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International Resource Panel

Decoupling 2
Technologies, Opportunities and Policy Options

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International Resource Panel

Decoupling 2 Technologies, Opportunities and Policy Options

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Abbreviations and acronyms

3R	Reduce, reuse and recycle
AF&PA	American Forest and Paper Association
AFD	French Agency for Development
BIR	Bureau of International Recycling
BLGCC	Black Liquor Gasification-Combined Cycle
BMRA	Metals Recycling Association
BMU	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CADDET	Centre for the Analysis and Dissemination of Demonstrated Energy Technologies
Cap	Capita
CBSM	Community Based Social Marketing
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CFCs	Chlorofluorocarbons
CO_2	Carbon Dioxide
CSCP	Collaborating Centre on Sustainable Consumption and Production
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DMC	Domestic Material Consumption
DAC	Development Assistance Committee (OECD)
DETR	Department for Environment, Food and Rural Affairs (UK)
DPSIR	Driving Forces, Pressures, States, Impacts, Responses
DTIE	Division of Technology Industry and Economics (UNEP)
DWAF	Department of Water Affairs and Forestry (South Africa)
ECLAC	UN Economic Commission for Latin America and the Caribbean
EEA	European Environment Agency
EFR	Environmental Fiscal Reform
EMAS	European Eco-Management and Audit Scheme
EPA	Environmental Protection Agency
ETS	European Union Emissions Trading System
EU	European Union
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
FAO	Food and Agriculture Organization of the United Nations
FIT	Feed-in tariffs
FPAC	Forest Products Association (Canada)
G-8	Group of Eight
G-20	Group of Twenty Finance Ministers and Central Bank Governors
GDP	Gross Domestic Product
GMI	Global Methane Initiative
GTZ	German Technical Cooperation
IAI	International Aluminium Institute
ICLEI	International Council for Local Environmental Initiatives
ICMM	International Council on Mining and Metals
IEA	International Energy Agency
IEEP	Institute for European Environmental Policy
IESNA	Illuminating Engineering Society of North America
IFA	International Fertilizer Industry Association
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IGPN	International Green Purchasing Network
ILCD	International Reference Life Cycle Data System
INBAR	International Network for Bamboo and Rattan
IPCC	Intergovernmental Panel on Climate Change
IRP	International Resource Panel
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Initiative
LCSA	Life Cycle Sustainability Assessment
LED	Light-emitting diode
NO_x	Mono-nitrogen oxides NO and NO_2
OECD	Organisation for Economic Co-operation and Development
PUB	Public Utilities Board of Singapore
RDCI	Rathkerewwa Desiccated Coconut Industry
RMI	Rocky Mountain Institute
SCP	Sustainable Consumption and Production
SDGs	Sustainable Development Goals
SETAC	Society for Environmental Toxicology and Chemistry
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UK	United Kingdom
USA	United States of America
USGS	U.S. Geological Survey
WADE	World Alliance for Decentralized Energy
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization
WPCC	World People´s Conference on Climate Change and the Rights of Mother Earth
WRAP	Waste and Resources Action Programme
Yr	Year

Units

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

Preface

The urgency for decoupling escalating resource use and environmental degradation from economic growth is now widely acknowledged by policy-makers, industry leaders and civil society. Indeed, it has become a key issue in the on-going deliberations on the Sustainable Development Goals (SDGs).

Decoupling lies at the heart of the mission of the International Resource Panel. Established by UNEP in 2007, the Panel provides independent, coherent, authoritative and policy relevant scientific assessments on the management of natural resources and the environment for the highest net benefit of present and future generations. Its analysis, based on full lifecycle impacts of resource use, has repeatedly highlighted the importance of decoupling for ensuring that the gains in human well-being made by economies are not lost because of the simultaneous costs arising from resource scarcity and environmental destruction.

In its first Decoupling report published in 2011, the Panel showed that breaking the link between human well-being and resource consumption is necessary and possible but in reality is hardly happening. In this follow-up report – *"Decoupling 2"* – the Panel highlights existing technological possibilities and opportunities for both developing and developed countries to accelerate decoupling and reap the environmental and economic benefits of increased resource productivity.

Many decoupling technologies and techniques that deliver significant resource productivity increases are already commercially available and used in both developing and developed economies. They allow economic output to be achieved with fewer resource inputs, reducing waste and saving costs that can further expand the economy or reduce its exposure to resource risks.

But while these technologies are readably available, their uptake and upscaling requires policies to remove barriers to decoupling and intentionally promote a transition towards greater resource productivity. Economies often do not naturally adjust to changes in resource availability by promoting innovation and resource productivity; they can suffer from blocks to transition which "lock-in" existing patterns of resource use. The legacy of past policy decisions and technological, behavioural, organisational and institutional biases against innovation in resource productivity present significant barriers to decoupling.

Facilitating decoupling will thus require removing these barriers and overcoming the "lock-in". Developing countries may have a relative advantage in decoupling, because they are not so strongly locked-in by resource-intensive consumption patterns, production systems, infrastructure and institutions as in the developed world. But in both cases, raising resource productivity is easier and more successful when policymakers are sensitive to the perceived needs of stakeholders and the interests, relative power, the norms and assumptions that shape economic and societal decisions.

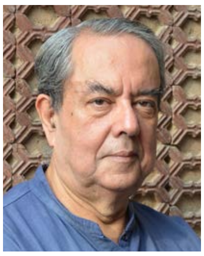
Obviously, a high level of leadership is needed in the public and private sectors to overcome the resistance that is commonly faced by such deep policy changes and to promote the needed policy action.

This report examines several policy options that have proved to be successful in helping different countries to improve resource productivity in various sectors of their economy. It also highlights examples that demonstrate significant progress towards decoupling economic growth from resource use.

In particular, the report mentions two policy proposals which are illustrative of the type of combined policy that is needed. One proposal uses taxation or subsidy reduction to move resource prices upwards in line with documented increases of energy or resource productivity. Another looks to shift revenue-raising onto resource prices through resource taxation at source or in relation to product imports, with recycling of revenues back to the economy.

There is growing evidence that decoupling will be one of the next big opportunities for innovation, wise use of resources, and thus for continued economic development. Policymakers along with corporate leaders with vision and an understanding of political realities can take significant steps to benefit from future resource trends and decoupling opportunities.

The International Resource Panel is committed to continue providing cutting-edge scientific knowledge on sustainable resource management and promote a better understanding of the opportunities of decoupling technologies and policies. We are grateful to the lead authors of this report for their encouraging findings and incisive recommendations, and we are very much looking forward to the reaction of policy-makers to the tremendous challenges and opportunities highlighted in this report for overcoming the barriers to decoupling and collecting the economic benefits of increased resource productivity.



Dr. Ashok Khosla
Co-Chair,
International Resource Panel (IRP)
New Delhi, India, May 2014

Foreword

One of the greatest challenges facing humanity today is to maintain the healthy growth necessary to lift the world's one billion people out of absolute poverty and manage the natural resources required for the well-being of nine billion people by 2050 – all while keeping environmental impacts within acceptable limits and sustaining life's natural support system.

The first Decoupling Report by UNEP's International Resource Panel (IRP), launched in 2011, sought to apply the concept of "decoupling" economic growth and human well-being from negative environmental impacts and escalating resource use to address this challenge.

Improving the rate of resource productivity (*doing more with less*) faster than the economic growth rate is the notion behind decoupling, to the extent of actually using less resources.

That goal, however, demands an urgent rethink of the links between resource use and economic prosperity, buttressed by a massive investment in technological, financial and social innovation, to at least stabilise and ultimately reduce per capita consumption in wealthy countries and help developing nations follow a more sustainable path.

The IRP's new *Decoupling 2* report demonstrates that the worldwide use of natural resources has accelerated, causing severe environmental damage and depletion of natural resources.

Annual material extraction grew by a factor of eight through the twentieth century. At the same time, the use of resources, such as freshwater, land and soil has transgressed sustainable levels.

This explosion in demand is set to accelerate as population growth and the increase in incomes continue to rise. More than 3 billion people are expected to enjoy "middle class" income levels in the next twenty years, compared to 1.8 billion today.

A global economy, based on the current consumption models, is not sustainable and carries significant economic consequences. Price volatility and supply shocks of resources have already been observed across a range of key materials and commodities. The volatility of food prices, for example, increased to 22.4 per cent in 2000-2012 compared to 7.7 per cent in the previous decade.

Placing the world's environmental resources – such as water, biomass, fish stocks and ecosystems – under too much stress can lead to sudden, non-linear collapse. Over-mining has led to a decline in average ore grades for several key metals, such as copper, gold and tin. As a result, three times as much resources and materials needs to be moved for the same quantity of metal extraction as a century ago. Global markets cannot respond adequately by simply raising the supply of resources to meet demand, especially when they are not set up to factor in the anticipated scarcity of resources.

The decoupling of economic growth rates from resource use is, therefore, more than just an imperative. It is the next big opportunity for green economic growth, innovation and sustainable development at large.

The *Decoupling 2* report highlights that efficient technologies do exist for both developing and developed countries to significantly reduce resource intensity and, where feasible, achieve the absolute decoupling of resource use. Decoupling allows economic output to be achieved with fewer resource inputs, reducing waste and saving capital. Those funds can further expand the economy or reduce its exposure to resource risks.

This new IRP report also explores the enabling environment required for national economies to promote decoupling and prosper in the future, through identifying and removing barriers, including technical and institutional "lock-in", which can hold back effective policy change.

The report concludes that with leadership, vision and an understanding of political realities, policy makers can take significant steps to reap benefits from future resource trends. These steps include the creation of favorable conditions for investment in technological and institutional innovation and transformation.

In 2014, the United Nations Open Working Group on Sustainable Development Goals will submit a proposal to the General Assembly that will set development priorities for the coming years.

It is my sincere hope that the findings of this important report will inspire Member States to embed sustainable resource management and the concept of decoupling in the post-2015 development agenda, and trigger visionary political and business leadership to foster policy co-ordination in the public and private domain aimed at effectively decoupling economic growth from the escalating use of energy, land, water and materials.

I would like to express my gratitude to the International Resource Panel, under the leadership of Ashok Khosla and Ernst Ulrich von Weizsäcker, for coordinating this important report.

Achim Steiner
UN Under-Secretary-General and
UNEP Executive Director
Nairobi, Kenya, May 2014

Executive Summary

Decoupling 2:
Technologies, opportunities and policy options

1 Introduction

As the work of the International Resource Panel (IRP) shows, the worldwide use of natural resources has accelerated, bringing with it the thinning or depletion of numerous resource stocks and causing negative environmental impacts (UNEP, 2010a). Adjusting our societies to these trends is one of the grand challenges of our times. The trends in resource use suggest that successful economies will be the ones that can increase the value they deliver, while using fewer resources.

