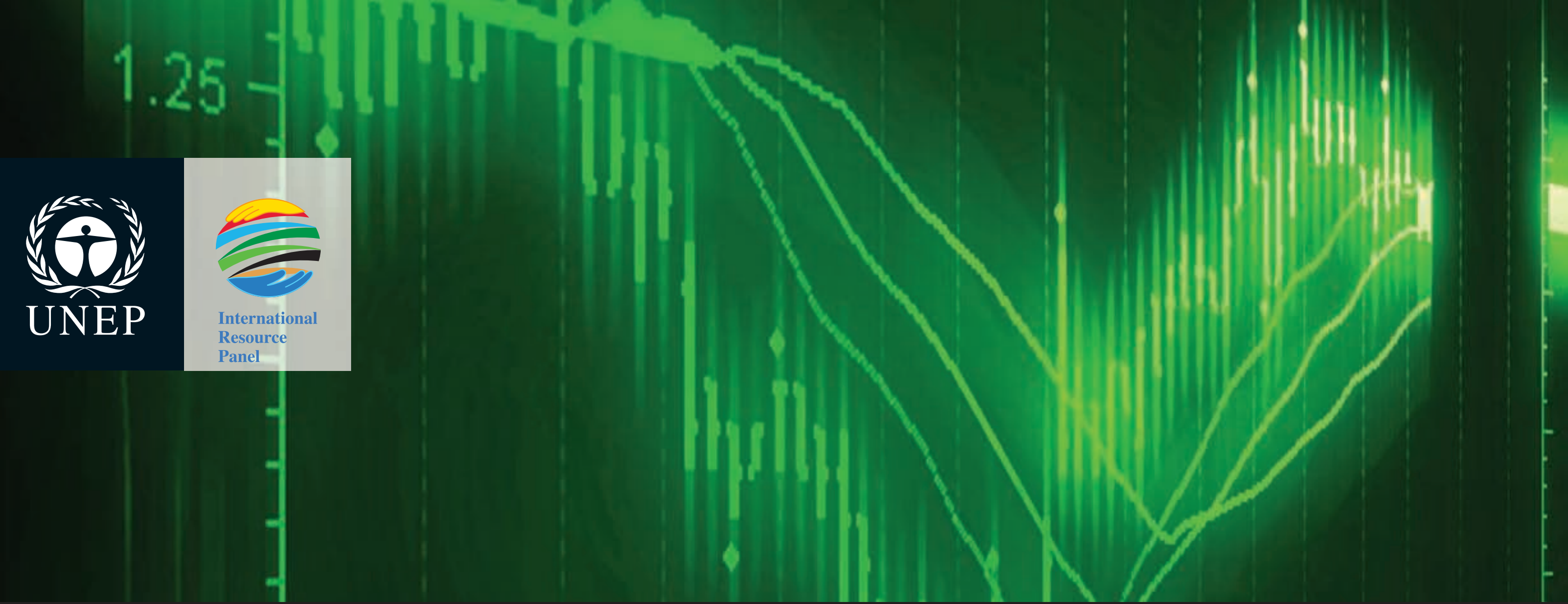

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International Resource Panel

DECOUPLING

natural resource use and environmental impacts from economic growth

Acknowledgements

DECOUPLING natural resource use and environmental impacts from economic growth

Editor: International Resource Panel

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The following is an excerpt of the report




DECOUPLING

natural resource use and environmental impacts from economic growth

Produced by the **International Resource Panel**

This document highlights key findings from the report and should be read in conjunction with the full report. References to research and reviews on which this report is based are listed in the full report.

The full report can be downloaded from **www.unep.org**. If you are reading a hardcopy, the CD-Rom can be found in the back cover. Additional copies can be ordered via email: resourcepanel@unep.org, or via post: United Nations Environment Programme Division of Technology Industry and Economics, 15 rue de Milan, 75441 Paris CEDEX 09, France

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 1), and resource consumption is still a reliable companion of economic prosperity (see Figure 8). 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 policymakers 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 each year 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 the 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

Objective and scope

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.

Objective and scope of the report

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 IRP to cover all resources and issues in a single report. Rather, this report will be complemented by parallel reports of the IRP on land and soil, water, metals, cities and technologies to mitigate GHG emissions.

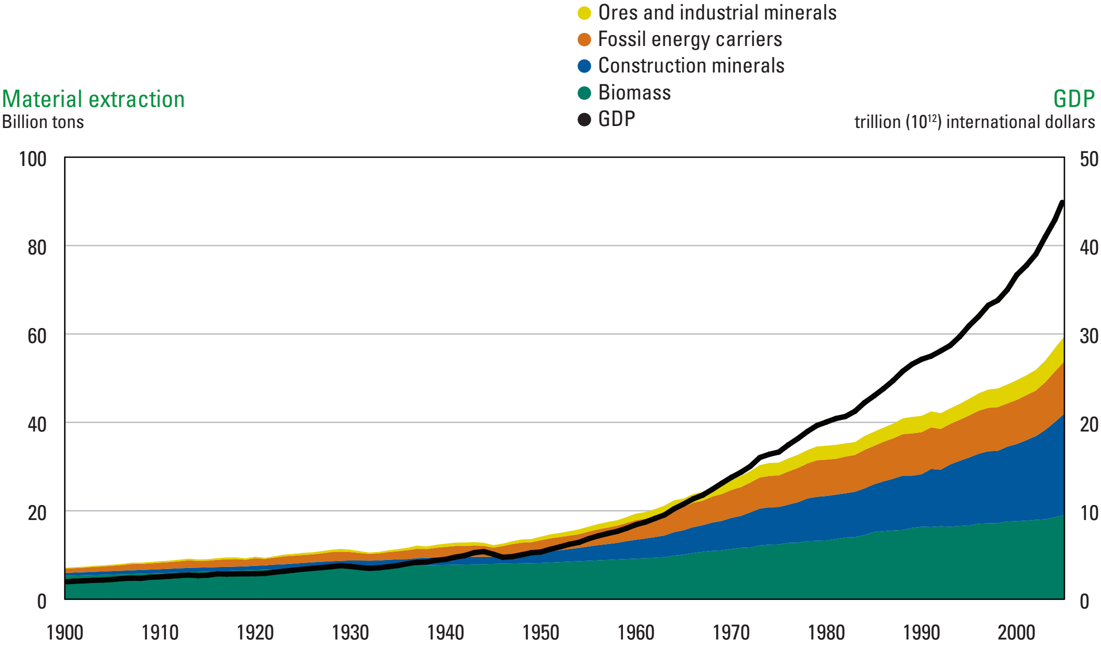
There are many gaps to be filled, and as the concept of decoupling is further developed, the IRP expects to identify other specific topics that warrant further assessment. It is hoped that sustainable development and new approaches to 'green economics' will greatly benefit from the contributions that the IRP will be making through its work on decoupling resource consumption from economic growth.

Key findings

The 20th century was a time of remarkable progress for human civilization. Driven by technological advances as well as demographic and economic growth, the annual 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, biomass by a factor of 3.6, and total material extraction by a factor of about eight, while GDP rose 23-fold (Figure 1). This expansion of material consumption was not equitably distributed and it had profound environmental impacts.

As earlier reports of the International Resource Panel (IRP) have concluded, overexploitation of resources, climate change, pollution, land-use change, and loss of biodiversity rose toward the top of

Figure 1. **Global material extraction in billion tons, 1900–2005**



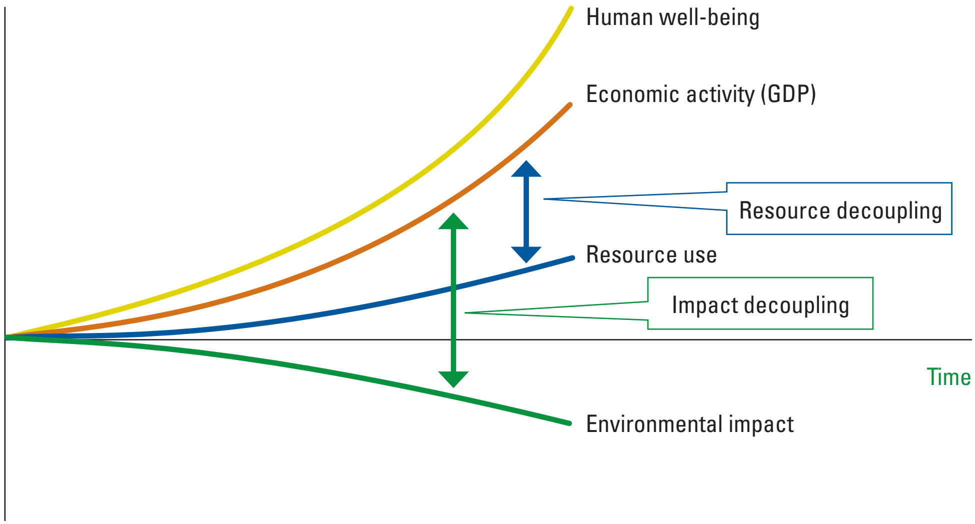
Source: Krausmann *et al.*, 2009

the list of major international environmental concerns. One result is that 'sustainability' has become an overarching social and economic imperative among governments, international organizations, and businesses. Leaders in these sectors now understand 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.

The dilemma of expanding economic activities while reducing the rate of resource use and reducing the environmental impact of any such use poses a serious challenge to society.

