Economics, 55:96-118.

Ayres, R.U. and Warr, B. (2005) Accounting for Growth: The Role of Physical Work, 16(2):181-209.

Barbier, E.B. (2009) A Global Green New Deal: Report prepared for the Economics and Trade Branch, Division of Technology, Industry and Economics, United Nations Environment Programme.

Barbiero, G., Camponeschi, S., Femia, A., Greca, G., Tudini, A. and Vannozzi, M. (2003) 1980-1998 Material-Input-Based Indicators Time series and 1997 Material Balances of the Italian Economy. ISTAT, Rome.

Behrens, A., Giljum, S., Kovanda, J. and Niza, S. (2007) The Material Basis of the Global Economy: Worldwide Patterns of Natural Resource Extraction and their Implications for Sustainable Resource use Policies. Ecological Economics, 64:444-453.

Berkhout, P.H.G., Muskens, C. and Velthuijsen, J.W. (2000) Defining the Rebound Effect. Energy Policy, 28(6-7):425-432.

Bleischwitz, R., Jacob, K., Bahn-Walkowiak, B., Petruschke, T., Rennings, K. (2008) Ressourcenpolitik zur Gestaltung der Rahmenbedingungen Ressourcenpolitik zur Gestaltung der Rahmenbedingungen. Wuppertal: Wuppertal Institut für Klima, Umwelt, Energie. MaRess Paper 3.1.

Blignaut, J. (2006) Macro-Perspectives on Water Supply and Demand: Implications of the 6% Economic Growth Rate. Presentation to National Environmental Advisory Forum: Pretoria, 3 October 2006.

BMU (2008a) Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit BMU (ed.): Leitstudie 2008. Weiterentwicklung der "Ausbaustrategie Erneuerbare Energien" vor dem Hintergrund der aktuellen Klimaschutzziele Deutschlands und Europas. BMU, Berlin.

BMU (2008b) Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit BMU (ed.): Ökologische Industriepolitik. Nachhaltige Politik für Innovation, Wachstum und Beschäftigung. BMU, Berlin.

BMU/IGM/WI (2006) Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit BMU; IG Metall IG; Wuppertal Institut für Klima, Umwelt, Energie WI (eds.): Ressourceneffizienz. Innovation für Wirtschaft und Arbeit. Wuppertal: WI.

BMU/UBA (2007) Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit BMU; Umweltbundesamt UBA (ed.): Umweltpolitische Innovations- und Wachstumsmärkte aus Sicht der Unternehmen. BMU/ UBA, Berlin/Dessau-Rosslau.

BMWi/BMU (2010) Bundesministerium für Wirtschaft und Technologie BMWi; Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit BMU (eds.) , Energiekonzept : Neun Punkte für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung.

Bond, P. (2006) Looting Africa. Zed Press, London.

Bringezu, S. and Bleischwitz, R. (2009) Sustainable Resource Management: Global Trends, Visions and Policies. Wuppertal Institute, Germany.

Bringezu, S. and Schutz, H. (2001) Material use Indicators for the European Union, 1980-1997. Economy-Wide Material Flow Accounts and Balances and Derived Indicators of Resource use. Luxembourg: Eurostat.

Bringezu, S., Schutz, H. and Moll, S. (2003) Rationale for and Interpretation of Economy-Wide Material Flow Analysis and Derived Indicators. Journal of Industrial Ecology, 7(2):43-67.

Bringezu, S., Schutz, H., Steger, S. and Baudisch, J. (2004) International Comparison of Resource use and its Relation to Economic Growth: The Development of Total Material Requirement, Direct Material Inputs and Hidden Flows and the Structure of TMR. Ecological Economics, 51(1/2):97-124.

Brown, L. (2008) Plan B 3.0: Mobilizing to Save Civilization. W.W. Norton & Company New York and London.

Bruckner, M., Polzin, C. and Giljum, S. (2010) Counting CO2 emissions in a globalised world: Producer versus consumer-oriented methods for CO2 accounting. German Development Institute Discussion paper 9/2010.

Buhrs, T. (2007) Environmental Space as a Basis for Enhancing the Legitimacy of Global Governance. CSGR/GARNET Conference on Pathways to Legitimacy? The Future of Global and Regional Governance: Warwick University, UK, 17-19 September 2007.

BUND/MISEREOR (1996) Bund für Umwelt und Naturschutz BUND; MISEREOR (eds.): Zukunftsfähiges Deutschland. Ein Beitrag zu einer globalen nachhaltigen Entwicklung. Birkhäuser, Berlin.

Bundesamt für Güterverkehr (2006) Marktbeobachtung Güterverkehr, Jahresbericht 2005, Cologne.

Buyny, S., Klink, S. and Lauber, U. (2009) Verbesserung von Rohstoffproduktivität und Ressourcenschonung – Weiterentwicklung des direkten Materialinputindikators, Statistisches Bundesamt, Wiesbaden.

Cairncross, E.K. (2005) Air Quality. Unpublished paper commissioned by the Department of Environmental Affairs and Tourism, Cape Town.

Castells, M. (1997) The Information Age Volumes 1, 2 and 3. Blackwell, Oxford.

Chapagain, A.K. and Hoekstra, A.Y. (2008) The global component of freshwater demand and supply: An assessment of virtual water flows between nations as a result of trade in agricultural and industrial products, Water International 33(1): 19-32.

China Council for International Cooperation on Environment and Development (CCICED) (2007a) Strategic Shift of Environment and Economy in China: Special Report.

China Council for International Cooperation on Environment and Development (CCICED) (2007b) Issues Paper.

Chinese Academy of Sciences (2006) Report on Sustainable Development Strategy of China 2006. Science Press, Beijing.

Chong, S.K. (2005) Anmyeon-do Recreation Forest: A Millennium of Management. In: P. Durst. (ed), In Search of Excellence: Exemplary Forest Management in Asia and the Pacific. Asia-Pacific Forestry Commission, FAO Regional Office for Asia and the Pacific, Bangkok.

Christian Aid (2005) The Economics of Failure: The Real Cost of 'Free' Trade for Poor Countries. Christian Aid, London.

City of Cape Town (2007) Report to the Chairperson: Utility Services Portfolio Committee Solid Waste Management. Department Sector Plan for Integrated Waste Management and Service Delivery in Cape Town. Cape Town, City of Cape Town, unpublished document.

Commission on Growth and Development (2008). The Growth Report: Strategies for Sustained Growth and Inclusive Development. World Bank, Washington, DC.

Communist Party of China (CPC) (2007) Report of the 17th National Congress of the CPC.

Daly, H. E. (1977) Steady-State Economics, Second Edition 1991, Washington DC: Island Press.

De Bruyn, S. (2002) Dematerialization and rematerialization as two recurring phenomena of industrial ecology, in: Ayres, R.U., Ayres, L.W. (Eds.), A Handbook of Industrial Ecology. Edward Elgar, Cheltenham, pp. 209-222.

De Bruyn, S., Markowska, A., De Jong, F. and Blom, M. (2009) Resource productivity, competitiveness and environmental policies. CE Delft, 1-72.