This report highlights existing technological possibilities, for developing and developed countries, and the economic advantages. It shows that there is growing evidence that decoupling will be one of the next big opportunities for economic growth, innovation and wise use of resources. The report explores the actions that a country would need to take to create the conditions for its economy to prosper in the future.

It finds that policymakers with leadership, vision and an understanding of political realities can take steps to benefit from the future resource trends. The report identifies the barriers that can hold back effective policy change, and examines technological, organisational and policy options that have proved to be successful in different regions of the world. It highlights the forms of policy action that can make faster progress towards the decoupling of economic growth from use of resources.

2 Changes in Resource Use and Scarcity

Trends in resource use

During the twentieth century, the annual extraction of ores and minerals grew by a factor of 27, construction materials by a factor of 34, fossil fuels by a factor of 12 and biomass by a factor of 3.6. In total, material extraction increased by a factor of about eight. The extraction of many metals has followed an essentially exponential growth path since the beginning of the twentieth century, as Figure 0.1 shows.

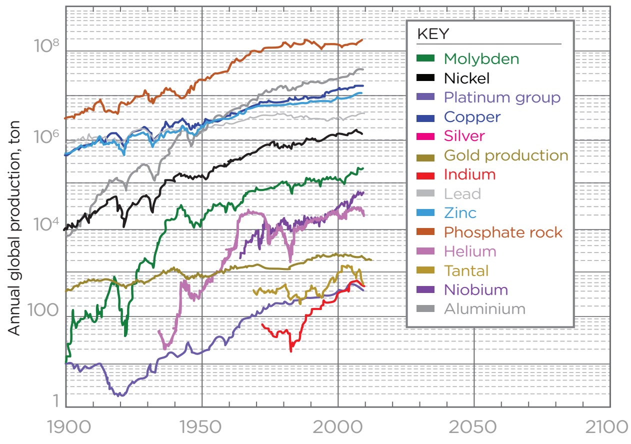


Figure 0.1 Extraction of many metals grew exponentially since the year 1900 (the ordinate on the picture being logarithmic) From: Sverdrup et al, 2013

Other reports have illustrated that the use of some natural resources essential to prosperity – including freshwater, land and soils, and fish – have similarly increased, in many cases beyond sustainable levels.

The underlying drivers for this explosion in demand appear set to continue. The UN projects global population to grow by more than 2.5 billion people by 2050 (UN, 2013) and incomes (on average) are on track to continue rising. According to one estimate, in 20 years there will be 3 billion more people worldwide enjoying "middle class" income levels, compared to 1.8 billion today (Kharas, 2010).

In our first Decoupling report, we described three future scenarios for resource use. In the scenario which represents many policymakers' current plans – in which levels of resource use per head for all global citizens reached the levels of current use of the average European – annual resource extraction would need to triple by 2050, compared to extraction in 2000. This probably exceeds all possible measures of available resources and assessments of the limits of the planet to absorb the impacts of their extraction and use. For example, global demand for water is expected to rise by 40%, so that in 20 years' time available supplies may probably satisfy only 60% of world demand (2030 Water Resources Group, 2009).

Consequences of these changes

It does not seem possible for a global economy based on the current high-consumption model of resources to continue into the future. The economic consequences of increasing resource use are already apparent in three areas: increases in resource prices, increased price volatility and disruption of environmental systems.

Price increases: During most of the nineteenth and twentieth centuries, commodity prices had a tendency of declining. But recent developments of massively increased demand have caused the reverse, as shown in Figure 0.2.

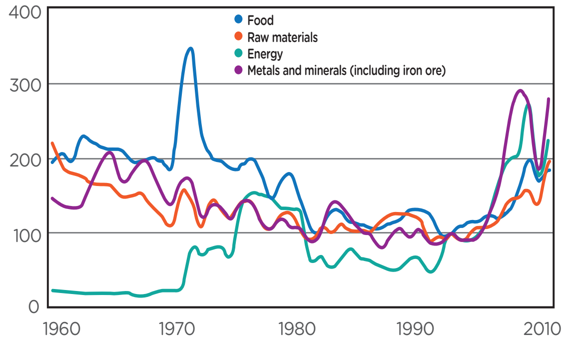


Figure 0.2 Commodity price indices
Source: World Bank Commodity Price Data, 2011.

Increased price volatility: Price volatility and supply shocks have already been observed across a range of key materials and commodities used in the economy. For instance, the United Nations Food and Agriculture Organization found that the volatility of food prices increased to 22.4 per cent in 2000-12 compared to 7.7 per cent in 1990-99[1]. Price volatility can be more disruptive than trends of price increase – some believe that rising global food prices led to civil dissatisfaction which fuelled the "Arab Spring" (see for example: Center for Climate Change and Security, 2013).

Disruption of environmental systems: There are strong links between resource use and damage and depletion of environmental systems, including greenhouse gas emissions (UNEP, 2010a). The UN Millennium Ecosystem Assessment documented several accelerating, abrupt, and potentially irreversible changes already occurring to the world's

1 Measured by the standard deviation around the average price. However, note that before 1990, food prices were also volatile, having a higher standard deviation than in the years 2000-12.

ecosystems, and a number anticipated to occur in the coming decades. These include possible fishery collapses, bleaching of coral reefs, desertification, increased vulnerability to natural disasters, and crop failures (Millennium Ecosystem Assessment, 2005). Studies show that such environmental deterioration is affecting economies and economic growth (Stern, 2006; Brown, 2008).

There are several reasons why the market is unlikely to respond adequately to these challenges by simply raising supply of resources to meet demand.

- The scale and rate of change has accelerated, and often outpaces the supply side response.
- There are real physical constraints: past mining of the most attractive ores has led to declining average ore grades for several key metals, such as copper, gold or tin, so that, for many metals, about three times as much material needs to be moved for the same quantity of metal extraction as a century ago.
- For environmental resources – like climate, fish stocks or local ecosystems, too much stress may lead to sudden, non-linear collapse (Smith et al., 2010).
- And, importantly, markets are not adequately set up to factor in much of the expected scarcity of resources – but rather reflect today's extraction cost of still conveniently available ores.

Strategic implications

The resource trends have strategic implications for economies. They appear likely to alter the relative importance of resources compared to other inputs into production – and in doing so change the basis of relative competitive advantage between countries. This implies that the economies that move first, or fastest, to adapt to the changed economic conditions stand to gain and bring greater security and wealth to their populations.

As the current model of development is not sustainable in the long term, a real change of course will be needed, significantly changing technologies, policies and consumption habits. Some commentators believe that the economic growth of many developing countries means that they, compared to those developed countries that are in some situations locked in wasteful infrastructures and habits, have more opportunities to adapt, and so can gain more from change.

At the same time, trends in resource use increase the risks of disruption to economic growth from potential resource scarcity and shocks, including environmental degradation and possible collapse. These often cause more severe effects in developing countries, than in richer economies.

3 Choices of Response for Policymakers

For economic prosperity and growth, one of the most appealing strategies for adapting is decoupling (UNEP, 2011 and Smith et al., 2010) – the seizing of opportunities for resource productivity, so that a nation can produce greater economic value out of fewer resource inputs (both material and energy) per unit of value[2]. When considering changes, decision-makers need to look as closely as they can at the productivity changes in the resources that matter most to them. Aggregate figures for resource use – which are frequently the most available – may not reflect the possibilities for decoupling economic growth from some particularly important resources.

2 Growth is more strongly decoupled where a greater share of an economy's growth comes from resource productivity relative to labour productivity

Decoupling, can mean different achievements. We propose to distinguish between three types of decoupling:

1. Decoupling through maturation. This type of decoupling is a "natural" process of overcoming clumsy and inefficient techniques, of building-up of infrastructures, and of actively reducing environmental pollution. This is related to the maturation process as countries shift from an extraction and production-based economy towards a service economy.

2. Decoupling through shifting to other countries the more material intensive stages in product life cycles (burden-shifting). If domestic extraction and production is replaced by imported materials and products, resource use may decline domestically, but still occur elsewhere in the world where the more material intensive, often more polluting, stages in products life cycles may be taking place. This type of decoupling is often labelled as burden-shifting, where resource-intensive activities and their environmental impacts are shifted offshore.

3. Decoupling through intentional resource productivity increase. This is what is really needed to reduce pressures on limited resources, on climate, and on the environment in general. It requires technological innovation, infrastructures conducive to resource efficient and low material intensity manufacturing and living, and appropriate attitudes and consumption patterns. Intentional decoupling is the main focus of this report.

Investments in resource productivity can bring multiple gains, ranging from reduced operational costs for companies and the public sector to better environmental quality and the creation of jobs (Smith et al., 2010). For example, energy efficiency policies in California are estimated to have created nearly 1.5 million jobs from 1977 to 2007. Similar figures emerged from Germany's resource productivity policies in the years before 2004, creating or saving more than 1 million jobs (Fischer et al., 2004).

Economic growth comes, partly, through investments in innovations, and policymakers can influence the nature of the innovations that receive investment through their enabling policies. A vivid visualisation of the relationship between innovation and economic growth is given by "Kondratiev cycles" (Freeman and Louçã, 2001). Economic growth has been observed to come in waves of prosperity, each driven by the spread of new technologies and structural economic change. Figure 0.3 illustrates the way that growth usually involves changes in technologies.

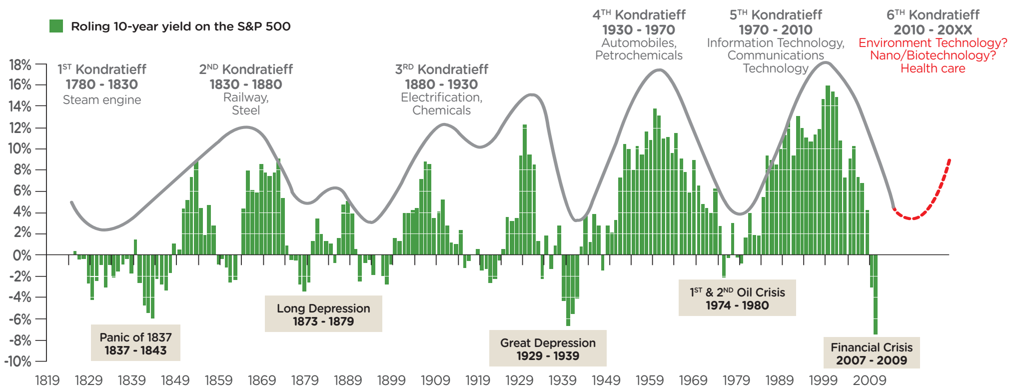


Figure 0.3 Kondratiev cycles. Source: Allianz Global Investors "The Sixth Kondratieff" – Long waves of prosperity, 2010. The description of the sixth Kondratieff suggests that resource productivity could become the overarching characteristic of the new cycle

Considering the trends in global resource use and environmental degradation, we might expect a well-functioning economy to naturally respond to information on resource scarcity by increasing innovations in resource productivity. That implies that decoupling would be one of the drivers of the next period of growth in successful economies.