In this paper, the International Resource Panel has sought to apply 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 2 captures the essence of the two key aspects of decoupling as

Figure 2. Two aspects of 'decoupling'



applied to sustainable development, namely **resource decoupling** and **impact decoupling.**

The IRP report on 'Priority Products and Materials' clarified how different economic activities influence the use of natural resources and the generation of wastes (an important negative environmental impact). This report focuses on the extraction of the four categories of primary raw materials depicted in Figure 1 – 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 globally (2005 data), with a clear tendency toward continued increases into the future.

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. 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. At least some of these resources are now showing greater price volatility, which may support a more rapid transition toward decoupling.

Decoupling will require significant changes in government policies, corporate behaviour and consumption patterns by the public. These changes will not be easy, and this report 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 concept of decoupling and clarify the most important decoupling challenges that the IRP should be addressing in its assessments in the coming years. Technology and policy options to facilitate decoupling will be assessed in a separate IRP report.

Drawing especially on case studies from South Africa, Germany, China and Japan, this report explores some of the ways in which decoupling relates to development. The rising economic costs of resource depletion and negative environmental impacts have led these countries to adopt policies that commit both governments and industries to reduce the amount of resources used for each unit of production (in other words, increase resource decoupling) and reduce negative impacts on the environment (in other words, implement impact decoupling).

While the future is unpredictable, it is useful to contemplate the implications of policy choices, of which **three scenarios** are considered here:

1. **business as usual and convergence,** where industrialized countries maintain their per capita resource consumption, and developing countries increase their consumption rates to the same level as industrialized countries. This would lead to a tripling of global annual resource extraction by 2050;

2. **moderate contraction and convergence,** where industrialized countries halve their per capita resource consumption, and developing countries increase their consumption rates to the same level as industrialized countries. This would lead to a 40% increase in global annual resource extraction by 2050;

3. **tough contraction and convergence,** where total global resource consumption is maintained at the year 2000 level, and the per capita resource consumption is the same in all countries. This by definition would keep global resource extraction at its current levels.

None of these scenarios will lead to actual reductions in global annual resource extraction, but all indicate that substantial reductions in the resource requirements of economic activities will be necessary if the growing world population hopes to live under conditions of sustainable resource management. Innovations will be essential, perhaps even leading to a progress indicator that complements GDP with environmental and social concerns. UNEP's Green Economy Initiative, for example, seeks to couple a revived world economy with reducing ecosystem degradation, water scarcity, and carbon dependence. Other innovations that can support decoupling will be discussed in more detail in future reports of the IRP Decoupling Working Group.

Decoupling is highly relevant to trade and the distribution of resources. Many resources follow a complex path from the beginning to the end of their life cycle, involving many actors along the way (Figure 3), so allocating responsibility for consumption (and therefore decoupling) along this value chain remains a challenge. 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. In some countries, metabolic rates are as low as four tons/capita/year, indicating a lack of satisfaction of basic needs. In other countries, metabolic rates amount to 40 tons/capita/year and more, indicating a demand upon the planet's resources that cannot be extended to all its inhabitants, let alone future generations.

This paper presents substantial evidence supporting the need for both resource decoupling and impact decoupling, and provides 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 all four of the categories of resources being considered here. 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 the hope that they will lead to a 'green economy' that enhances human welfare while sustaining environmental resources.

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1. Introduction

1.1 Why decoupling?

Human well-being and its improvement, now and for a larger world population in the future, is based upon the availability of natural resources such as energy, materials, water and land. Demographic and economic development have led to 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 for example). **Resource use links economic activities to the environment,** so this report uses an economic definition of 'material resources': **natural assets deliberately extracted and modified by human activity for their utility to create economic value.** These assets can be measured both in physical units (such as tons, joules or area), and in monetary terms expressing their economic value. Such a focus enables this report to apply accounting measures to the four categories of material resources it is assessing, at several levels where data on population and economic activity (GDP) are available.

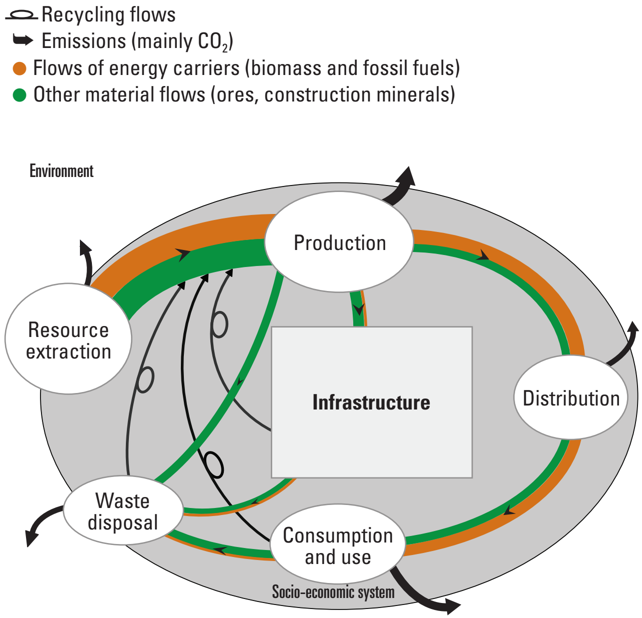
Undesirable environmental impacts can arise from any part of the **life cycle** of resource use: in the phases of extraction, production/manufacture, consumption/use, or post-consumption disposal (Figure 3).

These impacts may be caused by deliberate interventions into natural systems such as land-cover change and resource extraction, or by unintended side effects, such as emissions and wastes. These impacts may lead to disruptions of at least some of the ecosystem services that are essential to human well-being. 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.

Reducing both resource use and environmental impacts means reducing the material losses at each stage in the life cycle – losses that result from converting energy carriers into CO_2 (and other) emissions, and other material resources into wastes, in the process of generating economic services and value. Decoupling is about generating economic services and value with declining amounts of resources, declining wastes and emissions, and declining other environmental impacts.

This report will indicate how meeting the challenges of decoupling resource use and negative environmental impacts from economic activity can contribute to the

Figure 3. **The life cycle of resource extraction and use**



Note: flows of resources, emissions and wastes according to European proportions
Source: Fischer-Kowalski, 2011

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 ecosystem services.

The report seeks to establish a qualitative and quantitative foundation upon which strategies of decoupling can be built. For the assessment of resource uses and their environmental impacts, it will use a global and long-term perspective. However, while the challenges of resource depletion and environmental disruption are global challenges, they affect people differently in different localities. Extraction of a resource, its conversion into a commodity, its ultimate consumption, and its disposal or recycling, 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.**

1.2 Defining decoupling

'Decoupling' applied to natural resources has grown out of the concept of 'eco-efficiency' developed by the World Business Council for Sustainable Development (WBCSD) in 1992, and the 2001 OECD definition of decoupling as breaking the link between 'environmental bads' and 'economic goods'. From a developing world context, the UN Economic Commission for Latin America and the Caribbean (ECLAC) in 2004 promoted the idea of 'non-material economic growth', essentially decoupling economic growth from resource consumption.

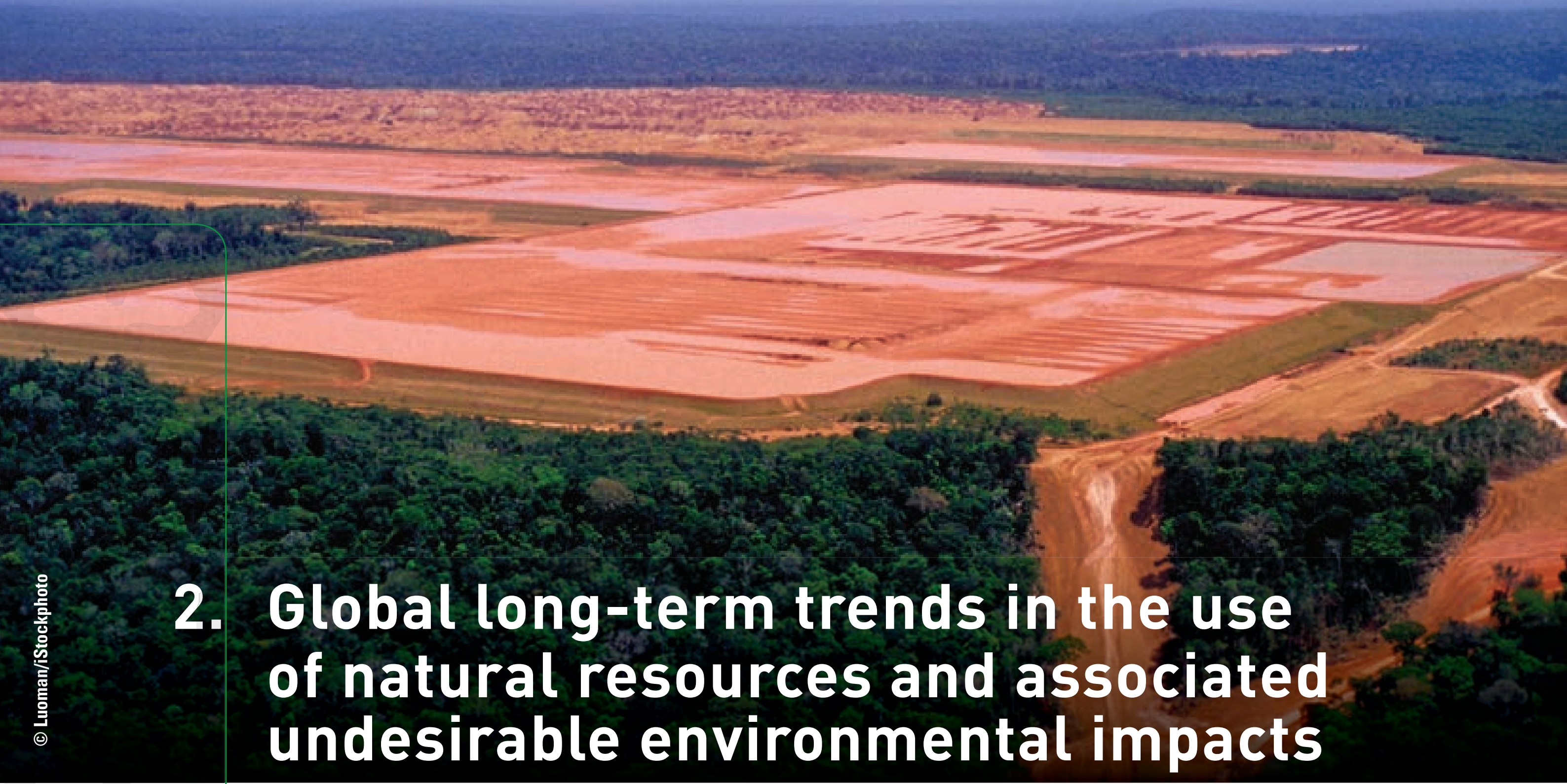
Building on such foundations, **resource decoupling** means reducing the rate of resource use per unit of economic activity. This 'dematerialization' is based on using less material, energy, water and land resources for the same economic output. Resource decoupling leads to an increase in the efficiency with which resources are used, indicated when economic output (GDP) is increasing relative to resource input, as illustrated in Figure 1.