De Marco, O., Lagioia, G. and Pizzoli Mazzacane, E. (2000) Materials Flow Analysis of the Italian Economy. In: Journal of Industrial Ecology, 4(2), S. 55-70.

Department of Water Affairs and Forestry (2006) South Africa's Water Sources: 2006. Pretoria.

DESTATIS (2008) Statistisches Bundesamt DESTATIS (ed.): Nachhaltige Entwicklung in Deutschland. Indikatorenbericht 2008. DESTATIS, 2008, Wiesbaden.

DETR/ONS/WI (2001) Total Material Resource Flows of the United Kingdom, (revised and updated 2002 by ONS). Department of Environment, Transport and the Regions of the UK, Office for National Statistics of the UL, Wuppertal Institute.

Dittrich, M. (2007) Konzept für ein Handelssystem mit globaler Dematerialisierung und einer gerecht verteilten Ressourceninanspruchnahme als Zielsetzung. Wuppertal Papers No. 166. Wuppertal. [available on http://www.wupperinst.org/globalisierung/pdf_global/inanspruchnahme.pdf].

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

Dittrich, M. (2010) Physische Handelsbilanzen. Verlagert der Norden Umweltbelastungen in den Süden? Kölner Geographische Arbeiten 91, Köln. Page 123.

Dittrich, M. and Bringezu, S. (2010) The physical dimension of international trade Part 1: direct global flows between 1962 and 2005. Ecological Economics, 69:1838-1847.

Doshi, V., Schulam, G. and Gabaldon, D. (2007) Lights! Water! Motion! Strategy and Business, 47:39-53.

Driver, M., Smith, T. and Maze, K. (2005) Specialist Review Paper on Biodiversity for the National Strategy for Sustainable Development. Cape Town: South African National Biodiversity Institute. Paper commissioned by the Department of Environmental Affairs and Tourism, South African Government, November 2005.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Leveque, C., Naiman, R.J., Prieur-Richard, A.H., Soto, D., Stiassny, M.L.J. and Sullivan, C.A. (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81, 163-182.

Ecofys/DLR *et al.* (2007) Ecofys; Deutsches Zentrum für Luft- und Raumfahrt. On behalf of Greenpeace International and European Renewable Energy Council (ed.): Energy (R) Evolution. A Sustainable World Energy Outlook. 2007 [available online at http://www.greenpeace.org/raw/content/international/press/reports/energyrevolutionreport.pdf].

Edenhofer, O., Luderer, G., Flachsland, C., Füssel, Hans-Martin, Popp, B., Knopf, B., Feulner, G. and Held, H. (2008) A Global Contract on Climate Change. Background paper for the conference "A Global Contract Based on Climate Justice: The Need for a New Approach Concerning International Relations" in Brussels, 11 November 2008.

EEA (2005) Sustainable use and management of natural resources. EEA Report No 9/2005. European Environment Agency (EEA), Copenhagen.

EEA (2008) Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries. EEA Report 2/2008. European Environment Agency (EEA), Copenhagen.

EEA (2011) Growth in the productivity of labour, energy and materials, EU-15 and EU-12. Available: http://www.eea.europa.eu/dataand-maps/figures/growth-in-theproductivity-of. Accessed online: Feb 2011.

Eisenmenger, N. and Giljum, S. (2006) "Evidence from Societal Metabolism Studies for Ecological Unequal Trade". In: A. Hornborg and C.L. Crumley (eds.). *The World System and the Earth System. Global Socio-Environmental Change and Sustainability since the Neolithic*. Left Coast Press Inc.: Walnut Creek, California. 288-302.

Ekins, P. (2000) Economic Growth and Environmental Sustainability. Routledge, New York.

Erb, K.H., Gaube, V., Krausmann, F., Plutzar, C., Bondeau, A. and Haberl, H. (2007) A comprehensive global 5min resolution land-use dataset for the year 2000 consistent with national census data. In: Journal of Land Use Science 2(3), S. 191-224.

Erb, K.H., Krausmann, F., Gaube, V., Gingrich, S., Bondeau, A., Fischer-Kowalski, M. and Haberl, H. (2009) Analyzing the global human appropriation of net primary production – processes, trajectories, implications. An introduction, Ecological Economics 69 (2), 250-259.

Eurostat (2001) Economy-wide Material Flow Accounts and Derived Indicators. A methodological guide. Luxembourg: Eurostat, European Commission, Office for Official Publications of the European Communities, 1-92.

Eurostat (2002) Material use in the European Union 1980-2000. Indicators and Analysis. Office for Official Publications of the European Communities, Luxembourg.

Eurostat (2007) Economy-wide Material Flow Accounting. A Compilation Guide. European Statistical Office, Luxembourg.

Evans, P. (2005) The Challenges of the Institutional Turn: New Interdisciplinary Opportunities in Development Theory. In The Economic Sociology of Capitalist Institutions, edited by N. V and R. Swedberg. Princeton: Princeton University Press, pp. 90-116.

Evans, P. (2006) What will the 21st Century Developmental State Look Like? Implications of Contemporary Development Theory for the State's Role. Conference on 'The Change Role of the Government in Hong Kong' at the Chinese University of Hong Kong. Hong Kong. Unpublished.

Femia, A. (2000) A material flow account for Italy, 1988. Eurostat Working Paper No 2/2000/B/8. Luxembourg.

Fischer-Kowalski, M. (2011) Analyzing sustainability transitions as shifts between socio-metabolic regimes. In: Environmental Innovation and Societal Transitions (forthcoming).

Fischer-Kowalski, M. and H. Haberl (2007) Socioecological transitions and global change: Trajectories of Social Metabolism and Land Use. Edward Elgar, Cheltenham, UK and Northhampton, USA.

Fischer-Kowalski, M., F. Krausmann, S. Giljum, S. Lutter, A. Mayer, S. Bringezu, Y. Moriguchi, H. Schütz, H. Schandl, H. Weisz (2011) Methodology and indicators of economy wide material flow accounting. State of the art and reliablity across sources. Journal of Industrial Ecology.

Gagnon, N., Hall, C.A.S. and Brinker, L. (2009) A Preliminary Investigation of Energy Return on Energy Investment for Global Oil and Gas Production. Energies, 2: 490-503.

Gallopin, G. (2003) A Systems Approach to Sustainability and Sustainable Development. Economic Commission for Latin America, Santiago.

GCI (2003) GCI Briefing on Contradiction and Convergence. Global Commons, UK.

Geels, F. W. (2002) Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study. Research Policy, 31(8/9): 1257-1274.

Geels, F. W. (2004) From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory. Research Policy, 33: 897-920.

Geels, F. W. (2010) Ontologies, Sociotechnical Transition (to Sustainability) and the Multi-Level Perspectives. Research Policy, 39: 495-510.

Geels, F. W. and J. W. Schot (2007) Typology of sociotechnical transition pathways: refinements and elaborations of the multi-level perspective. Research Policy, 36(3): 399-417.

German Federal Statistical Office - Statistisches Bundesamt (2000) Integrated Environmental and Economic Accounting - Material and Energy Flow Accounts. Wiesbaden

Giljum, S. (2002) Trade, Material Flows and Economic Development in the South: the Example of Chile. Paper presented at the 7th Biennial Conference of the International Society for Ecological Economics, Sousse, Tunisia.