In practice, there are several barriers and biases that hold back the desired improvements, meaning that the steep rise in resource productivity requires courageous policy changes (UNEP, 2011; pp. 48, 74). In the past era of declining resource prices, business has tended to focus on increasing labour productivity – with the result that labour productivity has grown at faster rates than other factors of productivity (Figure 0.4).

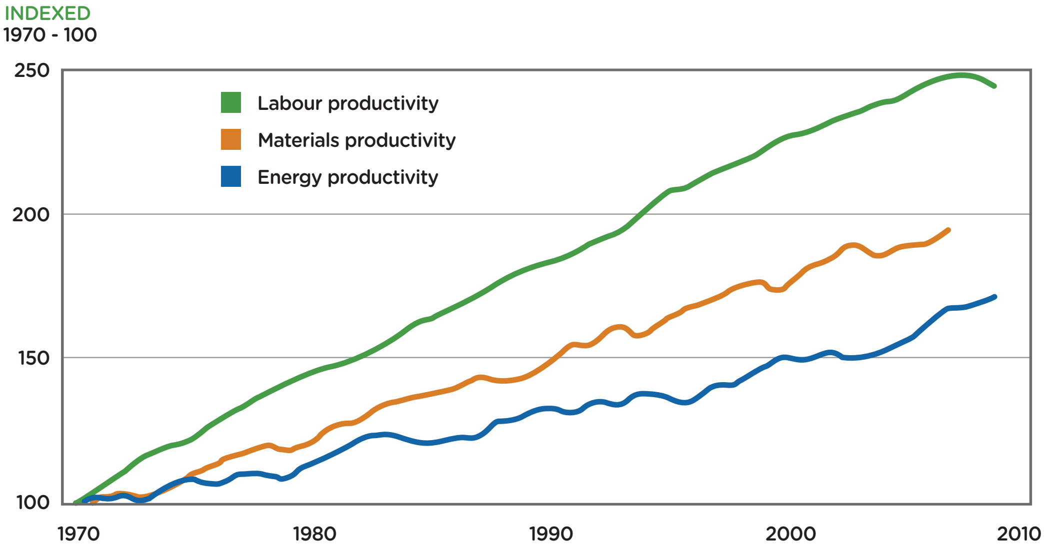


Figure 0.4 **Resource Productivity, Labour Productivity and Energy Productivity.**
Source: EEA, 2011

While the existing policy set may have been suitable for promoting growth in the past, it seems unlikely to meet the challenges of the future. The trends in resources imply that to maintain stable future economies and natural life support systems, resource productivity increases would need to be greater than the rate of economic growth for the world as a whole. This is called "decoupling". Decoupling can either reduce the use of resources absolutely as an economy grows, or only relatively – so that the rate of increase in resource use is lower than the growth rate of the economy. With absolute decoupling, in contrast, resource use declines, irrespective of the growth rate of the economies.

Indeed, for resources – although pressures differ greatly by resource and country – approximately a factor five improvement (Weizsäcker et al., 2009) in total resource productivity by 2050 would be required for OECD countries (resulting in just 20 per cent of today's material usage/unit of production), including also the resources embedded in the goods and services they import from other countries. This implies that each unit of production is produced using between 25 per cent and 10 per cent of its current resource inputs by 2050 (WBCSD, 2010), a much greater rate than resource productivity gains previously seen.

For instance, the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report, published in 2007, warns that to maintain an agreeable kind of climate, global emissions need to peak by 2015, and then reduce by 25-40 per cent by 2020 and 80 per cent by 2050. OECD countries would need to absolutely decouple their growth from their greenhouse gas emissions, at a rate that would give more room to developing countries to raise living standards until they too can achieve absolute decoupling. Apart from greenhouse gas emissions, such decoupling is also needed for a number of other resources such as forestry, fishery, food, waste, air pollution, minerals. The IPCC's Fifth Assessment Report, published in October 2013, also confirms these findings.

The required intentional policy change should influence all aspects of economic and environmental policies, with a view of facilitating their economy's transition to absolute decoupling.

Knowing that relative decoupling will not suffice on a global scale, the focus of this report is on the opportunities for countries to pursue strategies of better lives for their people while significantly reducing resource intensity and consumption patterns and, where feasible, even achieving absolute decoupling of resource use. As an encouragement for decoupling policies, our report shows that:

- The potential exists for much greater levels of absolute decoupling to be achieved through strategic changes in technologies and design. Much of the technologies and technique "know how" to achieve significant levels of resource productivity (as much as five to tenfold improvements) already exist. A number of publications over the last 15 years (Hawken et al., 1999; McDonough and Braungart, 2002; Hargroves and Smith, 2005; Pascala and Socolow, 2004; Pauli, 2010; Smith et al., 2010; Lovins and RMI, 2011) have shown that decoupling is technically possible for material resource consumption, greenhouse gases, and water extraction. (Chapter 3)
- Success stories exist of countries that achieved some modest absolute decoupling of economic growth from selected aspects of resource use and greenhouse gas emissions, from which we can learn. (Chapters 6 and 7)
- Much of the policy "know how" required to achieve economy wide "decoupling" exists in the form of legislation, incentive systems, administrative measures, and institutional reform. But additional policy options could be opened for a yet more strategic and long-term avenue towards ecologically sound growth. (Chapters 7 and 8)

4 Technological Responses Allowing Significant Decoupling

Increasing resource productivity is technologically possible: technologies and techniques that bring very significant resource productivity gains are already available, right across the range of resource consuming activities, with different technologies applicable at different levels of economic development.

The Rathkerewwa Desiccated Coconut Industry (RDCI) in Maspotha, Sri Lanka, provides a good example. RDCI could reduce 12 per cent of energy use, 8 per cent of material use and 68 per cent of water use, while increasing the production by 8 per cent during the same period by adopting a series of recommendations on its peeling process, water treatment, and fuel switching. The total investment required for implementing these recommendations was less than US$5,000, while an annual financial return of about US$300,000 was reported.[3] Sweden introduced an energy efficiency programme in 2005 for its energy intensive industries. A recent analysis showed average payback periods of less than 1.5 years (Stenqvist and Nilsson, 2013).

3 For details, see *http://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Cleaner_Production/RECP_SriLanka.pdf*

The wide range of existing opportunities is illustrated by Figure 0.5. Our report describes some of the more remarkable technologies and techniques.

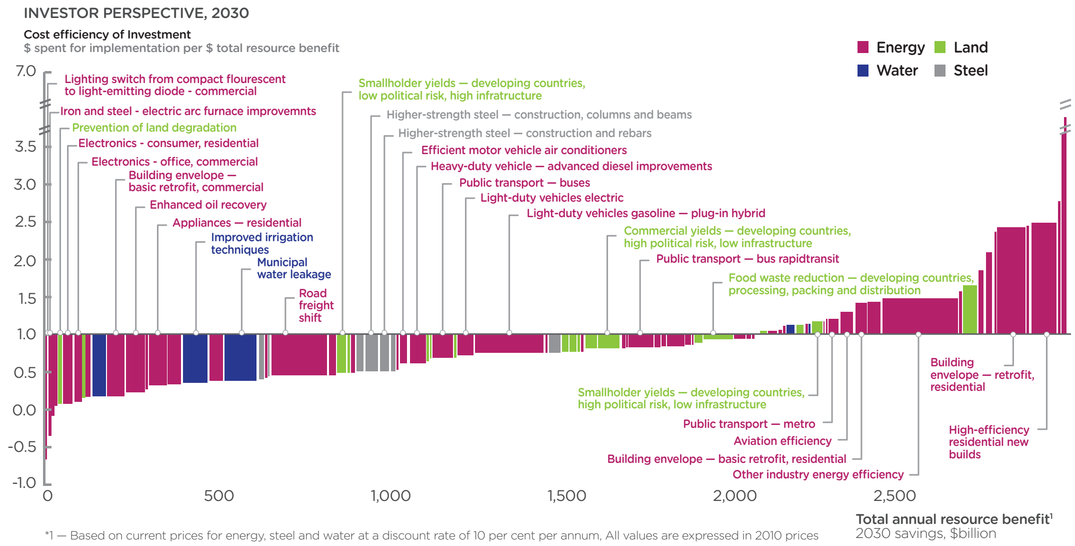


Figure 0.5 Mapping the range of opportunities for resource productivity gains.
Source: McKinsey Global Institute. Resource Revolution (2011)

The scale of the opportunity is very large. One estimate places the savings potential between US$2.9 trillion and US$3.7 trillion each year (by 2030). Ninety per cent of the opportunities had an internal rate of return of greater than 10 per cent, if adjusted for subsidies, carbon prices and a social discount rate (McKinsey Global Institute, 2011).[4] The following examples provide an illustration of some of the potential:

High-efficiency motors: These could potentially save 28-50% of motor energy use, with a typical payback period of one to three years (CADDET, 1995). Electric motors used in industry in China account for around 60 per cent of the country's total electricity consumption. The operational efficiency of these motors is 10-30 per cent below international best practice, depending on the industry. A pilot study at China's second-largest oil field suggested there was the potential to save more than 400 million kilowatt hours (kWh) of electricity per year in the oil field, with a payback period for recovery of the initial investment of 1.6 years (UNEP, 2010b).

Higher strength steel: Using steel with higher strength for re-enforcement of concrete, beams and columns saves steel: ArcelorMittal, the world's largest steel company estimates use of higher strength steel achieves a 32 per cent reduction in the weight of steel columns and 19 per cent in beams (McKinsey Global Institute, 2011, p. 105). China and developing countries tend to use lower-strength steel, with China using steel for reinforcement that is two-thirds the strength of steel averagely used in Europe. This offers a very good opportunity – as these countries' use of steel is very significant. (For example, China currently consumes 60 per cent of global steel reinforcement bar production.)