Resource decoupling can alleviate the problems of scarcity and intergenerational equity by reducing the rate of resource depletion, while reducing costs by raising resource productivity. On the other hand, productivity increases may result in accelerated economic growth that generates more use of resources rather than resource savings, a phenomenon known as the 'rebound effect'. Indeed, some economists argue that the availability of energy resources to be used is an indispensable driver of economic growth, thereby questioning whether resource decoupling is feasible. Evidence presented here indicates that some resource decoupling has in fact characterized the 20^{th} century (Figures 1 and 4).

Impact decoupling, by contrast, requires increasing economic output while reducing negative environmental impacts. Such impacts arise from the extraction of resources (such as groundwater pollution due to mining or agriculture), production (such as land degradation, wastes and emissions), the use phase of commodities (for example fuel combustion in transport resulting in CO_2 emissions), and in the post-consumption phase (again wastes and emissions). Impacts are decoupled when negative environmental impacts decline while value is added in economic terms.

Impact decoupling means using resources better, wiser or more cleanly. Reducing environmental impacts does not necessarily reduce resource scarcity or production costs, and may even increase them. An example of this is carbon capture and storage (CCS); since this impact decoupling 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.

A distinction must be drawn between decoupling and absolute resource use reductions. **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).** Such decoupling seems to be fairly common, but does not necessarily lead to absolute reductions in resource use. **Decoupling will lead to absolute reductions in resource use only when the growth rate of resource productivity exceeds the growth rate of the economy.** This latter case is reflected in the 'environmental Kuznets curve', where the environmental impact of production and consumption decreases as prosperity rises beyond a certain point.



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

Decoupling economic activity from undesirable environmental impacts requires an improved understanding of resource-use trends and their drivers. One approach to measuring resource use is 'material flow accounting' (MFA), which quantifies all materials used in economic activities. MFA accounts for the total material mobilized during the extraction process (i.e. the 'total material requirement') and for the materials actually used in economic processes ('direct material consumption'), measured in terms of their mass (metric tons). For reasons of data reliability and clarity, this report focuses on materials actually used in economic processes. As a rule of thumb, total material requirement is about twice as much as direct material consumption. The MFA methodology generates accounts in physical terms that are analogous to GDP and use the same system boundaries, so it yields data that support an analysis of decoupling of material resource use from economic activity.

Negative environmental impacts are **undesirable changes in the natural environment that can be causally linked to some socio-economic activity.** Environmental impacts are usually assessed on the product level by life cycle assessments (LCA) that refer to seven (or more) impact categories supported by statistical data: acidification; climate change and global warming; eco-toxicity; human toxicity; eutrophication/nutrient enrichment; photochemical ozone formation (summer smog); and stratospheric ozone depletion.

2.1 The global dynamics of material resource use

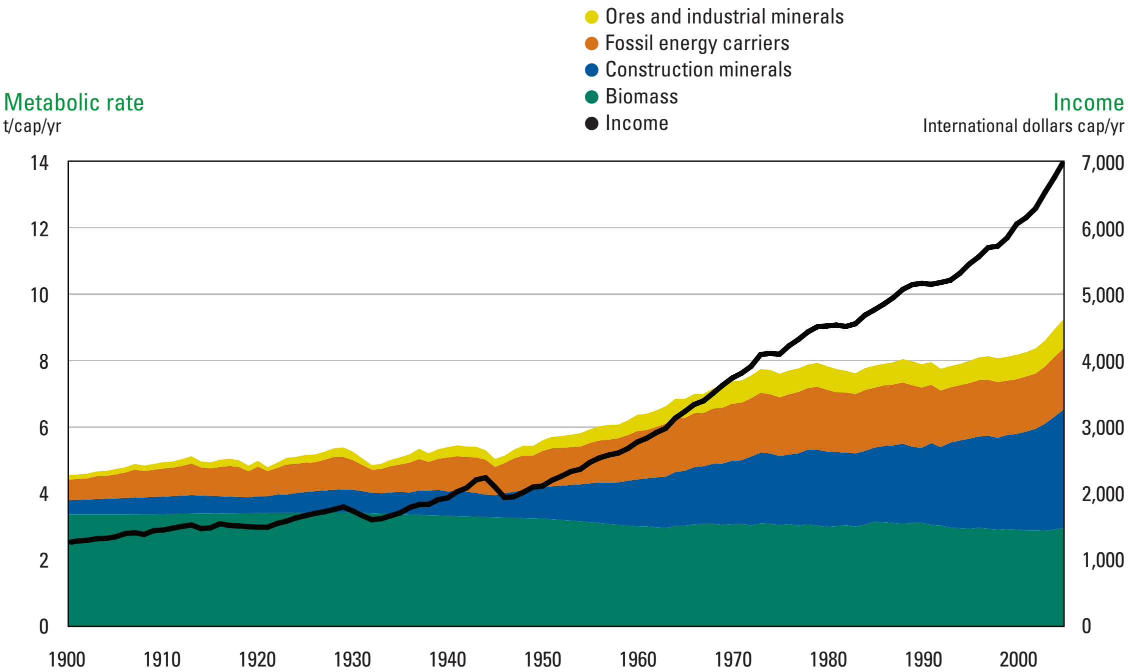
The **global** use of material resources equals the annual amount of raw materials extracted. On the level of **individual countries,** the amount of materials extracted domestically (termed DE, 'domestic extraction') is not equivalent to materials use, as national material use (termed DMC, 'domestic material consumption') also depends upon imports and exports.

At the beginning of the 21^{st} century, estimates for the quantity of global raw materials extraction ranged between 47 and 59 billion metric tons (47–59 Gt) per year. Global annual material extraction increased over the 20^{th} century by a factor of eight. For much of that century, biomass dominated material extraction and use, accounting for almost three quarters of the total in 1900. A century later, more biomass resources were being harvested, but the percent contribution to total material extraction had declined to only one third, because the global socio-economic metabolism increasingly turned towards mineral resources, including fossil fuels which replaced biomass used for combustion. In other words, the composition of materials used has shifted from renewable to non-renewable resources.

A major driver of the overall increase in raw material extraction and use is the expanding human population. Each country's material use (domestic material consumption, DMC) is coupled to the number of inhabitants. This is plainly evident for food, for example, but it also holds for other material resources that have become part of the national material standard of living. Thus the metabolic rate (resource use per capita) provides a fairly robust overall measure of consumption. Metabolic rates vary widely among countries and change with development and economic patterns. 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.

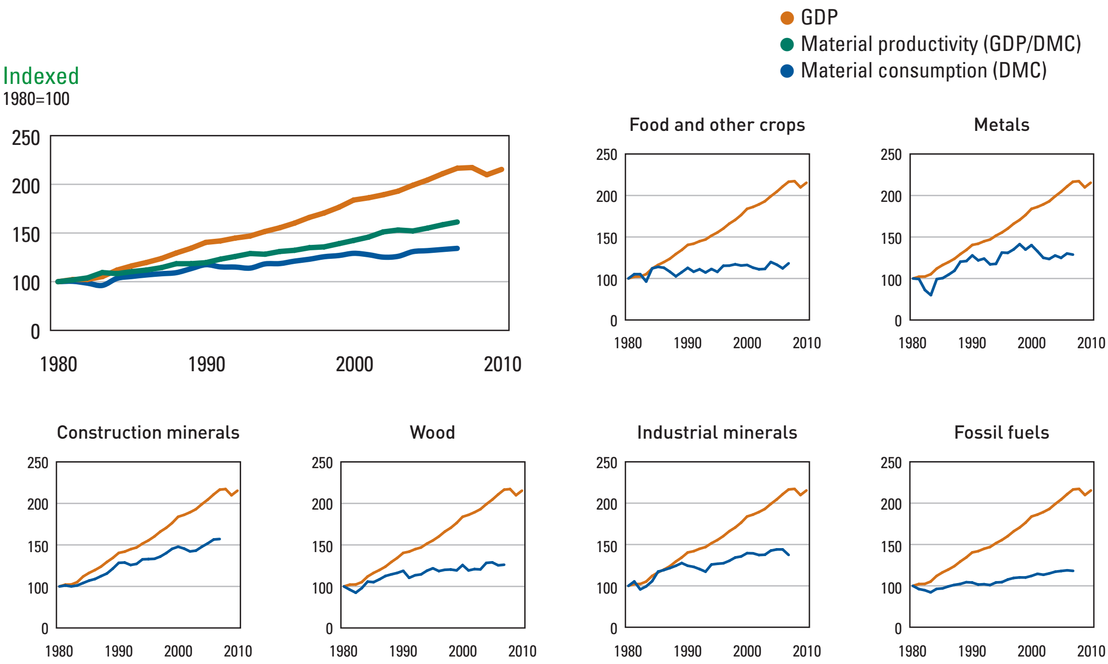
While global per capita income has increased sevenfold during the course of the 20^{th} century, average resource use per capita merely doubled (Figure 4). A global inhabitant in 2005 required somewhere between 8.5 and 9.2 tons of resources annually, while a hundred years earlier the average global metabolic rate per capita was just 4.6 tons. These findings indicate substantial per capita decoupling of resource use from economic development. Average global metabolic rates have sometimes grown slowly (such as the period from 1900 to the end of World War II), and sometimes rapidly (such as the period from the end of World War II up to the global oil crisis in the early 1970s). From the 1973 oil shock until the turn of the century, the global average has again remained fairly stable and continued to do so in the industrialized countries (Figure 5). Apparently, this oil crisis mattered not only economically (because price levels soon