Giljum, S., Behrens, A., Hintergerber, F., Lutz, C. and Meyer, B. (2008) "Modelling scenarios towards a sustainable use of natural resources in Europe". In: Environmental Science and Policy 11 (3), 204-216.

Giljum, S. and Eisenmenger, N. (2004). "International trade and the distribution of environmental goods and burdens: a biophysical perspective". In: *Journal of Environment and Development.* 13 (1), 73-100.

Giurco, D., T. Prior, G.M. Mudd, L. Mason, J. Behrisch (2010) Peak Minerals in Australia: A Review of changing Impacts and Benefits. Prepared for CSIRO Minerals Down Under Flagship, by the Institute for Sustainable Futures (University of Technology, Sydney) and Department of Civil Engineering (Monash University). Institute for Sustainable Futures, Sydney. University of Technology, Sydney.

Gleick, P.H. (2006) The World's Water (2006-2007): The Biennial Report on Freshwater Resources. Island Press, Washington, DC.

Gleick, P.H. (2009) The World's Water (2008-2009): The Biennial Report on Freshwater Resources. Island Press, Washington, DC.

Gonzalez-Martinez, A.C. and Schandl, H. (2008) The biophysical perspective of a middle income economy: Material flows in Mexico. Ecological Economics, 68(1-2): 317-327.

Government of Japan (2007) Becoming a leading Environmental Nation in the 21st Century, Japan's Strategy for a Sustainable Society, Cabinet Meeting Decision, Tokyo, June 1, 2007. [available on http://www.env.go.jp/en/focus/attach/070606-b.pdf].

Graham, S. and Marvin, S. (2001) Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition. Routledge, London and New York.

Green New Deal Group (2008) A Green New Deal: Joined-up policies to solve the triple crunch of the credit crisis, climate change and high oil prices. New Economics Foundation, London.

Greening, L.A. and Greene, D.L. (1997) Energy Use, Technical Efficiency, and the Rebound Effect: A Review of the Literature, Report to the Office of Policy Analysis and International Affairs, US Dept of Energy, Washington DC.

Greening, L.A., Greene, D.L. and Difiglio, C. (2000) Energy Efficiency and Consumption – the Rebound Effect: A Survey. Energy Policy, 28: 389-402.

Guy, S., Marvin, S. and Moss, T. (2001) Urban Infrastructure in Transition. Earthscan, London.

Haberl, H., Fischer-Kowalski, M. , Krausmann, F. , Weisz, H. and Winiwarter, V. (2004) Progress Towards Sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. Land Use Policy, 21(3): 199-213.

Haberl, H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W. and Fischer-Kowalski, M. (2007) Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. In: Proceedings of the National Academy of Sciences of the United States of America 104, pp. 12942-12947.

Haberl, H., Fischer-Kowalski, M., Krausmann, F., Martinez-Alier, J. and Winiwarter, V. (2009) A socio-metabolic transition towards sustainability? Challenges for another Great Transformation. Sustainable Development. [online].

Hails, C., Humphrey, S., Loh, J. and Goldfinger, S. (2008) Living Planet Report 2008. WWF International, Gland, Switzerland.

Hammer, M. and Hubacek, K. (2003) Material Flows and Economic Development, Material Flow Analysis of the Hungarian Economy. Laxenburg, Austria: IIASA Interim Report IR-02-057.

Hashimoto, S., Matsui, S., Matsuno, Y., Nansai, K., Murakami, S. and Moriguchi, Y. (2009) What Factors Have Changed Japanese Resource Productivity? A Decomposition Analysis for 1995–2002. Journal of Industrial Ecology, 12(5-6), 657-668.

He Juhuang (2001) Long-Term Prediction Model for Chinese Population and Economy. Journal of Quantitative and Technological Economy Studies, Edition 9. Beijing.

Hennicke, P. and Kristof, K. (2008) Impulsprogramm Ressourceneffizienz. Innovationen und wirtschaftlicher Entwicklung eine Richtung geben. Ein Vorschlag des Wuppertal Instituts. Wuppertal Institut für Klima, Umwelt, Energie (MaRess Paper 7.2), Wuppertal.

Herring, H. (2004) Rebound effect of energy conservation. In Encyclopaedia of Energy, edited by C. J. Cleveland. Elsevier, Amsterdam, pp. 237-245.

Heynen, N., Kaika, M. and Swyngedouw, E. (2006) In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism. Routledge, London.

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

Hirsch, R. L. (2008) Mitigation of Maximum World Oil Production: Shortage Scenarios. Energy Policy, 36: 881-889.

Hoekstra, A.Y. and Chapagain, A.K. (2007) The water footprints of Morocco and the Netherlands: Global water use as a result of domestic consumption of agricultural commodities. Ecological Economics, 64(1): 143-151.

Holdren, J.P. and Smith, K.R. (2000) Energy, the environment, and health. In: Goldemberg, J. et.al. (eds) The World Energy Assessment : Energy and the challenge of Sustainability, New York, United Nations Development Programme, 61-110.

Homer-Dixon, T.F. (2000) The Ingenuity Gap. Jonathan Cape, London.

Houser, T., Mohan, S. and Heilmayr, R. (2009) A Green Global Recovery? Assessing US Economic Stimulus and the Prospects for International Coordination. Peterson Institute for International Economics and World Resources Institute, Washington, DC.

HSBC (2009) More Green Money on the Table. Endseurope.com. [available on http://www.endseurope.com/docs/90401c.pdf].

Hubbert, M.K. (1956) Nuclear energy and the fossil fuels. Presented before the Spring Meeting of the Southern District Division of Production American Petroleum Institute Plaza Hotel, San Antonio, Texas March 7-8-9, 1956; Publication no. 95 Shell Development Company Exploration and Production Research Division, Houston, Texas, June 1956, http://www.hubbertpeak.com/hubbert/1956/1956.pdf; also published in: Drilling and production practice, American Petroleum Institute, Washington DC, p. 7-25 1956.

International Energy Agency (IEA) (2008) World Energy Outlook. Paris: International Energy Agency.

IPCC (2007) Climate Change 2007. Geneva: United Nations Environment Programme.

Isacsson, A., Johnsson, K., Linder, I., Palm, V. and Wadeskog, A. (2000) Material Flow Accounts – DMI and DMC for Sweden 1987-1997. Eurostat, Office for Official Publications of the European Communities, Luxembourg.

Jackson, T. (2009) Prosperity without Growth: the Transition to a Sustainable Economy. UK Sustainability Commission, London, UK.

Jänicke, M., Jörgens, H., Jörgensen, K. and Nordbeck, R. (2001) Governance for Sustainable Development in Germany. Institutions and Policy-Making. OECD, Paris.

Jochem, Eberhard (ed.) (2004) Steps towards a Sustainable Development. A White Book for R & D of Energy-efficient Technologies. Novatlantis, Zurich [available online at http://www.cepe.ethz.ch/publications/cepeBooks/WhiteBook_on_RD_energyefficient_technologies.pdf].