Even partial global switching to higher strength steel could save 105 million tonnes of steel a year, and save 20 per cent of the costs of the use of steel (Allwood, J. and Cullen, J., 2012).

4 The study suggests also that 70% of the opportunities have a greater than 10% IRR at current prices. The higher figure (3.7 trillion) applies if carbon is appropriately priced and perverse subsidies phased out.

Blanking sheet metal: The pressing out (or "blanking") of metal components of different size and shape from sheet metal necessarily leaves behind pieces of sheet metal that are not wanted and too small to use for other components. Intelligent organisation of the different shapes to be pressed out can realise significant metal savings. Deutsche Mechatronics GmbH operates in Germany using computer-driven shuffling and a good production planning system that could reduce metal use by 12 per cent.

Methane from waste landfill: In the United States of America (USA), approximately 480 landfill sites, representing around 27 per cent of the nation's landfills, capture released methane gas from decomposing organic waste (2009 figures) (Bracmort et al., 2009). It is estimated that between 60 and 90 per cent of the methane in the landfill gas can be captured and burnt. Nevertheless, methane from landfills contributes 1.8 per cent to the US total greenhouse gas emissions.

Drip irrigation: Agriculture is responsible for 70% of freshwater withdrawals (Weizsäcker et al., 2009). In many countries, 90 per cent of irrigated land receives irrigation water through open channels or by intentional flooding. The waste of freshwater through these methods, through evaporation, leakage and seepage is high. Farmers in India, Israel, Jordan, Spain and the USA have shown that sub-surface drip irrigation systems that deliver water directly to crop roots can reduce water use by 30-70 per cent and raise crop yields by 20-90 per cent, depending on the crop (Postel et al., 2001). Efficiency savings can be as high as 50-80 per cent, and can be made affordable for use in the developing world (Shah and Keller, 2002) with payback periods of less than a year.

5 Creating the Conditions for Investments in Resource Productivity

Success comes from creating the right conditions for investment

Policymakers can facilitate the widespread uptake of technologies and techniques for decoupling. A wealth of experience from policies on innovation, decoupling and environment can guide future policy action. Lessons can be learned from some great successes: for example in water efficiency. In Australia, GDP rose by 30 per cent and water consumption was reduced in absolute terms by 40 per cent from 2001 to 2009 (Smith et al., 2010).

Many countries have put in places policy mixes promoting decoupling. For example, at European Union (EU) level, recent initiatives, such as the 7th Environmental Action Programme and the Roadmap to a Resource Efficient Europe, and the Energy Efficiency Directive of 2012 are long-term strategies moving energy, climate change, research and innovation, industry, transport, agriculture, fisheries and environment policy all towards decoupling.

The roadmap also deals with tax policy, making the case for a shift from labour taxes to resource taxes, and discusses the phasing out of environmentally harmful subsidies. Similarly, China has strategically improved energy efficiency writing 20 per cent and 16 per cent efficiency gains into its eleventh and twelfth Five-Year Plans respectively, and adopting regulation and incentives to make it happen.

Whether, where and how decoupling occurs may depend on national decision makers' abilities to overcome biases which currently disadvantage investments in resource productivity. Countries that can overcome those barriers can lead the next wave of development, and gain advantage over their competitors.

Changing current biases

There are currently several factors that lead to bias against investments in resource productivity and two areas of barriers for policymakers to tackle. The first group arises from the effect of the historic policy framework. There a number of areas where current policy structures coming out of past government decisions steer economies away from resource productivity, examples of which are:

- Subsidies of up to US$1.1 trillion each year for resource consumption (McKinsey Global Institute, 2011). These subsidies encourage the wasteful use of resources while reducing the savings from investments to use the resources more efficiently.
- Taxation of people's work through labour taxes is typically higher than the tax burden on resources (and energy). As labour and resources are often alternative inputs into economic growth, this favours resource consumption rather than increased employment. Together with distortions from subsidisation of resources, taxation reduces the return on investment in resource efficient technologies and techniques. Taking the economy as a whole, it encourages development of an economy that is more resource intensive than it needs to be.
- Regulatory frameworks for markets have often been created in ways that discourage long-term management of resources, but rather promote their wasteful early use. Market regulations that have worked well for old technologies may disadvantage the entry of new technologies. For instance, in some developed country energy markets, bidding systems for electricity supply have taken place one day in advance of electricity delivery. This has put operators of wind turbines at a disadvantage, because they can only reliably predict their electricity output three hours in advance (OECD, 2010).

The second group of factors holding back decoupling are biases against change. These can be seen as physical and technological biases, behavioural biases, organisational and institutional biases.

- Technological bias can arise because many technologies are used in conjunction with existing physical infrastructure, giving existing technologies a significant advantage over alternative technologies that would require different infrastructure (for example, the lack of electric vehicles' recharging points compared to the large number of refuelling stations for oil-powered vehicles).
- Organisational and institutional biases arise from the way in which standard practices, cultural norms, accepted wisdom and rules influence peoples' behaviours and the decisions they make. To illustrate this with one example from the finance sector: due to the internal incentives and controls found in many banks and financing organisations, positive financing decisions tend to be made in areas familiar to the professional expertise of staff. The lack of track record for the investment performance of new technologies makes them appear more risky, and places them at a severe disadvantage when investment decisions are made (Hudson et al., 2013). This represents a problem as meeting the world's future consumption demands through resource efficient technologies (or supply side technologies) has been estimated to require around US$3 trillion of investment a year globally (McKinsey Global Institute, 2011) for which the financing will need to be found.

Both these groups of barriers need to be tackled to make full progress to a successful, resource-productive society. Policy changes can overcome these barriers. In doing so, it would create conditions where investments in resource productivity became more attractive than alternative investments, and open up the universe of opportunities offered by decoupling for both developed and developing countries.

'Lock-in' to political and economic structures

Relatively few opportunities for beneficial policy change are currently taken up. Part of the reason for this seems to be that political systems have their own inertia, which often act as a brake on policy reform, or block it entirely. The close interaction in nearly all countries between political decision-making and economic interests can lead to what is called "systems lock-in" because the policy framework is difficult to change without change to economic interests and vice versa. Political processes can therefore act as barriers to decoupling, because:

- Frequently, policy is formed in response to the interests of leading economic groupings. Where these groupings are biased towards the current arrangements that have given them market power, they tend to engage strongly to preserve existing policy. This can be the case even as underlying conditions change (like resource availability).
- Segmented policy-making governmental structures – with different ministers or departments favouring different specific interest groups – lead to policy inconsistency, with the effect of some policies being cancelled out by the indirect effect of others. This inconsistency, lack of clear direction and past records of changes in policy creates unpredictability and uncertainty about future investment return dependent on lasting policy change.
- The institutions through which policies are made often reflect existing norms, and change is often resisted, within the institutions (for example government departments) or industrial organisations shaping policy (Ekins and Salmons, 2010, p. 132).
- Where economic interests are at stake, groups are likely to contest evidence showing the need for change. Where there is some degree of scientific uncertainty about the future (as is inevitable) this can be used to discredit unfavourable information. Even evidence gathered by governments seeking to promote innovation may be sceptically received and scrutinised for bias. This rejection of, or unwillingness to hear, information demonstrating the benefits of change is a key barrier to achieving policy change – as success in policy reform often involves political and economic actors perception of their own self-interest to alter (Ekins and Salmons, 2010, p. 133-4).
- Policy-making procedures are often lengthy, and can have additional lead-in times before policy is expected to take effect – leading to lags in the policy framework in reaction to new information.

The inertia created by these political and procedural factors is frequently the primary barrier to successful decoupling. Understanding these aspects of the problem can assist policy makers in making further progress.

6 Making progress with Resource Productivity

Action on policies

Policy change, in the face of this significant inertia, requires leadership. A central part of this leadership will be a clear vision of a successful future economy, well adjusted to trends in resource use and scarcity. Many different policy changes can create these favourable conditions - chapter 7 of this report gives some illustrations of past and current policies in both developed and developing countries. So, there are opportunities for leadership for many people. This includes individuals working within organisations and institutions across most parts of government, the economy and civil society (including consumers). Inside government, there are opportunities for decision-makers with influence on policies regarding industry, development, innovation, environment, employment, and taxation.

This wealth of options for areas for positive change arises because decoupling is often best stimulated by creating favourable conditions for investment in resource productive innovation, and letting market forces provide the best solutions. For these kind of changes, there is clearly no "one size fits all" prescription or instrument, but some common features can be identified for policies aiming at ambitious goals of decoupling including:

- For decoupling, policy needs long-term objectives and the creation of incentives for others that align with those long-term objectives.
- Using a mix of policies simultaneously can maximise the potential for innovation and avoid unwanted knock-on effects in other parts of the economy.
- The potential of resource productivity is increased when policymakers consider the full set of interactions that their policy affects. Reaching the right decisions on policy will probably involve consideration of the indirect effects of a change on resources at each of the life-cycle stages of production and consumption.
- Although this report uses technological potential as the entry point into a transition to resource productivity, policies are also needed that encourage changes in consumption patterns – and support the community to consider arranging their daily habits, their homes and their nutrition so as to consume fewer resources while achieving improvements in quality of life.

Unlocking change in policies

Replacement, reform or complementary addition to parts of the old policy framework, and the reduction of the biases against decoupling is possible, and has often been achieved. Success in creating the conditions for decoupling would need to unlock the observed resistance to policy reform. In this task, the chances of success appear higher where the policymaker looks at the institutional framework in which the political decision is made. In practice for changes to policy, this means being aware of the set of actors who are able to influence the decision, their interests, relative power and the norms and assumptions which are shaping the decision. Those seeking change:

> "... need to become adept at institutional analysis, identifying those elements supportive, or hostile to, the reform in question, and work to strengthen the more supportive elements and weaken the more hostile ones." (Ekins and Salmons, 2010, p. 132)

For example, there are frequently synergies between policies for decoupling and other policy goals. These can be used to win support for policy change. This was the case in Germany which introduced a relevant tax reform from 1999-2003 in five consecutive steps, eventually shifting some €18 billion annually from indirect labour charges to taxes on energy. One motive for the tax reform was to reduce incentives for environmental harm, but it also allowed the corresponding reduction of other taxes on labour that lead to an estimated gain of 250,000 jobs (Knigge and Görlach, 2005). The World Bank's summary of benefits from an environmental fiscal reform (World Bank, 2005) gives one illustration of the potential achievement of multiple goals. (Figure 0.6).