Figure 4. **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 5. 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

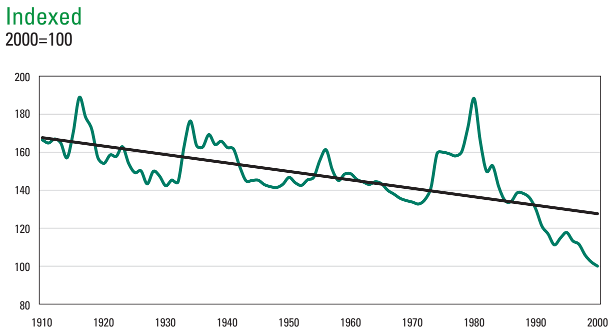
recovered, see Figures 6 and 7), but it also changed the pattern of relations between material use and income in industrial countries. Globally, though, in recent years metabolic rates have started to rise again, driven by rapidly growing resource use in large emerging economies such as Brazil, China and India which now display a pattern similar to that of the industrial countries in the 1950s and 1960s.

These data indicate that global material resource use during the 20th century has been rising at about twice the rate of population growth, but still at a substantially lower pace than the world economy. This resource decoupling has taken place 'spontaneously' rather than as a result of policy intention and even though resource prices declined by about 30% in the course of the 20th century (Figure 6). It is noteworthy, however, that resource prices declined by about 30% during the course of the 20th century as a result of accelerated discovery, technological advances, rising investment levels and global trading arrangements that increased global competition (Figure 6).

A similar phenomenon may now be happening in conjunction with the current economic crisis (Figure 7). A steep rise in raw material prices reached a maximum in 2007, and a return to usual price levels may have started in 2008. For the time being, though, it is hard to tell whether this return to price levels 'as usual' will lead to a further decline in prices, or a subsequent increase. If, however, the steady price rises since late 2009 continue, this may confirm that a combination of resource depletion and rising demand could bring the era of declining resource prices to an end. Although prices on their own will not result in decoupling, rising resource prices are a necessary but by no means sufficient condition for long-term decoupling.

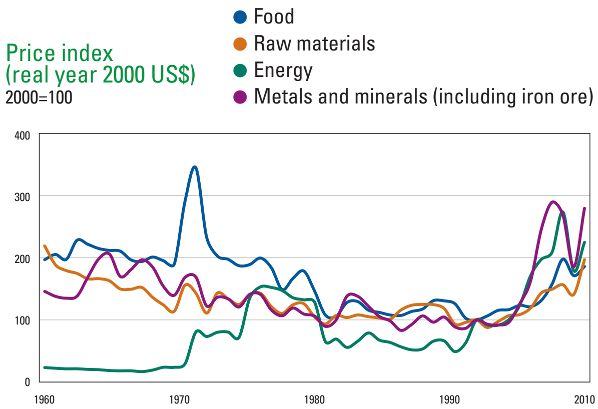
In a cross-country comparison, the relation between income and resource use per capita is uniformly continuous: as a rule, the more income, the more resource use. But Figure 8 indicates that some countries can achieve high incomes per capita while consuming relatively few resources, while

Figure 6. Composite resource price index (at constant prices, 1900–2000)



Source: Wagner *et al.*, 2002

Figure 7. Commodity price indices



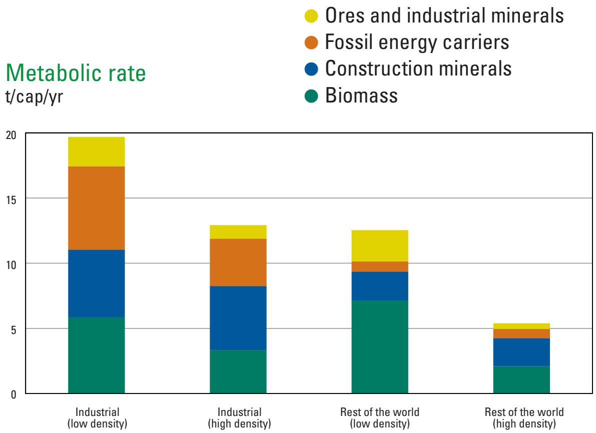
Source: World Bank Commodity Price Data (Pink Sheet), historical price data, available from http://blogs.worldbank.org/prospects/global-commodity-watch-march-2011

Figure 8. The global interrelation between resource use and income (175 countries in the year 2000)

Source: Steinberger *et al.*, 2010

Source: Steinberger *et al.*, 2010

Figure 9. **Average metabolic rates (resource use in tons/capita) by development status and population density**



High-density means a population density of 50 people/km^2 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

other countries have very high resource consumption levels per capita without a correspondingly high income. Two key factors account for much of the variation in the metabolic rates of countries: the transformation from agriculture-based to fossil fuel-based economies ('development'), and population density. Industrial countries 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, although income and material comfort do not substantially differ. Also among the not yet fully industrialized countries, those with high population density (such as China and India) showed average metabolic rates of 5 tons/capita in the year 2000, while the metabolic rates in comparable low-density developing countries (e.g. Brazil and South Africa) were more than twice as high (Figure 9). It appears that densely populated areas and regions need fewer resources per capita for the same standard of living and material comfort.

The decrease in need for materials with rising population density is essentially good news in a rapidly urbanizing world. The doubling of metabolic rates due to the traditional resource and energy-intensive industrial transformation, on the other hand, is a major challenge for those high-density countries: the resource and environmental burden of each of their inhabitants' is about to double. This is also a challenge for the rest of the world in terms of resource depletion and environmental impact, especially as almost two thirds of the world population live in these high density countries with – so far – very low metabolic rates.

It is necessary, therefore, to relate strategies dealing with resource use to

development strategies. While it seems fully justified to promote resource use reductions for industrialized countries, the low metabolic rates in developing countries often reflect a lack of satisfaction of basic needs and a low standard of material comfort. Social justice calls for environmental and economic space to address poverty through investment in the necessary material infrastructures.

However, the key issue is how these countries go about this. If they emulate the technologies and the industrial transformation of the past, their efforts will be undercut by the consequences of resource depletion and environmental impacts. Their optimal strategy, therefore, is to exploit the remaining space while simultaneously pursuing a less resource- and energy-intensive growth and development pathway. Resource and impact decoupling can help describe what such a less resource- and energy-intensive pathway could look like and how it could be achieved. Indeed, for many rapidly industrializing countries decoupling may be a precondition for achieving the types of innovation-driven growth rates that will be necessary to generate the diversified economies, basic infrastructures and ecosystem services needed to eradicate poverty.

2.2 Assessing the dynamics of global environmental impacts

UNEP's International Resource Panel published a report in 2010 that used environmental assessment tools to assess the environmental impacts of global production and consumption activities over the life cycle, and established a link between different categories of materials and environmental impacts. For more information, please see www.unep.org.

The report identified biomass as one of the most important drivers of environmental pressures, especially habitat change, climate change, water use and toxic emissions. The use of fossil fuels for heating, transportation, metal refining and the production of manufactured goods is of comparable importance, causing the depletion of fossil energy resources, climate change, and a wide range of emissions-related impacts.

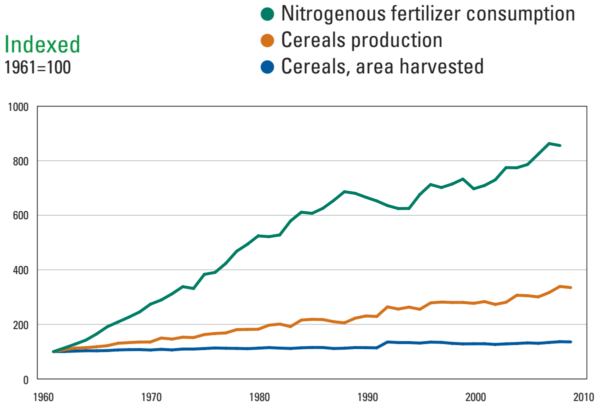
The impacts related to these activities are unlikely to be reduced, but rather enhanced, in a business as usual scenario for the future. These dynamics are also important considerations when it comes to resource decoupling.