Jochem, E., Kristof, K., Liedtke, C. *et al.* (2005) Studie zur Konzeption eines Programms für die Steigerung der Materialeffizienz in mittelständischen Unternehmen. Abschlussbericht im Auftrag des Bundesministeriums für Wirtschaft und Arbeit. Wuppertal/ Karlsruhe/ Wiesbaden: Wuppertal Institut für Klima, Umwelt, Energie, Fraunhofer-Institut für System und Innovationsforschung, Arthur D. Little.

Kaiser, A. (2007) Ressortübergreifende Steuerung politischer Reformprogramme. Was kann die Bundesrepublik Deutschland von anderen parlamentarischen Demokratien lernen? In: Bertelsmann Stiftung (ed.): Jenseits des Ressortdenkens. Reformüberlegungen zur Institutionalisierung strategischer Regierungsführung in Deutschland. Gütersloh: Bertelsmann Stiftung (Zukunft Regieren – Beitraege für eine gestaltungsfaehige Politik 1/2007), pp. 12-55.

Kemp, R. and Pearson, P. (2008) Measuring Eco-Innovation. Final Report of MEI project. Maastricht University, Maastricht.

Knoll, T. (2004) Das Bonner Bundeskanzleramt. Organisation und Funktionen von 1949-1999. VS Verlag, Wiesbaden.

Kobayashi, Y., Kobayashi, H., Hongu, A. and Sanehira, K. (2005) A practical method for quantifying eco-efficiency using eco-design support tools. Journal of Industrial Ecology, 9(4), 131-144.

Krausmann, F., Eisenmenger, N., Braunsteiner-Berger, J., Deju, M., Huber, V., Kohl, L., Musel, A., Nussbaum, M.L., Rechnitzer, S. and Reisinger, H. (2005) MFA for South Africa. Vienna: Institute for Social Ecology.

Krausmann, F., Erb, K.H., Gingrich, S., Lauk, C. and Haberl, H. (2008a) Global patterns of socio-economic biomass flows in the year 2000: A comprehensive assessment of supply, consumption and constraints. Ecological Economics, 65(3): 471-487.

Krausmann, F., Fischer-Kowalski, M., Schandl, H. and Eisenmenger, N. (2008b) The global socio-metabolic transition: past and present metabolic profiles and their future trajectories. Journal of Industrial Ecology, 12(5/6): 637-656.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.H., 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.

Laker, M.C. (2005) *South Africa's Soil Resources and Sustainable Development.* Cape Town: Unpublished paper commissioned by the Department of Environmental Affairs and Tourism.

Lenzen, M., Wiedmann, T., Foran, B., Dey, C., Widmer-Cooper, A., Williams, M., Ohlemüller, R. (2007) Forecasting the Ecological Footprint of Nations: A Blueprint for A Dynamic Approach. University of Sydney Center for Integrated Sustainability Analysis and Stockholm Environment Institute at the University of York, Sydney, Australia.

Lijphart, A. (1999) Patterns of Democracy. Government Forms and Performance in Thirty-Six Countries. Yale University Press, New Haven, CT.

Lovins, A.B. and Hennicke, P. (1999) Voller Energie. Vision: Die globale Faktor-Vier-Strategie für Klimaschutz und Atomausstieg. Buchreihe EXPO 2000, Campus Verlag, Frankfurt a. M., New York, 1999.

Lundvall, B.A. (2007) National Innovation System: Analytical Focusing Device and Policy Learning Tool. Swedish Institute for Growth Policy Studies, Ostersund, Sweden.

Luzzati, T. and Orsini, M. (2009) Investigating the energy-environmental Kuznets curve. Energy, 34: 291-300.

Maenpaa, I. and Siikavirta, H. (2007) Greenhouse gases embodied in the international trade and final consumption of Finland: An input-output analysis. Energy Policy, 35(1): 128-143.

Martin, L.W. (2004) The Government Agenda in Parliamentary Democracies. American Journal of Political Science, Vol. 48, No. 3, pp. 445-461.

Matos, G. and Wagner, L. (1998) Consumption of Materials in the United States, 1900-1995. Annual Review of Energy and the Environment, 23: 107-122.

Ministry of Environmental Protection of China (MEPC) (2009) Report on China Macro Environmental Strategy Studies.

Ministry of the Environment, Government of Japan (1994) The Basic Environmental Plan [available online http://www.env.go.jp/en/policy/plan/basic/foreword.html].

Ministry of the Environment, Government of Japan (1998) Quality of the Environment in Japan 1998 [available online http://www.env.go.jp/en/wpaper/1998/index.html].

Ministry of the Environment, Government of Japan (2007) Becoming a Leading Environmental Nation Strategy in the 21st Century – Japan's strategy for a Sustainable Society [available online http://www.env.go.jp/en/focus/070606.html].

Ministry of the Environment, Government of Japan (2008) The World in Transition, and Japan's Efforts to Establish a Sound Material-Cycle Society [available online http://www.env.go.jp/recycle/3r/en/approach/report_material-cycle/2008.pdf].

Ministry of the Environment, Government of Japan (2008) Annual Report on the Environment and the Sound Material-Cycle Society in Japan 2008 [available online http://www.env.go.jp/en/wpaper/2008/index.html].

Ministry of the Environment, Government of Japan (2009) Annual Report on the Environment and the Sound Material-Cycle Society in Japan 2009. [available online http://www.env.go.jp/en/recycle/smcs/a-rep/2009gs_full.pdf].

Ministry of the Environment, Government of Japan (2009) Material Flows in Japan 2006. [available online http://www.env.go.jp/en/recycle/smcs/material_flow/2006_en.pdf].

Ministry of the Environment, Government of Japan (2010) Annual Report on the Environment and the Sound Material-Cycle Society in Japan 2010. http://www.env.go.jp/en/recycle/smcs/a-rep/2010gs_full.pdf

Mohamed, S. (2008) Financialization and Accumulation in South Africa. Unpublished Powerpoint presentation, 7 April 2008. Johannesburg: Corporate Strategy and Industrial Development, University of the Witwatersrand.

Moll, S., Acosta J. and Villanueva, A. (2004) Environmental implications of resource use. Insights from input-output analyses. EEA ETC/WMF, Copenhagen.

Moll, S., Bringezu, S. and Schutz, H. (2005) Resource use in European countries: An estimate of materials and waste streams in the community, including imports and exports using the instrument of material flow analysis. Wuppertal Report No. 1. Wuppertal Institute, Wuppertal.

Montalvo, C. (2008) Sustainable systems of innovation: How level is the playing field for developing and developing economies? Paper presented at Globelics Conference. Mexico. 2008.

Moriguchi, Y. (2000) Industrial Ecology in Japan. Journal of Industrial Ecology, 4(1), 7-9.

Moriguchi, Y. (2007) Material flow indicators to measure progress toward a sound material-cycle society. J. Material Cycles & Waste Management, 9(2), 112-120.

Moriguchi, Y. (2011) National policies and international initiatives for sustainable management of waste and resources, Establishing a resource-circulating society in Asia: Challenges and opportunities, (Morioka, T., Hanaki, K. and Moriguchi Y., ed.), 171-183, United Nations University Press, Tokyo. (in printing).