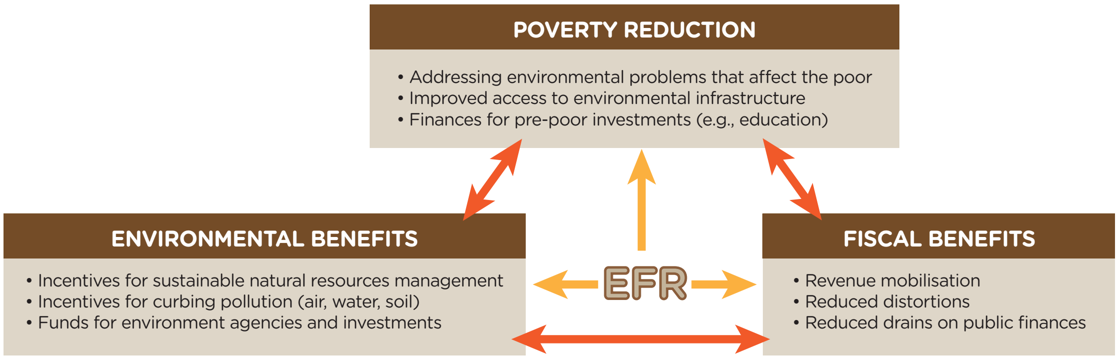


Figure 0.6 Assumed benefits from an Environmental Fiscal Reform (EFR).
Source: World Bank, 2005, l.c., p. 18

Based on past experience with policy changes[5], success in decoupling appears to be more likely where policymakers seeking change:

- Take account of the potential losers from policy change, and consider what will bring enough of them to favour change.
- Help those affected by change to focus their innovation towards a consensus future goal, by changing their expectations of the future. By creating shared visions and credible strategies, future investment patterns can be changed, often without great expense, as firms shift in advance to profit from new conditions.
- Create, or rely on, a source of sufficiently trusted independent advice – on the science or on the impacts of change. Objective, transparent scientific evidence is very useful: information sources seen to be self-interested will be much less effective
- Present concrete examples of policies or practices used in different countries, or in different realms of policy. Many of the reforms to increase decoupling will require new structures, behaviours or business models that may seem initially unfamiliar, and odd. Demonstrating that different arrangements work elsewhere can be convincing.
- Create an institutional structure for the specific policy decision that is participatory, sufficiently broad to contain enough people who can form a pro-reform coalition and set up in a way that allows potential supporters of change to voice their support. This facilitates information flows, and can help form a common vision for the future that reconciles previously opposing views.
- Use a simultaneous mix of policy instruments. This can help the actors in a value-chain of economic activity (for example, from raw material extraction to final product consumption and recycling) to change profitably together. This may be necessary to

5 This section draws on Chapter 5, Ekins.P and Salmons R, in OECD (2010) *Making Reform Happen*

overcome a "lock-in" between demand and supply, which can commonly happen when a seller offers what is being demanded, the purchaser buys what is being offered and there is little scope for either to innovate.

- Work to increase the cumulative effect of several smaller steps, as it is rarely the case that political or economic conditions exists that allow a policymaker to bring about a very large, radical change in resource productivity in one step.
- Be aware of options for reform and use political opportunities when they arise. Good economic times are often more favourable for introducing change, with less fear of negative consequences and greater availability of finance for innovative investments. Yet, crises can also facilitate reform, in different ways:
  - An unsustainable economic situation in New Zealand in the early 1980s, which included the state running excessive budget deficits (of 9 per cent of GDP), provided the rationale and impetus for a thorough reform of state support for the agricultural sector. The Effective Rate of Assistance to agriculture fell from 123% in 1983 to around zero in the 1990s.[6]
  - Crises may also provide opportunities for productivity reforming economic activity, when they lead to economic slack that can be stimulated to enter into new investments with low opportunity costs. By 2011, as a result of uncertainty on future returns on investments in difficult economic times, publically traded companies in Europe were holding excess cash of €750 billion (McKinsey Global Institute, 2012) which could be directed by adept policy change into new areas. Unemployed labour can be re-employed with appropriate training, in growth sectors of the future.

Changing the institutional framework to facilitate future policy reform

One aspect of successful reform is to take steps that create the conditions for further, future policy reform. Making changes to decision-making processes, either internal to an organisation or external, can indirectly facilitate future change.

In government, this could mean making a change to the decision-making structures (like the mandate of ministers or committees) that allows decisions promoting the long-term management of resources to be taken more easily. It could also mean implementing a policy that increases the future economic and political weight of innovators, or favourably changes the perception of potential opponents to change (for example by changing company reporting to include information on resources that helps companies take resource factors into account in their business decisions).

Changes to institutional decision-making structures have long been appreciated to have important beneficial outcomes, and this is particularly the case for overcoming the bias of decision-making towards the short term.

For example, the UK is seen as a strong, liberal economy. In part this is because, in 1998, authority over monetary policy was passed from the government to the central Bank of England. This transferred the power to set interest rates – a power of huge importance to the economy. The aim was to provide greater economic stability by distancing those decisions from short-term political influence.

6 The Effective Rate of Assistance is estimated by comparing the value added of an assisted sector with the same value added of an unassisted sector (at a world or reference price.) It includes direct and indirect assistance.

There have also been many examples where international agreements have acted as stimulation for domestic action. In part this is because concerted action between countries, which reduces fears of unfavourable distortions in international markets. But it is also because an international commitment can act as a persuasive tool against opponents of change, not least by indicating that change is viewed as internationally important.

7 Putting Decoupling into Practice – Linking resource price rises to resource productivity gains

Economic instruments to push technologies and markets towards higher resource productivity typically run into one characteristic difficulty: if price signals are strong, industries may just give up or emigrate, and consumers tend to contest the government imposing painful price signals. But if price signals are weak, there is a high likelihood of effects remaining insignificant.

A potential way out is a price signal that steadily increases at the pace of decoupling successes. For example, if the average efficiency of the car fleet rises by one per cent in one year, a one per cent price increase of petrol at the pump would seem fair and tolerable. However, the firm announcement of the continuation of this scheme will induce car manufacturers and traders as well as consumers to speed up efforts to reduce petrol consumption per kilometre or to avoid unnecessary trips. Hence a small signal can have a strong impact if continued over a long period of time.

A policy of this kind can combine several of the considerations to unlock inertia described above, and may come close to the type of combined policy which is needed.

One proposal for a policy could use taxation or subsidy reduction to move the price of a chosen resource upwards in line with documented increases of energy or resource productivity. In the sections below we look at different qualities of this proposal. In practical terms, one would not prescribe an exact price trajectory but a "corridor" within which prices can fluctuate a little. Interventions would only be made when such fluctuations are leaving the corridor. Interventions can also reduce prices or taxes if fluctuations leave the corridor upwards. The main purpose is predictability so that investors, manufacturers, and consumers know what is going to happen.

Broadening the economic discourse

By establishing a "ping-pong" between price rise and efficiency gains, costs (which are what influences competitiveness and livelihoods) would, on average, not increase. Under the "ping-pong" policy, on average, one would pay the same amount of money for the same quality of energy services as during the year before – paying a higher price for each unit of energy, but consuming fewer units of energy, as each unit of energy delivers more output thanks to the productivity gain. Of course, some industries and some families cannot increase their resource productivity as fast as the average gains take place. Politics will have to address this problem by a balanced mix of support measures or exemptions without destroying the incentive to innovate or adapt.

Creating a vision of the future and reducing uncertainty

The proposal would not entirely remove uncertainty about returns on investments in resource productivity, as variations in resource prices and uncertainty about future energy or resource productivity increases would remain. However, uncertainty would be reduced, in particular long-term uncertainty about the direction of prices. This would serve as a strong and predictable incentive to investors, states, individual companies or research laboratories to systematically invest in ever more resource productivity. It seems plausible that the mutual reinforcement between prices and efficiency increases will lead to a long term and ultimately dramatic increase of resource productivity.

An interesting partial analogy exists to the proposed "ping-pong" dynamics between resource productivity gains and resource prices. It is the increase over at least 150 years in labour productivity and gross wages per hour of work. As productivity increased, workers could successfully demand higher wages. And as wages went up, employers were driven to speed up further increases of labour productivity. Figure 0.7 shows the parallel dynamics between labour productivity and wages in the USA over 60 years.

Figure 0.7 The parallel increase of labour productivity and of gross hourly wages in the United States of America from 1947 – 2007.
Source: US Bureau of Labor

Obviously, the analogy is far from perfect. Wage negotiations typically occur without any state intervention, while the increase or moderation of energy prices does require such interventions. And it is not clear to what extent higher resource prices might lead to moving operations to other countries; in the case of rising wages this is less likely to occur because other countries tend to show the same dynamics of wages rising with productivity.

Creating sufficient winners in favour of change

The proposal has aspects that give it the potential to create sufficient winners to form a coalition that supports its introduction. It would provide a source of government revenue, creating choices for the government to reduce taxation on other people or firms in the economy, increase spending or to reduce fiscal deficits. Linking the size of the tax to productivity increases means that the total potential revenue does not decline, even as the number of units of resource consumed decreases.

Secondly, by increasing resource tax at the rate of average efficiency gain, the proposal increases the relative competitive advantage of firms which have above average resource productivity gains: these firms reduce costs relative to their competitors. This not only provides greater incentives for competition based on increased resource productivity, but also provides reasons for the more innovative and productive firms to take political positions in favour of change.

Taking account of potential losers in a policy mix

Introducing a slow, incremental, long-term increase of prices in the way suggested might allow industry and families to gradually adapt to higher price levels and yet would serve as a strong signal for all long-term investments and decisions. Often the signalling effect alone induces more resource-efficient behaviours, as firms and people adjust in anticipation.

The generation of revenues allows some recycling of those revenues to the losers from the policy change. Following a model from Sweden's tax on nitrous oxides, the revenues from the policy could be returned to clusters of firms (such as the non-ferrous metals industries) – not per energy unit consumed but per job added or affected by price rises in ways which do not reduce the incentive effect of the resource price increase.

Countries have also found ways to protect vulnerable low-income people (who have limited capacity to improve their resource use) from policy-induced price rises. In many countries of the world, a move from generally low and subsidized energy and water prices to realistic market prices (encouraging private capital to invest in more supplies) has been accompanied by policies that allow for a preferential low price level for poor families. South Africa has set a good example within its integrated water plan.