Industrial minerals and ores are a very heterogeneous class of resources, dominated quantitatively by ferrous metals and mineral fertilizers. The most accessible impact information is from the extraction phase in the life cycle of those resources, where impacts often involve disturbance to land, air and water systems. The location of resource extraction is relevant from an environmental impact point of view because environmental regulations vary in different parts of the world. Those standards tend to be tighter in wealthy industrial countries than in poorer developing countries. Extraction of industrial ores and minerals has doubled in the past 25 years and shifted from industrial towards developing and newly-industrializing countries (NIC); in 2006, more than half of all minerals and ores were extracted outside of industrial countries.

Fossil fuels are closely associated with CO_2 emissions in the use phase, as well as local impacts in the extraction phase. Over the past 100 years or so, while GDP rose by a factor of 22, fossil fuel use rose by a factor of 14 (and GHG emissions by a factor of 13). The increasing use of coal for energy may even raise the volume of GHG emissions per unit of fossil fuel use.

An additional concern for non-biotic materials is the decline of ore grades and oil production capacity, and the increasing expense, energy and other environmental factors it will take to extract them.

Figure 10. **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

The use of biomass is strongly related to impacts on global sulphur and nutrient cycles, with human induced flows now equalling natural flows. Some studies have shown that biomass extraction may be somewhat decoupling from land use, but coupled with increasing amounts of fertilizer use per unit of agricultural yield (see Figure 10).

Strategies to reduce impacts

Most environmental policies have been directed at specific impacts, such as halting deforestation, keeping the stratospheric ozone layer intact, reducing 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, these policies met with variable levels of success and tended to impose additional costs (some might say they paid for their real costs).

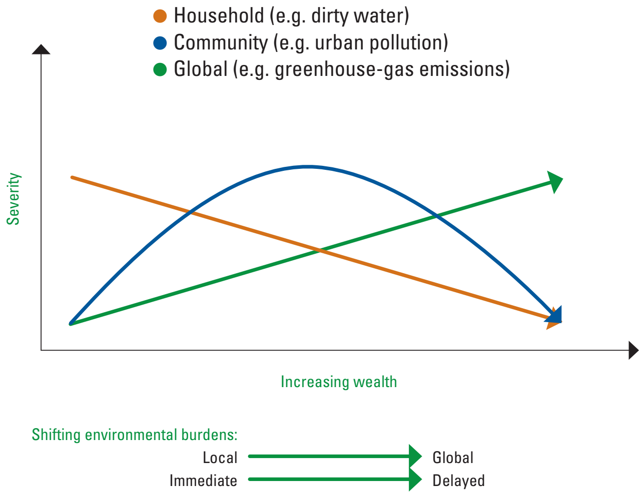
Undesirable environmental impacts can be reduced by three main strategies:

(a) changing the mix of resources used through substitution of more harmful by less harmful resources; (b) using resources more environmentally carefully throughout their life cycle; and (c) reducing resource use.

Strategy (a), **substitution**, is effective but has limits. As shown in this report, the use of all material resources is increasing substantially. Even on more detailed levels, it is hard to find any one material that is at present used less than a few decades ago. For example, the IRP reports on metals demonstrate a clear trend toward using increasing amounts of a greater variety of metals as resources, now including virtually all naturally-occurring metal elements. This expansion puts limits on (present or future) substitution. Further, the purposes for which material resources can be used are very different and limited by their physical and chemical properties.

Strategy (b), **using resources environmentally more carefully throughout their life cycle**, has been and is a key strategy for environmental policies. Figure 11 illustrates the interdependence between the scale of environmental impact and increasing wealth: household-level

Figure 11. **Environmental risk transition framework**



Source: Adapted from Wilkinson *et al.*, 2007 environmental burdens (such as dirty water or indoor pollution) decline with a rise in wealth, community-level burdens (such as urban air pollution) display a hump-shaped curve, and global environmental burdens (such as greenhouse gas emissions) rise. Over time, global impacts on the environment may become more important than local ones, and delayed impacts are becoming more important than immediate ones (see green arrows at the bottom of Figure 11). Those global, delayed impacts (such as climate change) may be less accessible to traditional, life cycle-oriented environmental policies. Nevertheless, changes in key technologies (such as, for example, in the technology of producing cement) may make a big difference to the environmental impact of resource use, also at the global level.

Strategy (c), **reducing resource use**, is the most powerful, as it reduces all environmental impacts associated with a certain resource use, and it is the most economical, as it also reduces production costs in the long run. It cannot be achieved by environmental policies alone: to be effective, it requires concerted strategies from a variety of political actors and from business. This strategy becomes more important when resource extraction and use is approaching certain limits: the closer the limits, the higher the likely environmental impact per unit of resource use. This holds for biotic resources like fish catch or logging, it also holds for fossil fuels with 'unconventional' fuels representing a larger environmental burden, and it can also be assumed for industrial minerals and ores. Internationally, for most metals, ore grades are declining, and thus need a higher input of energy and an increasing volume of extraction for the same output.

In conclusion, it appears that short-term and local environmental impacts of resource use across the resource life cycle have been 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. Different strategies to reduce these impacts are available for policymakers. The IRP's second report on decoupling will focus on assessing the technology and policy options that can make decoupling happen.

2.3 Scenarios of future global materials use

Can the growth in resource consumption and economic factors shown in Figures 1 and 4 continue into the future? Or will societies face some limits to growth as populations and their metabolic rates increase? Such questions are impossible to answer with much authority, but scenarios – plausible stories of how the future may develop, based on a coherent and internally consistent depiction of the key drivers of change – can help to provide insight into the policy challenges of the future. The **three scenarios presented in the report underline the urgency of decoupling resource consumption and negative environmental impacts from economic development.**

The scenarios are for the year 2050, compared to a year 2000 baseline. They assume population growth according to UN projections (medium variant) and a continuation of the current patterns that densely populated regions and countries require only about half the metabolic rate for the same standard of living as sparsely populated areas. All scenarios also assume that developed industrialized countries and developing countries (some of which are already committed to rapid industrialization of their economies) will converge by 2050 to a point where all countries have roughly similar per capita levels of resource use.

In two respects, the scenarios are not fully realistic: first, convergence trends at present cannot be observed for all countries. The implications of this are that the vision of 'convergence by 2050' (which expresses a normative commitment to socio-economic justice) is only one option. The 'fortress world' scenario as outlined in other reports, in which a large number of countries are excluded from access to resources, might be just as likely. Second, **no impact of physical constraints is built into the scenarios.** This is clearly unrealistic, but the scenarios seek to demonstrate the implications of ignoring resource constraints (as nearly all the mainstream growth and development models do).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Wherever the future global consumption of a resource comes close to supply constraints, the threat of distributional conflicts will arise, as indicated by the many resource-based conflicts that already exist in the world today.

Scenario 1: Business as usual

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

In this scenario, relative decoupling in industrial countries 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 some of the least developed countries, convergence implies at least a fivefold increase in their metabolic rates, which may significantly reduce poverty in the process. This scenario complies well with trends observed in the recent decades; for industrialized countries, metabolic rates had remained fairly stable since the mid-1970s while in many developing countries a steep increase could be observed. 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.

This scenario results in a global metabolic scale of 140 billion tons annually by 2050, and an average global metabolic rate of 16 tons/capita/year. In relation to the year 2000, this 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 or switch to renewable energy, and probably represents an unsustainable future in terms of both resource use and emissions, exceeding all measures of available resources and assessments of limits to the capacity to absorb impacts.

Scenario 2: Moderate contraction and convergence

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

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 moderately increase their metabolic rates and catch up to these reduced rates by the year 2050. This scenario presupposes substantial structural change, requiring a new pattern of industrial production and consumption that would be quite different from the traditional industrial model. With resource productivity gains similar to past

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achievements, these metabolic rates could support a comfortable 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 innovations for decoupling.

This scenario amounts to a global metabolic rate of 70 billion tons 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/year.

Taken as a whole, this scenario would be achievable only with significant decoupling through investments in 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, developing countries in this scenario have the chance to achieve a rising share of global resources, and for some absolute increase in resource use, while industrial countries must cut their consumption.

Scenario 3: Tough contraction and convergence

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

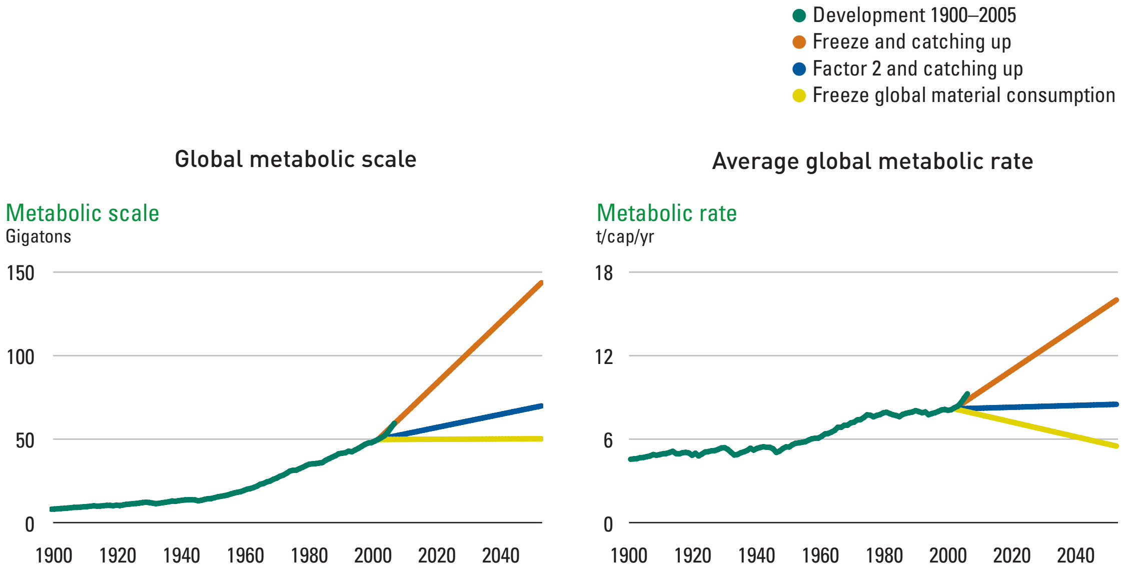
The level of global resource consumption in 2050 is limited to the global resource consumption of the year 2000. Metabolic rates of industrial and developing countries converge at around 6 tons per capita per year. This scenario requires far-reaching absolute resource use reductions in the industrialized countries, by a factor of 3 to 5. Countries classified as 'developing' in the year 2000 would have to achieve 10–20% reductions in their average metabolic rates.