Mudd, G.M. (2009) The Sustainability of Mining in Australia - Key Production Trends and Their Environmental Implications for the Future. Research Report RR5, Published by the Dept of Civil Engineering, Monash University and the Mineral Policy Institute.

Mudgal, S., Fischer-Kowalski, M., Krausmann, F., Chenot, B., Lockwood, S., Mitsios, A., Schaffartzik, A., Eisenmenger, N., Cachia, F., Steinberger, J., Weisz, U., Kotsalainen, K., Reisinger, H. and Labouze, E. (2010) Preparatory study for the review of the thematic strategy on the sustainable use of natural resources. Contract 07.0307/2009/545482/ETU/G2, Final report for the European Commission (DG Environment), Paris.

Müller, E. (2002) Environmental Policy Integration as a Political Principle. The German Case and the Implications of European Policy. In: Lenschow, A. (ed.): Environmental Policy Integration. Greening Sectoral Policies in Europe. Earthscan, London. 2002, pp. 57-77.

Munoz, P., Giljum, S. and Roca, J. (2009) The Raw Material Equivalents of International Trade. Journal of Industrial Ecology, 13(6): 881-898.

Muradian, R. and Giljum, S. (2007) Physical Trade Flows of Pollution-Intensive Products: Historical Trends in Europe and the World. In: Hornborg, A., McNeill, J. and J. Martinez-Alier (editors). Rethinking Environmental History: World-System History and Global Environmental Change. Altamira Press, U.S.

Muradian, R., O´Connor, M. and Martinez-Alier, J. (2002) Embodied Pollution in Trade: Estimating the 'Environmental Load Displacement' of Industrialised Countries. Ecological Economics 41(1): 41-57.

Muukkonen, J. (2000) TMR, DMI and material balances, Finland 1980-1997. Eurostat, Office for Official Publications of the European Communities, Luxembourg.

Nakicenovic, N. and R. Swart (2000) Special Report on Emission Scenarios. Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.

National Development and Reform Commission (NDRC) (2008) Progress Report on the Circular Economy, October 2008.

National Research Council (2003) Cities Transformed. National Academies Press, Washington, DC.

Newman, P. and Kenworthy, J. (2007) *Greening Urban Transportation*. Worldwatch Institute. State of the World: Our Urban Future New York & London: W.W. Norton & Company.

Nielsen, P., Tukker, A., Weidema, B., Lauridsen, E. H., and Notten, P. (2005) Environmental Impact of the Use of Natral Resources. Technical Report EUR 21485 EN. Joint Research Centre. Institute for Prospective Technological Studies.

NIES/MOE (2007) Material Flow Account for Japan. National Institute of Environmental Studies on behalf of the Ministry of the Environment.

Niestroy, I. (2005) Sustaining Sustainability. A Benchmark Study on National Strategies Towards Sustainable Development and the Impact of Councils in Nine EU Member States. European Environment and Sustainable Development Advisory Councils EEAC (EEAC Series Background Study No. 2), The Hague.

OECD (2008) Measuring Material Flows and Resource Productivity. Volume III. Inventory of Country Activities. OECD, Paris.

OECD (2008b) Measuring Material Flows and Resource Productivity. Synthesis Report. OECD, Paris.

OECD (2009) Sustainable Manufacturing and Eco-Innovation. OECD, Paris.

OECD and IEA (2008) World Energy Outlook 2008.

Organisation for Economic Cooperation and Development (OECD) (2002a) Indicators to Measure Decoupling of Environmental Pressure and Economic Growth. OECD, Paris.

Organisation of Economic Cooperation and Development (OECD) (2002b) Environmental Performance Review of Japan. The OECD Environment Programme. OECD, Paris.

Oxfam (2005) Africa and the Doha Round: Fighting to Keep Development Alive. Oxfam, Oxford.

Pedersen, O. G. (2002) DMI and TMR for Denmark 1981, 1990, 1997. An assessment of the Material Requirements of the Danish Economy. Statistics Denmark.

People's Republic of China (PRC) (1979) China Statistics Yearbook 1979. China Statistics Press, Beijing.

People's Republic of China (PRC) (2007) China Environmental Statistics Yearbook, 1990-2007. China Statistics Press, Beijing.

People's Republic of China (PRC) (2008) China Water Resources Statistics Yearbook, 1998-2008. China Statistics Press, Beijing.

People's Republic of China (PRC) (2009a) Government Work Report, submitted by the Chinese government to the 2nd Plenary Session of the 11th National People's Congress, March 2009.

People's Republic of China (PRC) (2009b) China Statistics Yearbook 2009. Beijing: China Statistics Press, Beijing.

Perez-Rincon, M.A. (2006) Colombian international trade from a physical perspective: Towards an ecological "Prebisch thesis". *Ecological Economics*, 59(4): 519-529.

Perkins, R. (2003) Environmental Leapfrogging in Developing Countries: A Critical Assessment and Reconstruction. Natural Resources Forum, 27(3):177-188.

Peters, G. 2008. From Production-Based to Consumption-Based National Emission Inventories. Ecological Economics, 65 (1): pp. 13-23.

Peters, G. and Hertwitch, E. (2008) CO_2 embodied in international trade with implications for global climate policy. *Environmental Science and Technology*, 42 (5): pp. 1401-1407.

Petrovic, B. (2007) Materialflussrechnung: Inputreihe 1960 bis 2005. Statistik Austria, Direktion Raumwirtschaft, Wien.

Pfister, C. (1996) Das 1950er Syndrom: Der Weg in die Konsumgesellschaft. Haupt, Bern, Wien.

Pieterse, E. (2008) City Futures. Juta, Cape Town.

Pollin, R., Garrett-Peltier, H., Heintz, J. and Scharber, H. (2008) Green Recovery: A Programme to Create Good Jobs and Start Building a Low-Carbon Economy. Center for American Progress, Washington, DC.

Quantec (2010) RSA Economic Indicators. http://www.quantec.co.za. Accessed 7 February 2010.

Raupach, M.R., Marland, G., Ciais, P., Le Quere, C., Canadell, J.G., Klepper, G. and Field, C.B. (2007) Global and regional drivers of accelerating CO2 emissions. Proceedings of the National Academy of Sciences of the United States of America, 104(24): 10288-10293.

Ren, Yong *et al.* (2005) Development Patterns of Circular Economy in China (J), China Population, Resource and Environment, Vol.5, No.5, pp137-142.

Ren, Yong *et al.* (2008) Mechanisms and Policies of Payment for Ecological Services. Beijing: China Environmental Science Press.

Ren, Yong (2009) Chinese Pathways and Initiative of Decoupling Environmental Degradation from Economic Growth. Research Report submitted to the Decoupling Working Group, International Panel for Sustainable Resource Management. Policy Research Center for Environment and Economy, Ministry of Environmental Protection, Beijing, China.

Renner, M. and Sweeney, S. (2008) Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World. UNEP/ILO/IOE/ITUC, Geneva.

Republic of South Africa, Department of Environmental Affairs and Tourism (2007) "People Planet Prosperity. A Framework for Sustainable Development in South Africa", [Online], pp. 24 February 2008. Available from: www.sustainabilityinstitute.net. [24 February 2008].