Creating new institutional arrangements

The design of a policy mechanism that raised prices of energy or resources in line with efficiency increases would require new, presumably legally binding, institutional arrangements. Those would be context specific to autonomous countries, but would be likely to involve binding pre-commitment of government to the mechanism, with independent and credible mechanisms for monitoring and calculating documented efficiency gains.

8 Conclusions

Trends in global consumption and exhaustion of natural resources and environmental systems imply that the decoupling of economic growth from resource use will become ever more important for stable, successful economies. These trends are already sufficiently significant to influence the factors that make economies competitive.

Many technologies and techniques that deliver significant resource productivity increases are already commercially available and used in developing and developed economies. They allow economic output to be achieved with fewer resource inputs, reducing waste and savings costs that can further expand the economy or reduce its exposure to resource risks.

A well-functioning economy might be expected to naturally adjust to changes in resource availability by directing investments into areas of economic activity that bring patterns of resource use in line with society's goals (for example, into innovation in resource productivity). In practice, we see that many economies do not naturally adjust in this way, but suffer from blocks to transition which "lock-in" existing patterns of resource use.

These obstacles to decoupling can be categorised as arising from:

- the legacy of past policy decisions (including those made before information on resource trends was available); and
- technological, behavioural, organisational and institutional biases against innovation in resource productivity.

Facilitating decoupling **will involve removing these obstacles**, to create the conditions in which investments in resource productivity become widespread. **Developing countries may have a relative advantage in decoupling**, because they are not so strongly locked-in by resource-intensive consumption and productions patterns, infrastructure and institutions.

There has been a wealth of experience across the world in policy to intentionally facilitate the decoupling of resource use, or impacts of resource use, from economic growth, with some notable successes. **They indicate that absolute decoupling of economic growth from resource use is possible**.

The chances of success appear higher where policymakers look at the institutional framework in which the political decision is made. This means **being aware of the set of actors** who are able to influence the decision, their interests, relative power and the norms and assumptions which are shaping the decision. **Leadership will be needed to break out of resistance to policy changes**. Leaders within the public and private sectors can draw on past experiences with policy for guidance on how to take forward decoupling.

There are forms of policy available to promote decoupling that combine several of these considerations. The report mentions two, which are illustrative of the type of combined policy which is needed. One proposal uses **taxation or subsidy reduction to move resource prices upwards in line with documented increases of energy or resource productivity**. Another looks to **shift revenue-raising onto resource prices through resource taxation at source or in relation to product imports, with recycling of revenues back to the economy**.

Introduction

The focus of this Decoupling 2 report is to illustrate the steps by which countries can realise their strategies of better lives for their people, now and into the future, through improving resource productivity.

The report shows that the potential exists for significant increases in resource productivity (as much as five- to 10-fold improvements), and that these could be achieved through strategic changes to current policy regimes. It shows that technologies and techniques, which bring very significant resource productivity gains, are already available, right across the range of resource-consuming activities. It also shows that much of the policy design "know-how" we need to achieve significant levels of resource productivity already exists in the form of legislation, incentive systems, and institutional reform, and aspects of it have been tried out and implemented, encouraging other nations to study and where appropriate replicate such success stories.

The report shows that many nations have already achieved decoupling of economic growth from numerous pollutants, like sulphur dioxide emissions, with some having achieved modest progress in separating economic growth from growth in greenhouse gas emissions and from growth in the use of some resources.

The report aims to assist the world's leaders in government and business understand the issues and opportunities around decoupling.

1 Changes in Resource Use and Scarcity

Sometimes, even experts hold inaccurate beliefs about future economic conditions. One of the recent, catastrophic, illustrations of this was the misvaluation of assets that triggered the 2007-08 global financial crisis.

Widely held beliefs about the future commodity prices and availability of resources like minerals, water and land may often be similarly out of line with the likely future reality. In our view, future trends of increasing resource use seem likely to continue to change some of the conditions that currently support economic success.

Resources are the foundation for industrial growth and prosperity for countries and firms, and changes in their price and availability brings the likelihood of change in relative competitive advantage. The changing conditions may create new winners and losers, with the advantage going to those who strategically prepare for the change.

Although changes in the cost of energy are frequently discussed in policy and economic circles, the cost and availability of other resources are more important for many industrial sectors. For example, in Germany, according to official statistics, the costs of material inputs for the processing industry is around 40 per cent of total production cost, while the direct energy cost (not counting energy cost used in the provision of material inputs) is around 2 per cent[7].

As we showed in our first decoupling report, countries such as China and Germany have already seen negative impacts from patterns of resource use and have responded. That report (UNEP, 2011b) highlights the significant trends in global resource use in the twentieth century and their implications.

7 German Federal Statistics Office.

It found that the annual extraction of ores and minerals in that period grew 27 times, construction materials by 34 times, fossil fuels by 12 and biomass by 3.6. In total, material extraction increased to about eight times its previous level.

The extraction of many metals has followed an essentially exponential growth path since the beginning of the twentieth century, as Figure 1.1 shows.

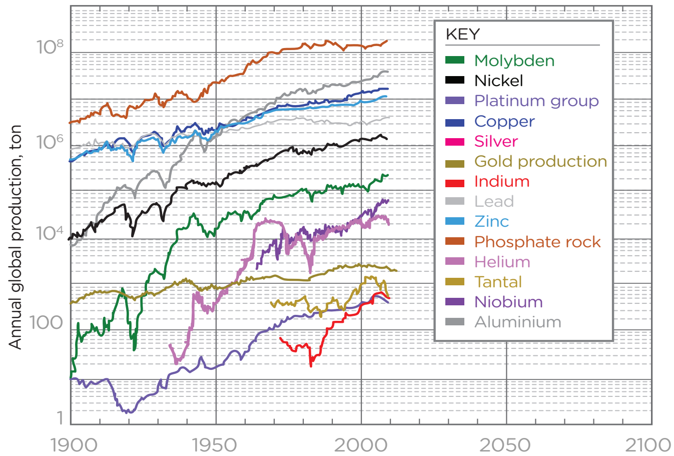


Figure 1.1 Extraction of many metals grew exponentially since the year 1900 (the ordinate on the picture being logarithmic)
From Sverdrup et al, 2013

Other reports have illustrated that the use of some of the natural resources essential to prosperity – including freshwater, land and soils, and fish – have similarly increased, in many cases beyond sustainable levels.

1.1 The drivers of changes in resource use

The two great drivers of changes of resource use are population and per capita income growth.

1.1.1 Population

During the twentieth century, world population increased from 1.65 billion to more than 6 billion. By the second half of 2011, our global population exceeded 7 billion. The rate of global population growth rate has fallen from its peak above 2 per cent per year in 1963 to around 1.3 per cent today. However, because the population is so much larger now than in 1963, the number of additional people on the planet each year is now significantly larger than in 1963 (UN, 2011).

1.1.2 Income

The impact of a growing population on resource use is related to the volume of resources each citizen consumes, which in fact, has been broadly correlated with the level of increasing incomes. Per capita incomes have, on average, been growing, although unequally, with very large disparities between countries and between individuals within countries.

With this income increase, average resource use per person has increased (though this average also hides great differences between individuals). One hundred years earlier, the average global per capita use was 4.6 tonnes; by 2005 the notional average inhabitant used somewhere between 8.5 and 9.2 tonnes of resources annually.

1.2 Future trends in these drivers of resource use

These two drivers of increasing resource use seem almost certain to continue:

- The UN projects global population to add more than 2.5 billion extra humans by 2050, with population continuing to grow further to 10.9 billion by the end of the century in its medium variant estimation (UN, 2013).
- Growth in per capita incomes is predicted to continue to increase, with differences between countries. All countries are aiming for

> the consumption levels of the most wealthy, with those in the wealthiest countries looking to consume more. Some have estimated that within the next 20 years, there will be 3 billion additional people worldwide enjoying "middle class" income levels, on top of the 1.8 billion today (Kharas, 2010).

The significance of the growth in population and incomes becomes apparent when considering that the rich countries that historically consume 80 per cent of global natural resources represent only around 18 per cent of the global population (UNEP, 2010a). As ever-increasing shares of the global population look to reach better standards of living, ever-greater resource use is expected.

1.2.1 Implications for resource demand

With populous lower-income nations fast increasing incomes from a low base, the resulting pace of increase in resource demand is amplified. The five emerging economic powers that make up the BRICS group (Brazil, Russia, India, China and South Africa), represent 42 per cent of world population. Their gross domestic products (GDPs) have been growing at rates of up to 10% per year, but the average per capita incomes are still significantly lower than that of the high-income countries. Currently, one person in India "consumes", on average, four tons of resources per year, while a Canadian consumes an average of 25 tons. As populations in emerging economies adopt similar technologies and lifestyles to those currently used in Organisation for Economic Cooperation and Development (OECD) countries, global metal needs will be three to nine times larger than all the metals currently used in the world (UNEP, 2013a).

Cautious predictions of the future suggest that due to economic growth, demand for one area of resources – food, feed and fibre – could increase by 70 per cent by 2050 (FAO, 2009). Looking at the dynamics in China and elsewhere, this appears to be a low estimate. The size of China's population and increase in economic growth gives indications of the global consequences of convergence of standards of living.

> *If China were to match the US for levels of car ownership and oil consumption per person it would need approximately 850 million more cars and more than doubling the world output of oil. If China alone were to consume seafood at the per capita rate of Japan, it alone would need 100 million tonnes, more than today's total catch.*
>
> **Sustainable Consumption – UNEP Global Status Report, 2002**

In our first report on decoupling, we set out different scenarios for future material resource use. In each of these – one of which included profound change in the resource productivity of the world economy – resource use increased by 2050. To reflect equity goals, each scenario assumes that by 2050, every citizen in the world will be able to assume the same amount of material resources as others[8].

In the scenario that represents many policymakers' current plans – in which levels of material resource use per head for all global citizens reached the levels of current use of the average European – annual resource extraction would need to triple by 2050, compared to extraction in 2000.

This probably exceeds all possible measures of available resources and assessments of the limits of the planets to absorb the impacts of their extraction and use. It does not seem possible for an economy based on the current high-consumption model of resources to continue into the future.

8 'Material resource use' in our first report includes: construction materials, ores and industrial minerals, fossil fuels and biomass and is aggregated by mass, expressed in tons.

1.3 The Consequences of increasing resource use

The economic consequences of increasing resource use are already apparent in three areas: increases in resource prices, increased price volatility, increased scarcity and disruption of environmental systems.

1.3.1 Increasing resource prices

As the demands resulting from growth of the global economy reach supply constraints for resources, two effects are likely: an increase in the price of those resources, and increased volatility in those resource prices, as speculation and a scramble to acquire resources impact on markets.