This scenario amounts to a global metabolic scale of 50 billion tons by 2050 (by definition the same as in the year 2000) and allows for an average global metabolic rate of 6 tons/capita/year.

Taken as a whole, this scenario would require unprecedented levels of innovation. Despite population growth to roughly 9 billion people the pressure on the environment would remain roughly the same as it is now. 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. It should, however, be noted that this scenario is consistent with the 2.2 tons of carbon per capita recommended by the IPCC as the convergence point that could prevent warming by more than 2 degrees centigrade.

The implications of these scenarios are far reaching. All demonstrate that without significant improvements in resource productivity, it will not be possible to meet the needs of 9 billion people by 2050. The policy implications

Figure 12. **Resource use according to three different scenarios up to 2050**



Source: Krausmann *et al.,* 2009 (Development 1900–2005) and own calculations (see text) are clear: as the economic consequences of resource scarcities and degraded environments start to work their way through the world economy, policymaking will start to take more and more seriously the implications of scientific research about decoupling. 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, **change will only be able to go as fast as the levels of investment in innovations for decoupling across the entire value chain.**

The bottom line is that threats to consumption need not be equated to threats to well-being and reasonably comfortable lifestyles, but rather as threats to particular kinds of resource-intensive modes of consumption.

Table 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

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3. Decoupling and the need for systems innovations

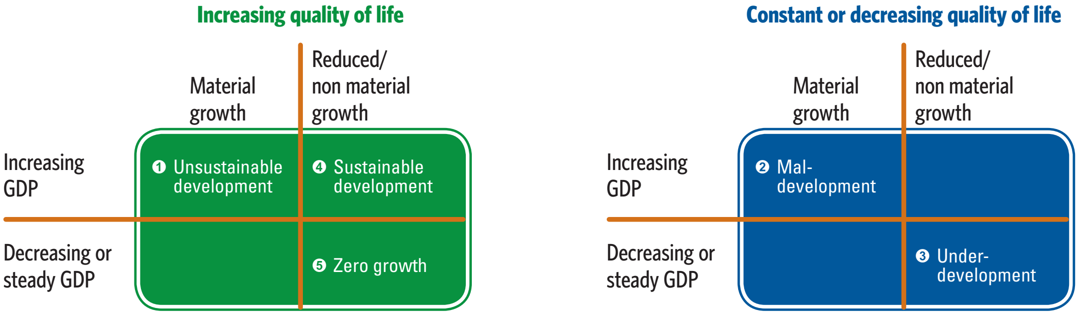
3.1 Rethinking growth

The logic of decoupling described here redefines growth from a sustainability perspective. The term 'growth' means different things to different audiences. Businesses and governments focus on economic growth, using indicators such as GDP. Environmentalists tend to focus on the growth of physical throughput in the economy, or physical/material growth. Such growth implies spreading over more physical area, expanding material and energy throughput, or increasing the stock of physical products, buildings and infrastructure. Physical growth is coupled to increased environmental pressures and resource depletion.

Based on this understanding of these two types of growth, it becomes conceptually possible for economic growth (defined as money flow) to be decoupled from physical growth of the economy (resource consumption) and associated environmental pressures. Some economists believe that it is possible to reduce the material intensity of GDP, so that GDP can grow indefinitely in a finite material world.

Some development economists distinguish between *development* (improvements in

Figure 13. The different guises of development



Source: Redrawn from Gallopin, 2003, p. 27

well-being plus material economic growth), *mal-development* (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 13).

This implies that development strategies for developing countries could be split into two modes (which could be consecutive phases in certain circumstances). The first mode would entail moving from *mal-development/underdevelopment to development* whereby improvements in well-being for the majority are achieved via inclusive material economic growth. This is mainstream development economics, but it virtually ignores ecological sustainability.

The second development mode would entail a shift to sustainable development whereby improvements in well-being are achieved via *non-material economic growth.* This approach is often considered together with the idea of 'leapfrogging' which usually means either shortening the transition from the first to the second mode considerably, or skipping the development phase altogether. Leapfrogging, however, requires substantial capacity for sustainability-oriented innovations and an appropriate set of institutional arrangements to provide incentives and harness innovations that demonstrate economically viable 'leapfrog' technologies that will make more sustainable development a viable option.

In conclusion, decoupling can lead to a rethinking of assumptions about economic growth and, by implication, GDP as the key indicator of growth. The GDP indicator remains a good measure of economic activity. But it needs to be joined by indicators of growth that encourage decoupling and dematerialization, in order to generate a more balanced understanding of development. The next step would be to find an agreed indicator of development that reflects progress made in decoupling.

3.2 Innovation and decoupling

Resource and impact decoupling will require radical changes in the global metabolism that will depend on innovations for more sustainable resource use. Knowledge and information are key drivers of economic growth, and the returns on investments in knowledge often outweigh the returns on investments in capital and un-/semi-skilled labour. Innovations include new knowledge and information processing capacities that are built into production processes as technologies, operating routines or managerial/organization systems at the firm and/or macro-economy level.

The problem with the national innovation systems that have been promoted by many governments over the past few 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 is required.

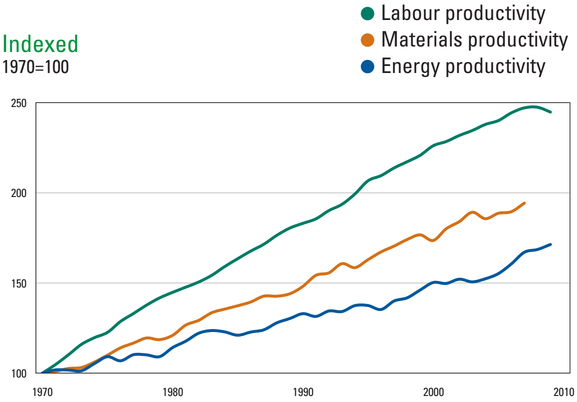
'Eco-innovation' is such a new concept. It is defined by the OECD as "the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives". 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.

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. Figure 14 shows 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 15, showing that labour costs have gone up steadily, while prices of materials and energy remained static or even declined (until recently, when many material costs increased rapidly).

The key to decoupling in practice will be sustainability-oriented innovations that make it possible to increase resource productivity, thereby reducing metabolic rates (assuming that the rebound effect remains modest). Increasing resource productivity may also justify increasing resource prices, thereby benefitting resource producers (often in developing countries).

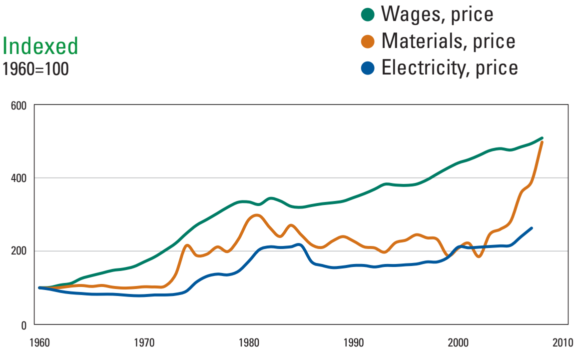
Innovations are continuous learning processes that are necessary in a highly complex globalized world where fixed bits of knowledge rapidly become obsolete. The modern economy is better seen as a learning economy rather than a knowledge economy, underlining the importance of innovations in technology, institutions, and relationships that manage cooperation,

Figure 14. Resource Productivity, labour productivity and energy productivity in EU-15



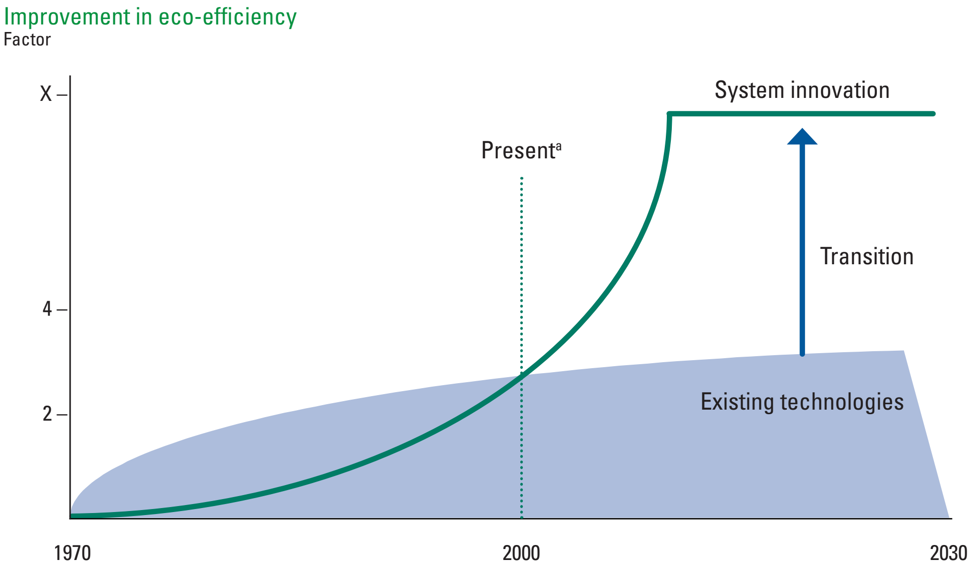
Note: Labour productivity in GDP per annual working hours; material productivity in GDP per domestic consumption (DMC) and energy productivity in GDP per total primary energy supply (TPES).
Source: EEA, 2011

Figure 15. 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 worldwide 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

Figure 16. System innovation



a At time of publication
Source: Vollenbroek, 2002

social cohesion, solidarity, social learning and benefit sharing.