Republic of South Africa, Department of Trade and Industry (2007) A National Industrial Policy Framework. Pretoria: Department of Trade and Industry.

Republic of South Africa, Department of Water Affairs and Forestry (2004) National Water Resource Strategy. Pretoria: Department of Water Affairs and Forestry.

Republic of South Africa, Department of Water Affairs and Forestry (2002) The Development of a Sanitation Policy and Practice for South Africa. Pretoria: Department of Water Affairs and Forestry.

Republic of South Africa National Treasury (2006) A Framework for Considering Market-Based Instruments to Support Environmental Fiscal Reform in South Africa. Pretoria: Government Printer.

Rodrigues, J. and Giljum, S. (2005) The accounting of indirect material requirements in material flow-based indicators. ICFAI Journal of Environmental Economics, III(2): 51-69.

Rogich, D., Cassara, A., Wernick, I. and Miranda, M. (2008) Material Flows in the United States: A Physical Accounting of the U.S. Industrial Economy. WRI Report.

Romero-Lankao, P., Nychka, D. and Tribbia, J.L. (2008) Development and greenhouse gas emissions deviate from the 'modernization' theory and 'convergence' hypothesis. Climate Research, 38: 17-29.

Roy, J. (2000) The rebound effect: some empirical evidence from India. Energy Policy, 28: 433-438.

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

Sachs, J.D. and Warner, A.M. (2001) The Curse of Natural Resources. European Economic Review, 45(4-6): 827-838.

Sachs, W. (2002) The Joburg Memo: Fairness in a Fragile World. Heinrich Boll Foundation, Berlin.

Sala, E. and Knowlton, N. (2006) Global marine biodiversity trends. Annual Review of Environment and Resources, 31(1): 93-122.

Sanderson, F.J., Donald, P.F., Pain, D.J., Burfield, I.J. and van Bommel, F.P.J. (2006) Long-term population declines in Afro-Palearctic migrant birds. Biological Conservation, 131(1): 93-105.

Satterthwaite, D. (2007) The transition to a predominantly urban world and its underpinnings. International Institute for Environment and Development, London.

Saunders, H.D. (1992) The Khazzoom–Brookes postulate and neoclassical growth. Energy Journal, 13(4): 131-148.

Sauter, R. and Watson, J. (2008) Technology Leapfrogging: A Review of the Evidence. Report for DFID. SPRU, Sussex.

Scasny, M., Kovanda, J. and Hak, T. (2003) Material flow accounts, balances and derived indicators for the Czech Republic during the 1990s: results and recommendations for methodological improvements. Ecological Economics, 45(1): 41-57.

Scenario Building Team (2007) Long Term Mitigation Scenarios: Strategic Options for South Africa. Pretoria: Republic of South Africa. Department of Environmental Affairs and Tourism.

Schaffartzik, A., Krausmann, F. and Eisenmenger, N. (2009) Der Rohmaterialbedarf des österreichischen Außenhandels. Endbericht an das BMLFUW, Vertrag GZ: BMLFUW-UW.1.4.18/0057-V/10/2008, Wien.

Schandl, H. and Schulz, N.B. (2002) Changes in United Kingdom's natural relations in terms of society's metabolism and land use from 1850 to the present day. Ecological Economics, 41(2): 203-221.

Schandl, H. and Eisenmenger, N. (2006) Regional patterns in global resource extraction. Journal of Industrial Ecology, 10(4): 133-147.

Schandl, H., Weisz, H. and Petrovic, B. (2000) Materialflussrechnung für Österreich 1960 bis 1997. Statistik Austria, Wien.

Schipper, L. (2000) On the rebound: the interaction of energy efficiency, energy use and economic activity. Energy Policy, 28(6-7): 351-500.

Schmidheiny, S. (1992) Changing course: A global business perspective on development and the environment. MIT-Press, Cambridge, MA.

Schutz, H., Moll, S. and Bringezu, S. (2004) Globalisation and the shifting environmental burden: material trade flows and the EU – Which globalization is sustainable? Wuppertal Papers 134e. Wuppertal Institute, Wuppertal.

SERI (2008) Global Resource Extraction 1980 to 2005. Online database. Sustainable Europe Research Institute.

SERI Global and Friends of the Earth Europe (2009) Overconsumption? Out use of the World's Natural Resources. Vienna/Brussels: SERI Global.

Shui, B. and Harriss, R.C. (2006) The role of CO2 embodiment in US-China trade. Energy Policy 34(18), 4063-4068.

Shibaike, N., Shinomura, Y., Ichinohe, M., Tanaka, M., Takata, N., Miyake, K., Aihara, S. and Takeyama N. (2008) Activity of Japanese Electronics Industry on Environmental Performance Indicator toward Future Standardization, Proceedings of Electronics Goes Green 2008+, Berlin: 473-477.

Shiklomanov, I.A. and Rodda, J. (2003) World Water Resources at the Beginning of the 21st Century. Cambridge University Press, Cambridge.

Smil, V. (2002) Nitrogen and Food Production: Proteins for Human Diets. Ambio, 31(2): 126-131.

Smil, V. (2008) Energy in Nature and Society. General Energetics of Complex Systems. MIT Press, Cambridge, MA.

Sorrell, S. (2007) The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency. UK Energy Research Centre, Sussex.

Sorrell, S., Speirs, J., Bentley, R., Brandt, A. and Miller, R. (2009) Global Oil Depletion: An Assessment of the Evidence for a Near-Term Peak in Global Oil Production. A Report produced by the Technology and Policy Assessment Function of the UK Energy Research Centre. UK Energy Research Centre, Sussex.

Stamm, A., Dantas, E., Fischer, D., Ganguly, S. and Rennkamp, B. (2009) Sustainability-Oriented Innovation Systems: Toward Decoupling Economic Growth from Environmental Pressures?. German Development Institute, Bonn.

State Environmental Protection Agency of China (SEPA) (2004) Report on National Environmental Security Strategy. China Environmental Science Press, Beijing.

Steger, S. and Bleischwitz, R. (2009) Decoupling GDP from resource use, resource productivity and competitiveness: a cross-country comparison. In: Bleischwitz, Raimund (Hrsg.): Sustainable growth and resource productivity : economic and global policy issues. - Sheffield : Greenleaf Publishing, 2009, S. 172-193.

Steinberger, J.K. and Timmons, R.J. (2008) The changing relation of energy consumption and human development: a global study 1975-2005. Advances in Energy Studies, TU Graz, 29 June – 2 July 2008.

Steinberger, J.K., Krausmann, F. and Eisenmenger, N. (2010) Global patterns of material use: a socio-economic and geophysical analysis. Ecological Economics, 69(5): 1148-1158.

Stern, D.I. (2004) The Environmental Kuznets Curve. In: Modelling in Ecological Economics, edited by J. Proops and P. Safonov. Edward Elgar, Cheltenham, UK, Northampton, MA, USA, pp. 173-202.

Stern, N. (2007) The Economics of Climate Change. The Stern Review. Cambridge University Press, Cambridge.