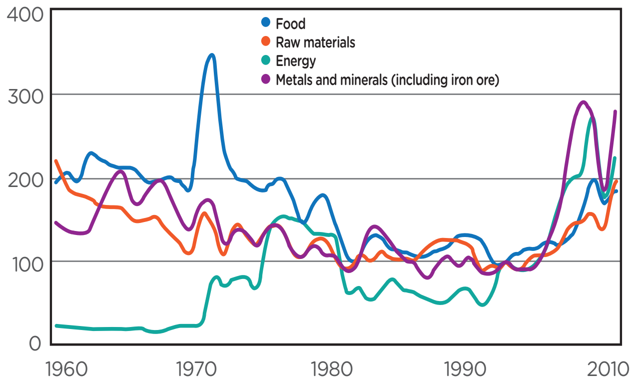


Figure 1.2 Commodity price indices.
(Source: World Bank Commodity Price Data, 2011. Trend lines added, courtesy Mark Swilling (World Bank, 2011a)

From the evidence, it seems possible that for many resources, the shift in balance between demand and supply has already been reached, and these negative effects can be seen. Even though the continuing global downturn has now reduced demand pressures for some resources, a review of resource prices to 2013 provides a pointer that a long era of declining real resource prices has come to an end, and that prices may now have already begun a rising trend.

For example, since 2000, metal prices have risen 176 per cent, rubber prices by 350 per cent, energy prices by an average of 260 per cent, and food prices by more than 100 per cent (McKinsey Global Institute, 2011). Some predict that global food prices will increase by 120-180 per cent by 2030, accelerating past trends in price rises (Willenbockel, 2011).

These price rises affect the economy. Evidence from Europe might be taken as significant for the world as a whole: An official EU "Eurobarometer" survey in the past five years found that some 75 per cent of European businesses reported that they have experienced an increase in material costs (Eurobarometer, 2011). Figure 1.3 shows the results of a forward-looking Eurobarometer survey indicating that European firms expect price rises to continue (EIO, 2010).

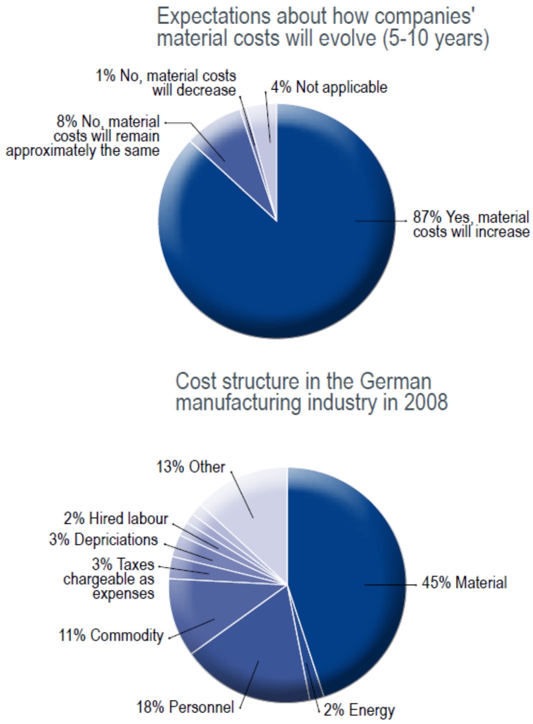


Figure 1.3 Expectations about how companies' material costs would evolve in the 5-10 years following 2011[9]

Rising commodity prices not only result in higher costs to business, but also risk short-term inflationary effects that could harm economic growth. Rising commodity prices also make it harder to reduce global poverty.

9 Data from DEMEA, presented in Berlin July 2010, with image and text from (EIO, 2010).

1.3.2 Increased price volatility and price shocks

In addition to rising price trends, commodity price volatility in the last decade is now higher than at any other time in the last 100 years (Figure 1.4). This is partly due to stronger linkages between energy, water, resources and food production. These strong linkages have resulted in shortages and price changes in one commodity or resource rapidly impacting on other commodity prices.

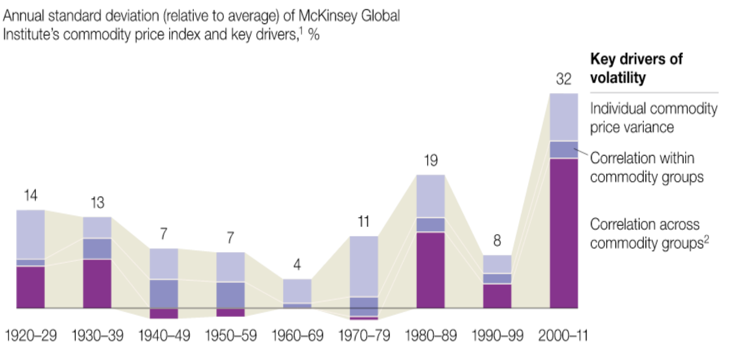


Figure 1.4 **Scale and Drivers of Commodity Volatility by Decade from 1920 to 2011**
(Source: Dobbs et al., 2012)

For some of the key elements used in production, Figure 1.5 below illustrates both the volatility and the annual price increase for certain key materials used in the economy, with mostly dramatic figures both regarding price hikes and volatilities.

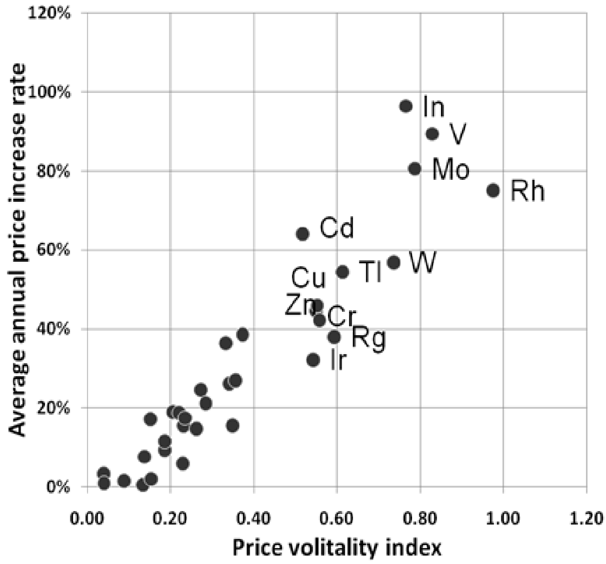


Figure 1.5 **Price Volatility and Prices Increases of various key elements.**
Source: "Natural Resources Consumption and Sustainable Industrial Development", S. Suh, Sustainable Industrial Development, Fall Issue 2008

Recent sustained spikes in food prices caused by supply shortfalls relative to global demand are believed by some to have fuelled civil dissatisfaction. In 2007 and 2008, higher food prices were linked to riots in numerous countries, including Pakistan, Burkina Faso, Cameroon, Senegal, Mauritania, Mexico and India. Some believe that rapidly rising global prices for food in 2010 led to civil dissatisfaction which fuelled the "Arab Spring" (e.g. Center for Climate and Security, 2013). (Figure 1.6)

The linkage between energy demand and food prices was one factor in rising corn prices in 2007, with an increase in use of corn for biofuel increasing global corn demand. Overall, the United Nations Food and Agriculture Organization (FAO), found that the volatility of food prices increased to 22.4 per cent in 2000-12 compared to 7.7 per cent in 1990-99 (measured by the standard deviation around the average price)[10].

10 However, before 1990, food prices were also volatile, having a higher standard deviation than in the years 2000-12.

1.3.3 Increasing resources scarcities

In addition to price trends and volatility, for some resources there are particular concerns about scarcity. These include land, freshwater and fish, which play key roles in the supply of food. Other resources are needed for the diffusion of new technologies. This scarcity can come from two causes: declining stocks for which cost-effective substitutes are not readily available; and disruptions to the flow of resources, for example, caused by political factors.

Metals and minerals

- Some metals risk becoming very expensive, as metal concentrations in accessible ores keep declining. More pessimistic forecasts say that some rare earth metals may even risk running out within two decades unless recycling rates are rapidly increased (USGS, 2008; quoted in Diederen, A., 2009, see figure 5 based on table 1). High-tech industries are increasingly worried about the price hikes of rare

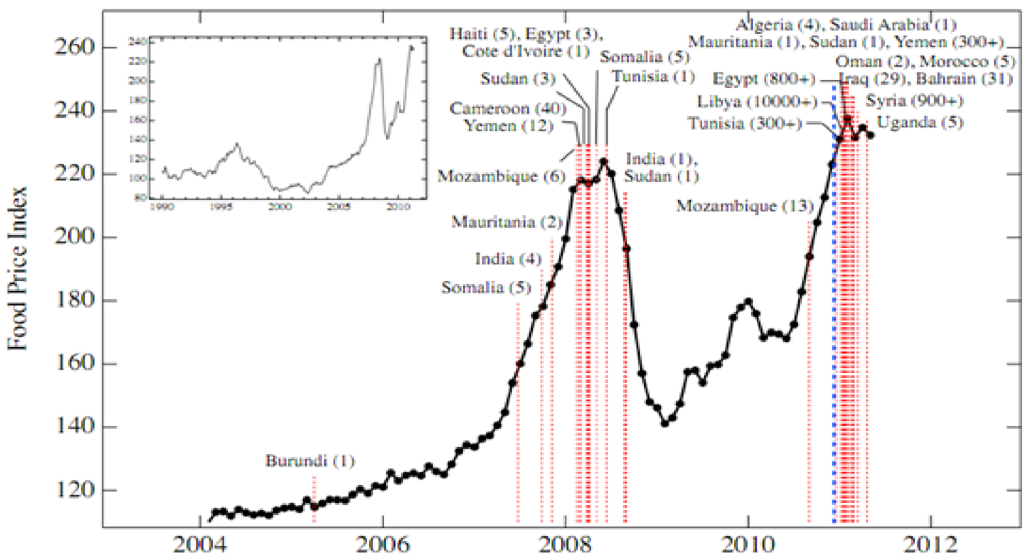


Figure 1.6 **FAO Food Price Index from January 2004 to May 2011 and food riot events. The figure in parentheses is the reported number of deaths from each riot.**
Source: Lagi et al., 2011

metals. Better recycling could help reduce such concerns – yet today, less than 1 per cent of specialty metals are recycled (UNEP, 2011a).