Past innovation concerned with economic competitiveness and growth has contributed to an extraordinary increase in production, consumption and economic growth and therefore improvements in average human welfare. However, this has occurred along an unsustainable trajectory. Innovation now needs to be harnessed for environmental protection and restoration.

Merging these seemingly disparate themes of sustainability and systems of innovation offers an opportunity to develop sustainability-oriented innovation systems that contribute to decoupling through reducing environmental pressure and contributing to sustainability during economic activities.

Figure 16 is an idealized image that demonstrates the difference between incremental innovations and systems innovation. Changes at the system level offer the most effective way to achieve decoupling, even by a factor of 10.

Development depends on the capacity for innovation, and much has been learned over the past two decades 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 much more attention than resource decoupling). The challenge is to apply the insights about innovation to resource productivity. Eco-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 imposed by technological and physical infrastructures that are rapidly becoming obsolete as more ecological thresholds are breached.

3.3 Cities as spaces for innovation

Cities have historically been centres of political, economic, cultural and informational power. As of 2007, over 50% of people lived in cities. As the world's population grows from the current 6.8 billion people (2010 estimate) to 8 billion by 2030 and perhaps 9 billion by 2050, cities are likely to absorb most of the growing population. **The bulk of the growth could well be in secondary and tertiary cities**, not the existing sprawling mega-cities like Cairo, Calcutta, Shanghai, and San Paulo. By 2015, nearly 60% of the total world's people are expected to be living in cities of less than a million people.

People have been attracted to cities by globalization, resource efficiency, improved infrastructure, economic opportunities, and the information and communication technology (ICT) revolution. The global economy is now organized into networks of cities, with computerized coordination and logistical systems that provide jobs, education, shelter, protection, cultural assimilation, and access to information to billions of people. Unsurprisingly, growing urbanization correlates with rising levels of GDP per capita, though 1 in 3 urban dwellers still live in slums.

The property development industry as a key driver of growth (using cheap credit to fuel consumption of imported goods securitized against property) helps explain the 40% increase in the extraction of industrial and construction minerals since 1980. The construction industry worldwide is now a

$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.

Just as countries have metabolic rates, so do cities. They may seem to have a lower metabolic rate than the countryside, but they externalize many energy- and materially-intensive services to the peripheral areas. 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 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 innovations.

Judging from current trends, urban infrastructure could become a primary focus of innovations surrounding energy use, mobility and the water cycle (sources, uses and re-uses), mediated by a wide range of extremely complex 'socio-technical' and 'socio-ecological' networks. Zero-carbon sustainable cities are being planned, for example in Dongtan near Shanghai, Masdar in Abu Dhabi, Treasure Island in San Francisco Bay and Songdo in South Korea. While these are capital-intensive and have yet to meet their goals, they may be pioneers for future decoupling.

A worldwide movement of urban leaders is seeking ways for cities to reduce their metabolic rates. The International Council for Local Environmental Initiatives (ICLEI) is the most significant global network promoting sustainable cities. It now includes 1000 cities and presents a global case for decoupling urban infrastructure to reduce dependence on resources located beyond the boundaries of the metropolitan areas. This may include a radical shift to public transportation for people and goods, reduced dependence on fossil fuels, increased dependence on locally grown food and localized supply of (recycled) water, much higher densities and the end of sprawl, integrated living and working neighbourhoods, zero waste systems, cleaner production, and responsible ecologically sustainable consumption (driven in part by the way big supermarkets are embracing the organic food revolution and by the growing popularity of fair trade brands).

In conclusion, innovations for more sustainable use of resources are already

underway in the world's cities. The concept of decoupling can become an operational tool that will help cities to determine their metabolic rates and the potential for reducing these rates over time.

3.4 Lessons from the country case studies

This section draws lessons from case studies on China, Germany, Japan and South Africa. 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 a large low-density developing economy (such as Brazil). Nevertheless, the four case studies demonstrate emerging responses to resource depletion and environmental impacts at the country level.

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.

The case studies indicate that the rising economic and environmental costs of resource depletion have affected the economic growth and development trajectories of these countries, leading to various forms of resource 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.

In broad terms, policymaking 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 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 resulting increase in material flows from 40 to 59 billion tons (40–59 Gt) per annum 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** National Strategy for Sustainable Development (NSSD) comprises strategic, mostly quantitative, trend objectives and a set of 21 indicators grouped under different headings. Indicator 1 ('resource conservation') 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 are the cornerstone of the government's position on resource use.

South Africa's key macro-economic policy frameworks do not recognize resource constraints as an economic factor, although the South African scientific community considers resource depletion as an urgent priority for water and soil, while decoupling is needed with respect to energy and a wide range of environmental impacts. The 2008 National Framework for Sustainable Development (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. The NFSD referred specifically to the need for 'dematerialization' which was defined in terms of decoupling.

Since the adoption of its *Scientific Outlook of Development* in 2003, the **Chinese** government has fundamentally altered its development philosophy, leading to the objective of 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. 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', which it proposes to build 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. 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.

As can be seen from this brief review, decoupling economic growth from negative environmental impacts and promoting resource productivity have found a place on the policy agenda of all four countries. They have adopted policies that call for the integration of economic and sustainable development policies. Although decoupling will be much more challenging to achieve in practice, the fact that consensus has been reached on what is needed is of great significance.

Although decoupling as defined in this report is a long-term process of macro-structural transformation to build sustainable socio-ecological 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 level of investment in innovations for more sustainable use of resources. This will be the focus of the second Decoupling Report from the IRP.

4. Decoupling, trade and development dynamics

Global trade of the resources being assessed here is a complicated process, with different influences at the various stages of the life cycle (Figure 3), 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 from reality.

The geographic distribution of resource extraction seldom corresponds 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 international trade shifts costs and benefits in ways that often are difficult to unravel.

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% annually. 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 three times higher for agricultural products. The latter two are material resources being assessed in this report, while the first contains variable amounts of these resources; this makes it impossible to present an analysis of only the primary raw materials being assessed here. However, the perspectives provided on total international trade can be considered to be at least indicative of trade in raw materials.

Growing trade in monetary terms is reflected in 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 monetary and physical trade flows has occurred because trade in manufactured products with a higher price per ton has grown faster than trade in raw materials; in 2005, manufactured products made up only about a quarter of physical trade, but contributed almost three quarters of the economic value.

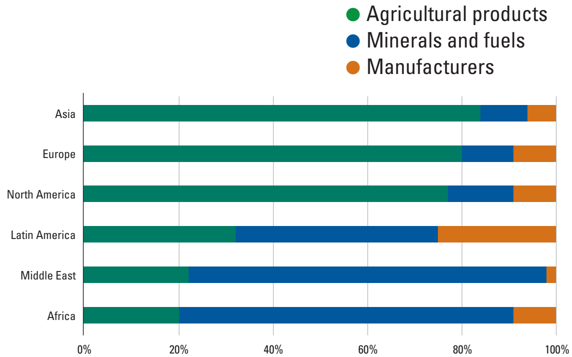
Intensifying global trade also implies growing environmental pressures associated with trade activities. On the one hand, these include direct pressures, in particular due to the impacts of transportation. On the other hand, the indirect (or embodied) environmental pressures are augmented with growing 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. 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. **Material extraction embodied in global trade was estimated to be about 20% of total worldwide material extraction** in the year 2000.

International trade thus contributes 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 resource is extracted) versus from a **consumption** perspective (i.e. allocation to the country where a product is finally consumed). Production-based systems are far more common, particularly because they use clear system boundaries. However, complementary consumption-based accounting systems along the life cycle of a product are required to take trade-related effects into account. This more comprehensive system of accounts could serve as the empirical basis for developing options for sharing environmental responsibility among countries that are playing different roles along the entire value chain.

Half of the volume of world trade is shared between the EU-27 (excluding intra-EU trade), China, the USA, and Japan, with about 45% of world exports and 51% of world imports. At the other end of the spectrum, 49 of the least developed countries, mostly in sub-Saharan Africa and Central Asia, together hold a share of only 1.1% of global trade. While some developing and emerging countries (most notably China, but also Brazil, Mexico, Malaysia, India and many others) have achieved successful integration into the global trade system, globalization has not benefitted all countries and individuals.