Steurer, R. and Martinuzzi, A. (2005) Towards a New Pattern of Strategy Formation in the Public Sector. First Experiences with National Strategies for Sustainable Development in Europe. In: Environment and Planning (C: Government and Policy), Vol. 23 (2005), No. 3, pp. 455-472.

Stiglitz, J., Sen, A. and Fitoussi, J.P. (2009) Report by the Commission on the Measurement of Economic Performance and Social Progress. Governance of France. Report commissioned by President Sarkozy, Paris.

Sturm, R. and Pehle, H. (2007) Das Bundeskanzleramt als strategische Machtzentrale. In: Bertelsmann Stiftung (ed.): Jenseits des Ressortdenkens. Reformüberlegungen zur Institutionalisierung strategischer Regierungsführung in Deutschland. Gütersloh: Bertelsmann Stiftung (Zukunft Regieren – Beitraege für eine gestaltungsfaehige Politik 1/2007), 2007, pp. 56-106.

Sullivan, D.E., Sznopek, J.L. and Wagner, L.A. (n.d.) 20th Century U.S. Mineral Prices Decline in Constant Dollars. Open File Report: 00-389. Washington, DC: United States Geological Survey.

Swilling, M. (2007) *Growth, Sustainability and Dematerialisation: Resource Use Options for South Africa*, by Mark Swilling, commissioned by The Presidency, South African Government, presented at the Workshop on Scenarios for South Africa in 2019, The Presidency, Pretoria, July 2007.

Talberth, J. (2008) A New Bottom Line for Progress. In: 2008 State of the World: Innovations for a Sustainable Economy, edited by Worldwatch Institute. W.W. Norton and Company, London and New York, pp. 18-32.

Talberth, J., Cobb, C. and Slattery, N. (2007) Sustainable Development and the Genuine Progress Indicator: An Updated Methodology and Application in Policy Settings. Redefining Progress, Oakland, CA.

The Energy Conservation Center Japan (ECCJ) (2008). Top Runner Program: Developing the world's best energy-efficient appliances. Revised edition, January 2008. [available online http://www.eccj.or.jp/top_runner/img/32.pdf].

Tilman, D. (1999). Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. Proceedings of the National Academy of Sciences of the United States of America, 96(11): 5996-6000.

Tils, R. (2007) The German Sustainable Development Strategy. Facing Policy, Management and Political Strategy Assessments. In: European Environment, Vol. 17 (2007), No. 3, pp. 164-176.

Tukker, A. (2005) Leapfrogging into the Future: Developing for Sustainability. International Journal of Innovation and Sustainable Development, 1(1/2): 65-84.

Turton, A.R. (2008) *Three Strategic Water Quality Challenges that Parliamentarians Need to Know About*. CSIR Report No. CSIR/NRE/WR/IR/2008/0079/C prepared for the October Parliamentary Briefing. Pretoria: Council for Scientific and Industrial Research (CSIR).

UBA (2008) Umweltbundesamt (ed.): Resource Consumption of Germany. Indicators and Definitions. Final Report. Dessau-Rosslau: UBA (UBA Texte 08/08).

United Nations Development Programme (UNDP) (1998) [Online: retrieved October/22/2006]. United Nations Development Programme: New York: 5 November 2006. Available from: http://hdr.undp.org/reports/global/1998/en/.

United Nations Development Programme (UNDP) (2007) Human Development Report 2007/2008 Fighting Climate Change: Human Security in a Divided World. New York: United Nations Development Programme.

UNEP (2004) Global environment outlook scenario framework. Background paper for UNEP's third global environment outlook report (GEO-3). UNEP, Nairobi.

UNEP (2009) Towards sustainable production and use of resources: Assessing Biofuels, A report of the Biofuels Working Group to the International Resource Panel, Bringezu, S., Schutz, H, O'Brien, M., Kauppi, L., Howarth, R.W., McNeely, J., Otto, M.

UNEP (2010a) Metal Stocks In Society - Scientific Synthesis, A Report of the Working Group on Global Metal Flows to the International Panel for Sustainable Resource Management. (Graedel, T.E., Dubreuil, A., Gerst, M., Hashimoto, S., Moriguchi, Y., Müller, D., Pena, C., Rauch, J., Sinkala, T., Sonnemann, G.). UNEP.

UNEP (2010b) Assessing the Environmental Impacts of Consumption and Production: Priority Products and Materials, A Report of the Working Group on the Environmental Impacts of Products and Materials to the International Panel for Sustainable Resource Management. Hertwich, E., van der Voet, E., Suh, S., Tukker, A., Huijbregts M., Kazmierczyk, P., Lenzen, M., McNeely, J., Moriguchi, Y.). UNEP.

UNEP (2011) Recycling Rates of Metals: A Status Report, A Report of the Working Group on Global Metal Flows to the International Panel for Sustainable Resource Management. (Graedel, T., Allwood, J., Birat, J.P., Buchert, M., Hagelüken, C., Reck, B., Sibley, S.F., Sonnemann, G.) forthcoming. UNEP.

United Nations (2004) World Population Prospects: The 2004 Revision: United Nations.

United Nations (2006) State of the World's Cities 2006/7. London: Earthscan & UN Habitat.

United Nations Human Settlements Programme (2003) The Challenge of Slums: Global Report on Human Settlements. Earthscan, London.

United Nations Statistical Division (2008) UN Commodity Trade Statistics Database (UN Comtrade). [available at http://unstats.un.org/unsd/comtrade/].

van der Voet, E., van Oers, L. and Nikolic, I. (2005a) Dematerialization: not just a matter of weight. Journal of Industrial Ecology, 8(4): 121-137.

van der Voet, E., van Oers, L., Moll, S., Schütz, H., Bringezu, S., De Bruyn, S.M., Sevenster, M. and Warringa, G. (2005b) Policy Review on Decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries. Universitair Grafisch Bedrijf, Leiden.

van Wyk, L. (2007) The Meaning of Green Buildings and its Relevance to South Africa. Green Buildings Conference: Pretoria, 8-9 November 2007.

Vollenbroek, A. (2002) Sustainable Development and the Challenge of Innovation. Journal of Cleaner Production, 10:215-223.

Von Blottnitz, H. (2005) Solid Waste. Cape Town: Unpublished paper commissioned by the Department of Environmental Affairs and Tourism.

von Malmborg, F. (2007) Stimulating Learning and Innovation in Networks for Regional Sustainable Development: The Role of Local Authorities. Journal of Cleaner Production, 15: 1730-1741.

Wachter, B. (2006) Japanese Top Runner Program: Successfully stimulating energy efficiency. Leonardo Energy, 2006-10-19 [available online http://www.leonardo-energy.org/drupal/node/991].

Wagner, L., Sullivan, D. and Sznopek, J. (2002) Economic Drivers of Mineral Supply. U.S. Geological Survey Open-File Report 02-335. Washington DC.

Wakeford, J. (2007) Peak Oil and South Africa: Impacts and Mitigation. Cape Town: Association for the Study of Peak Oil and Gas - South Africa.

Wang, Menkui (2005) Important Issues of China's Mid-to-long-term Development 2006-2020. China Development Press, Beijing.

WBGU (2003) German Advisory Council on Global Change (ed.) World in Transition. Towards Sustainable Energy Systems. Summary for Policy. Berlin.

Weinzettel, J. and Kovanda, J. (2009) Assessing Socio-economic Metabolism through Hybrid Life Cycle Assessment - The Case of the Czech Republic. Journal of Industrial Ecology, 13(4): 607-621.

Weisz, H. (2006) Accounting for raw material equivalents of traded goods. A comparison of input-output approaches in physical, monetary, and mixed units. [87], 1-29. 2006. Vienna, IFF Social Ecology. Social Ecology Working Paper.

Weisz, H., Krausmann, F., Amann, C., Eisenmenger, N., Erb, K.-H., 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.

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

Weizsaecker, E.U. v., Lovins, A.B. and Lovins, H.L. (1998) Factor Four, Doubling Wealth - Halving Resource Use. The New Report to the Club of Rome. Earthscan, London.

Weterings, R. *et al.* (1997) 81 mogelijkheden Technologie voor duurzame ontwikkeling. Publicatiereeks Milieustrategie Ministerie van VROM: 97288/a/5-97 (81 options. Technology for Sustainable Development, report for Ministry of Housing, Physical Planning and the Environment).

Weterings, R. and Opschoor, P.H. (1992) The Ecocapacity as a Challenge to Sustainable Development. Netherlands Advisory Council for Research on Nature and Environment, Rijswijk.

Wilkinson, P., Smith, K.R., Joffe, M. and Haines, A. (2007) A global perspective on energy: health effects and injustices. The Lancet, 370(9591): 965-978.

World Bank (2006) World Development Indicators. The World Bank, Washington, DC.

World Trade Organization (WTO) (2008) International trade statistics 2008. World Trade Organisation, Geneva.

World Trade Organization (WTO) (2009) International trade statistics 2009. World Trade Organisation, Geneva.

Wu, Yuping *et al.* (2008) New Orientations of Green Trade Policies of China against the Backdrop of Backdrop of Global Financial Crisis. Environment and Economy, edition 11.

Wurzel, R., Jordan, A., Zito, A. and Brückner, L. (2003) From High Regulatory State to Social and Ecological Market Economy? New Environmental Policy Instruments in Germany. Environmental Politics, Volume 12, Issue 1, Spring 2003, pp. 115-136.

Xiaoqiu, Chen and Lijia, Qiao (2001) A Preliminary Material Input Analysis of China. Population and Environment, 23(1): 117-126.

Yunfeng, Y. and Laike, Y. (2010) China's foreign trade and climate change: A case study of CO2 emissions, Energy Policy Volume 38, Issue 1, January 2010, Pages 350-356.

Zieschank, R. (2006) Einsatz von Indikatoren im Rahmen der Nachhaltigkeitsstrategie der Bundesrepublik. Anmerkungen aus Sicht eines Befürworters. (Challenger Report) RNE, Berlin.

About the International Resource Panel

The International Resource Panel (IRP) was established to provide decision makers and other interested parties with independent and authoritative policy-relevant scientific assessments on the sustainable use of natural resources and, in particular, on their environmental impacts over their full life cycles. It aims to contribute to a better understanding of how to decouple economic growth from environmental degradation. This report on decoupling is part of the first series of reports of the IRP, covering amongst others biofuels, metal stocks in society and environmental impacts of consumption and production.

Working Group on Decoupling

The objectives of the International Resource Panel are to:

a. provide independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of natural resources and in particular their environmental impacts over the full life cycle; and

b. contribute to a better understanding of how to decouple economic growth from environmental degradation.

The rationale and overall objective of the Working Group (WG) relate to the second bullet point and the core strategic basis for the work of the International Resource Panel.

The first report titled Decoupling natural resource use and environmental impacts from economic growth defines decoupling. It offers important sets of data on resource extraction and use, and it presents findings that indicate that decoupling is happening, but absolute resource use reductions are a rare exception. The four country studies (China and South Africa for the developing world, and Germany and Japan for the highly industrialized world) show that developing countries pursue no strategies of absolute decoupling and that industrialized countries may have policies but very modest successes in absolute decoupling. The Report is very cautious about policy implications, in line with the mandate of the International Resource Panel.

The combined challenges of global warming, limits of fossil fuels and some other resources, destruction of habitats of wild living plants and animals seem to make a case for arrive at an absolute decoupling worldwide in the not too distant future. It is suggested to put the emphasis of the second report on technologies that will allow a massive improvement of eco-efficiency; case studies at national, sectoral or city levels of successful decoupling of wellbeing from resource consumption; and policy instruments that have been proven to be effective in reducing resource use. Case studies from the private sector are welcome.

The second report will explore to what extent economic growth and wellbeing can be decoupled from resource consumption and environmental impacts. Opportunities for decoupling at the micro level would also be of use in later information dissemination and policy relevance, particularly at the sectoral level. The Working Group will look at technology options and policy instruments that can facilitate and accelerate decoupling.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

- sustainable consumption and production,
- the efficient use of renewable energy,
- adequate management of chemicals,
- the integration of environmental costs in development policies.

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

- **The International Environmental Technology Centre** – IETC (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information, see www.unep.fr

Humankind has witnessed phenomenal economic and social development in the past century. However, there are increasing signs that it has come at a cost to the environment and to the availability of cheap resources. Despite progress, there is still great disparity between the rich and the poor.

The dilemma of expanding economic activities equitably while attempting to stabilize the rate of resource use and reduce environmental impacts poses an unprecedented opportunity and challenge to society. In this report, the International Resource Panel has sought to apply the concept of decoupling economic growth and human well-being from environmental impacts and resource use to address this challenge.

The report provides a solid foundation for the concept of decoupling, clearly defining key terms and providing empirical evidence of escalating resource use. It shows that decoupling is already taking place to some extent, but is lagging far behind its potential. The scenarios show that we are facing a historic choice about how we use resources and the report scopes the potential of innovation, rethinking economic growth and the role of cities in building more resource efficient economies. Four case studies at the country level show how policy makers are implementing decoupling strategies.

This report focuses on material resources, namely fossil fuels, minerals, metals and biomass and will be complemented by parallel reports of the IRP on land and soil, water, metals, cities and technologies to mitigate GHG emissions. These future reports will contribute to the International Resource Panel's objective to build a better understanding of how to decouple environmental impacts from economic growth and improved human well-being.

It is hoped that policy makers aiming to green their economies will greatly benefit from the contributions that the International Resource Panel is making through its work on decoupling resource consumption from economic growth.

www.unep.org

United Nations Environment Programme
P.O. Box 30552 Nairobi, 00100 Kenya
Tel: (254 20) 7621234
Fax: (254 20) 7623927
E-mail: uneppub@unep.org
web: www.unep.org

UNEP

For more information, contact:
UNEP DTIE
Sustainable Consumption and Production Branch
15 rue de Milan
75441 Paris CEDEX 09
France
Tel: +33 1 4437 1450
Fax: +33 1 4437 1474
E-mail: resourcepanel@unep.org
www.unep.org/resourcepanel

ISBN: 978-92-807-3167-5
DTI/1388/PA