Industrialized countries (here including China) largely export manufactured products. Many developing regions, on the other hand, continue to rely strongly on the export of raw materials. Latin America

Figure 16. Composition of exports (in monetary units) by world regions, 2006



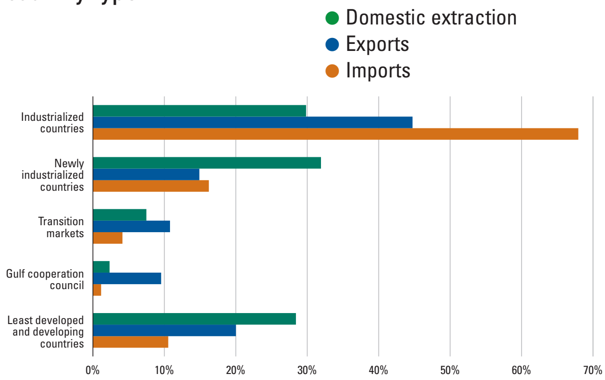
Source: WTO, 2008

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) (Figure 16). However, this general pattern has some important deviations, as some industrial countries, typically those with a low population density, such as Australia, Canada, and the USA, also play a major role as exporters of primary products.

The total extraction of material resources is as unevenly distributed across the world as might be expected (Figure 17). 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 17 illustrates, industrialized countries have the highest share in trade activities, while their share of materials extraction corresponds roughly to their share of world population. Even if they are

Figure 17. 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

also active exporters, they import two thirds of all traded materials. This difference is also reflected when comparing economic (monetary) and physical trade balances (Figure 18).

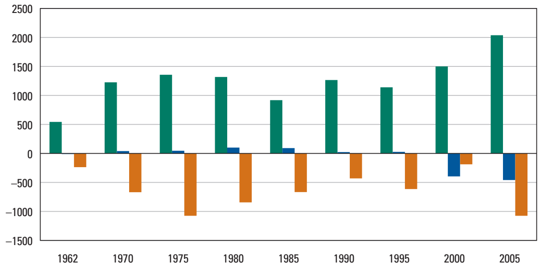
While monetary trade balances tend to be relatively even (except for the growing trade deficit of the USA), physical trade balances have a systematic asymmetry; industrial countries tend to be net material importers, while developing countries have served as net exporters over the whole time period. During the last decade, the group of countries with economies in transition have also become net exporters. In 2005, the industrial countries net imported around 2 billion tons (2 Gt), of

Figure 18. **Physical and monetary trade balances of three country types, 1962 to 2005**[a]

- Industrial countries
- Transformation countries
- Developing countries

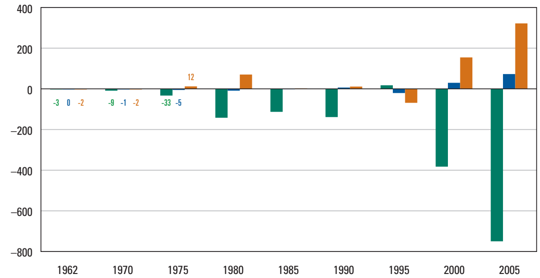
Physical trade balances

Million tons



Monetary trade balances

Billion US$



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

which two thirds originated from developing countries and one third from the former Comecon countries.

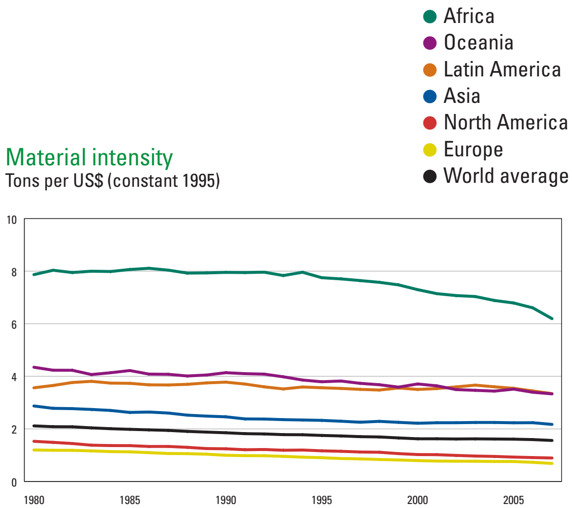
Current **economic specialization and resulting physical trade patterns have had both positive and negative implications for economic development in developing countries**, with the balance depending largely on the enabling and regulatory conditions and the specific conditions that are agreed. Factors cited for contributing to the negative impacts have included low prices for raw materials, limited domestic processing, rent-seeking, and many other factors.

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 UNEP's Governing Council). Improved policies to support decoupling include reducing global resource use through exploiting transport and physical or geological potentials in a way that minimizes negative environmental impacts; incorporating in trade negotiations the full value chain of the commodities being traded; and agreeing on prices that incorporate environmental factors and social costs that are now considered 'externalities'.

Such measures would support the desire of developing countries to diversify their economies so that they can reduce dependence on the export of a small number of commodities, support the development of domestic markets, and promote sustainable economic development.

Some decoupling has accompanied the expansion of material consumption, as the overall material intensity of the global economy declined from 2.1 tons in 1980 to 1.6 tons per US$1000 in 2002 (Figure 19). In other words, 25% less material input was required in 2002 compared to 1980 to produce one unit of real GDP. 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

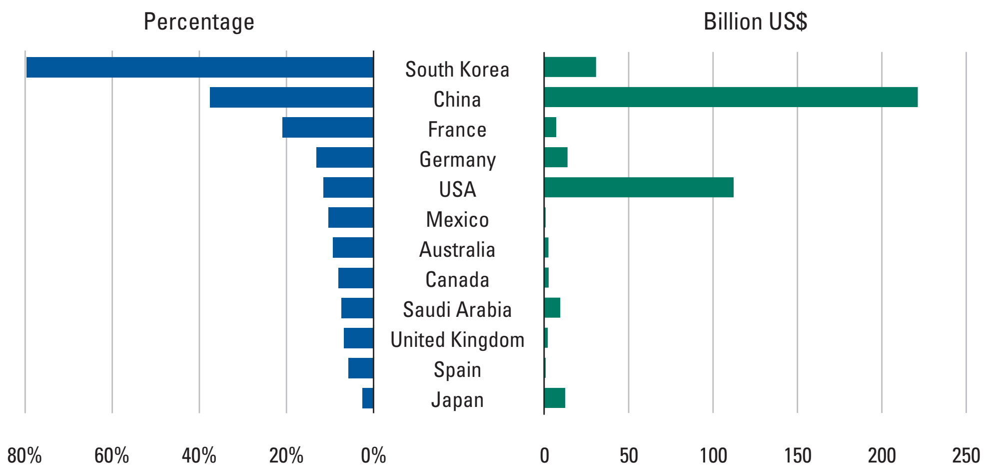
Figure 19. **Material intensity of the world economy: Domestic extraction of materials per unit of GDP by world region**



Source: Behrens *et al.,* 2007

industrialized countries, at least some of which experienced low, or even negative, GDP growth rates in some years. However, Figure 19 also shows 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 in 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

Figure 20. Eco-friendly spending, total amount and percentage of total fiscal stimulus package



Source: HSBC, 2009

highly inefficient (Africa) 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? 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.** For example, the $2–$3 trillion that will be invested to revive the global economy has been inspired by more than a narrow economic recovery vision, as some countries have incorporated 'green growth' elements into their economic rescue packages (Figure 20). These include expanding public transport and freight rail services, constructing 'smart' electrical grid management systems, investing in renewable energy (wind, solar, bio-energy), greening of living spaces, restoring rivers and forests, and recycling wastes. 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'.

5. Major policy challenges

This Assessment Report has provided evidence that it is time to recognize the limits to the natural resources available to support future resource demands created by traditional approaches to economic growth and human development. **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 policies 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 activities can provide a policy tool for calibrating the shifts required over time to manage the transition to a more sustainable global economy.

The report has distinguished between resource and impact decoupling, and between decoupling and absolute resource use reductions. Relative resource decoupling is happening on a global scale, but is more pronounced in the developed economies that are already consuming relatively large amounts of resources. Little contemporary evidence of impact decoupling is available, the historical achievements of environmental policies notwithstanding. 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).

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

- 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.

6. Conclusion

This Assessment Report has shown that both resource and impact decoupling are taking place, albeit at a modest pace. This might be taken to imply that any innovation that results in less inputs or impacts per unit of output will contribute to decoupling. However, the 'rebound effect', in which savings from efficiency are used to exploit other resources, suggests some caution is required. 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. Figure 7 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, 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 more scarce is risky: the opposite may transpire when it is already too late to take corrective measures.

But Figures 1 and 4 demonstrated that during the 20th century, GDP grew substantially faster than material extraction in the four categories of resources considered here. The 'dematerialization' of the world economy has happened more or less spontaneously, effectively raising resource productivity by about 1–2% annually on the global level. This decoupling has been particularly apparent among the industrial countries, suggesting that considerable additional room for decoupling remains.

UNEP's International Resource Panel will be addressing the challenges of applying the concept of decoupling more comprehensively in separate reports, including applications to water, land and soil, and other key natural resources.

Abbreviations

CCS	Carbon capture and storage
CO_2	Carbon Dioxide
DE	Domestic Extraction
DMC	Domestic Material Consumption
ECLAC	UN Economic Commission for Latin America and the Caribbean
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
GDP	Gross Domestic Product
Gt	Gigatons
ICLEI	International Council for Local Environmental Initiatives
IRP	International Resource Panel
LCA	Life cycle assessment
MFA	Material flow accounting
MTB	Monetary trade balance
NFSD	National Framework for Sustainable Development
NSSD	National Strategy for Sustainable Development
OECD	Organisation for Economic Co-operation and Development
PTB	Physical trade balance
TPES	Total Primary Energy Supply
UN	United Nations
UNEP	United Nations Environment Programme
USA	United States of America
WTO	World Trade Organization

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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.