- Shortage of some of the world's key metals will be felt within 50 years, potentially affecting many industries (USGS, 2008).
- World phosphorus production appears likely to peak in a relatively short timescale with relatively limited alternatives for use of phosphate as fertilisers for agriculture. Known deposits of phosphate rock are large enough to last some hundreds of years. Yet declining qualities may make these uneconomic. Some studies suggest a peak in as little as 25 years' time, others significantly longer (Gilbert, 2009; Cordell et al., 2009; IFA, 2006; Jasinski, 2007; Laherrere, 2000; Lewis, 2008, Stewart et al., 2005).

Freshwater

- Extraction of freshwater (Brown, 2008) in many parts of the world exceeds sustainable yields, with groundwater extracted from wells the main source of drinking water for more than 3 billion people (Shah et al., 2007). Water tables are already falling rapidly in countries that contain more than half the world's people, including the biggest three grain producers: China, India, and the United States (Shiklomanov, 1998, cited in Gleick, 2001, p. 52).
- Global demand for water is expected to rise by 40 per cent. In 20 years' time, available supplies may probably satisfy only 60 per cent of world demand (2030 Water Resources Group, 2009, p.7).
- In part, this is also due to predicted supply changes, for example, the increasing rate of disappearance of the Himalayan and Andean glaciers that regulate river flow and supply clean water for over more than 1 billion people. Although dams contained four times more water in 2008 than in 1960, freshwater scarcity and water stress could grow from affecting 1 billion to more than 3 billion people by 2030 (OECD, 2008a).

Land

- Global cropland is expanding at the expense of savannahs, grasslands and forests, and expected rise of demand for food, fibre and fuel will only increase the pressure on the land resource base. If current conditions continue, by 2050, there could be between 320 and 849 million hectares of natural land converted to cropland. At the same time, land degradation continues to expand, affecting today an estimated 23 per cent of global soils and in its severe form leads to the abandonment and shift of 2 to 5 million hectares of cropland.
- One response has been increasing acquisition of land in foreign countries by external investors. Globally, in 2012, foreign investors bought land equivalent to the area of France for production for export. These sales of land also imply the sale of a country's freshwater, soil fertility and ecosystem services that are linked to that land.

Fisheries

- The UN Food and Agriculture Organization has found that globally, 25 per cent of fish stocks were overexploited or depleted, and around half fully exploited in 2005 (FAO, 2005b) with severe depletion of the larger fish. A 2003 study published in the journal Nature concluded that 90 per cent of the large fish in the oceans had disappeared over the previous 50 years (Myers and Worm, 2003; Crosby, 2003). Two examples are Atlantic stocks of the bluefin tuna that have been cut by 94 per cent, and the harvest of the Caspian

Sea sturgeon – source of the world's most prized caviar – which fell from 27,700 tons in 1977 to 461 tons in 2000. A comprehensive analysis of global commercial stocks in 2012 estimated that more than half the stocks worldwide were shrinking year-on-year, with many stocks already below two thirds of the level at which they would provide the maximum sustainable yearly yield (Costello et al., 2012).

1.3.4 Increased disruption of environmental systems

The extraction and use of material resources is also closely linked to negative impacts on aspects of the environment. For example, there are strong links between the use of material resources in the economy and the level of fossil fuels burnt. (Our 2010 Report on Environmental Impacts describes the relationship between the use of different resources and greenhouse gas emissions, UNEP, 2010a).

Parts of the environment can easily be seen as resources in their own right – because they provide benefits to people and the economy. Examples include soil fertility, stocks of biodiversity (rather like fish), clean air and a stable climate. Although these environmental resources often do not have prices, or owners, their degradation has significant impact on factors affecting prosperity and alleviation of poverty. The role and value of environmental resources in economic production, stability and wellbeing is now well established. (See Box 1.1)

Box 1.1 The value of clean air, biodiversity and a stable climate

1. Clean air

Clean air is a resource that is essential for human health, and for crops and other natural systems. Its pollution has significant economic costs – both direct and indirect (e.g. from lost working hours).

A range of studies[11] from across the world (OECD, 2008a) have reported economic losses of between 2-4 per cent of GDP in cities and countries because of air pollution, with most of the economic costs coming from health costs and premature deaths, and from damage to the built and natural environment from acid rain and tropospheric ozone. Estimates of the costs of air pollution to economies include 1.16-3.8 per cent for China, two per cent for the European Union, four per cent for the Ukraine, 2-5 per cent for Russia, 0.7-2.8 per cent for the USA.

2. Biodiversity

A global 2010 study on the economic value of biodiversity (Sukhdev et al., 2008) concluded that cumulative economic costs from the loss of ecosystems services and biodiversity from overharvesting of biota and biomass under a "business as usual" scenario would be equivalent to around 7 per cent of GDP per annum in costs by 2050 – equivalent to around US$2-4.5 trillion each year.

3. Climate

A range of studies have highlighted that the costs of postponing action on climate are significant, even in the short term. For instance, the 2006 Stern review quantified the economic costs of irreversible climate change between 5-20 per cent of global GDP per annum by 2050 (Stern, 2006).

As the use of material resources has increased there have been major negative impacts on these resources (UNEP, 2010a). The United Nations' 2005 Millennium Ecosystem Assessment documented several accelerating, abrupt, and potentially irreversible changes already occurring to the world's ecosystems. These include algal blooms from overuse of nitrogen fertilizers, bleaching of coral reefs, desertification, increased vulnerability to natural disasters, and crop failures (Millennium Ecosystem Assessment, 2005). At that time, approximately 60 per cent of the ecosystem services that support life on

11 UNEP refs at Source: Adapted from World Bank (2008), Markandya and Tamborra (2005), Strukova et al. (2006), Bobylev et al (2002), Mendelsohn and Muller (2007)

Earth, such as high-quality freshwater, soil fertility and biodiversity, were being seriously degraded or used unsustainably.

These negative impacts, or exhaustion, to parts of the environment often have direct effects on people and the economy – for example through damage to health, water shortages, loss of fish stocks or increased storm damage.

It also has very serious indirect implications, with negative impacts on local and global environmental systems – like the climate system – that are essential for providing stable conditions for our life on Earth. As a means to illustrate this, Johan Rockstrom from the Stockholm Resilience Centre and others produced a representation of the extent to which human impacts on the global environment have gone beyond planetary boundaries (Figure 1.7, from 2008), after which risks of sudden or irreversible environmental changes increase (Rockström et al., 2009):

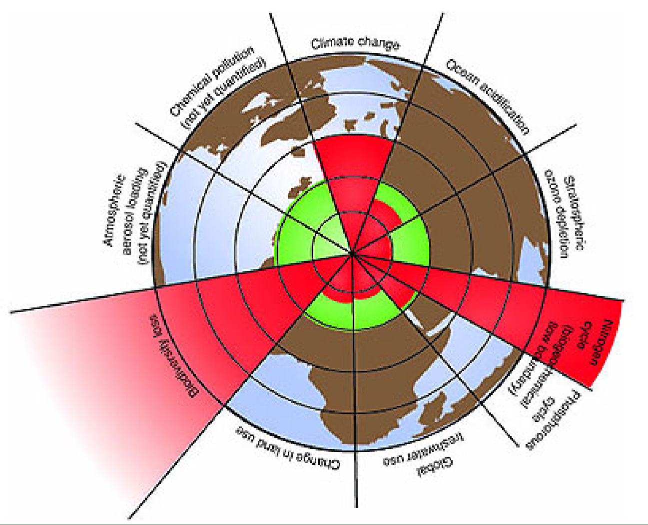


Figure 1.7 A representation of the extent to which human activity is operating within safe levels of environmental impacts, highlighting that safe thresholds for three out of nine planetary boundaries have already been crossed.
Source: Rockström et al., 2009

Empirical evidence that the global economy has already overshot the thresholds allowing continued provision of resources from many areas of the world's ecosystems is also covered in detail in numerous publications, including the United Nations Environment Programme (UNEP) Global Environmental Outlooks[12], International Panel on Climate Change (IPCC) assessments[13], OECD DAC Development Reports[14], Human Development Report[15], the State of the World reports.[16] Some of the science suggests that humanity has two to three decades to change economic patterns to ensure irreversible decline of ecosystem resilience is avoided.

Climate

The best known and most deeply researched of these systems is the climate system[17]. Since 1950, the concentration of CO_2 emissions has increased from around 320 parts per million (ppm) (Petit et al., 1999) to an average of just under 400ppm in 2013[18] along with other greenhouse gases that increase this total by some 25%.

Emissions of greenhouse gases are on track to increase much further according to the International Energy Agency. The International Energy Agency (IEA) forecasts that, under business as usual economic growth, world energy demand will increase by more than 60 per cent between 2004 and 2030 (IEA, 2005), with future growth of more than one third from 2012 to 2035 (IEA, 2012). The IPCC estimates that capping greenhouse gas output at 840 billion tons gives a 50 per cent chance of meeting the UN target of restraining warming below 2°C (3.6°F) (IPCC, 2013).

12 http://www.unep.org/geo/

13 https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

14 http://www.oecd-ilibrary.org/development/development-co-operation-report_20747721

15 http://hdr.undp.org/en

16 http://www.worldwatch.org/bookstore/state-of-the-world

17 See: IPCC Assessments at https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

18 http://www.esrl.noaa.gov/gmd/ccgg/trends/

1.4 Why these problems appear unlikely to be solved by a "leave it to the market approach."

There have been predictions in the past that resource constraints would be impossible to overcome. Thomas Malthus's concern in 1798 that the supply of land was insufficient to meet the food needs of a quickly growing human population is perhaps the most famous. In many (though not all – see section 4.8) of these cases, progress or the functioning of markets overcame the feared constraint. In general, the past expansion of demand for resource consumption in the twentieth century did not lead to global resource scarcity, with very important exceptions.

The resource constraints now facing decision-makers are of a different nature – one that appears impossible to be solved by market forces under current economic trends:

> "The next 20 years appear to be quite different from the resource-related shocks that have periodically erupted in history" (McKinsey Global Institute, 2011, p. 2)

There are several distinguishing features that make an adequate supply-side response from the market unlikely:

1.4.1 The scale and rate of change often outpaces the supply side response

The pace of increase of demand has accelerated. The increase in global GDP represents a reasonable proxy for the changing pace of resource demands. GDP increased six-fold from 1950 to 1998 with an average growth of 3.9 per cent a year. This compares to a rate of increase of 1.6 from 1820 to 1950, and 0.3 per cent from 1500 to 1820 (Maddison, 2001) (Figure 1.8). At the same time, the scale of demand is very much greater, meaning that each percentage increase in demand requires a far greater increase in resources.

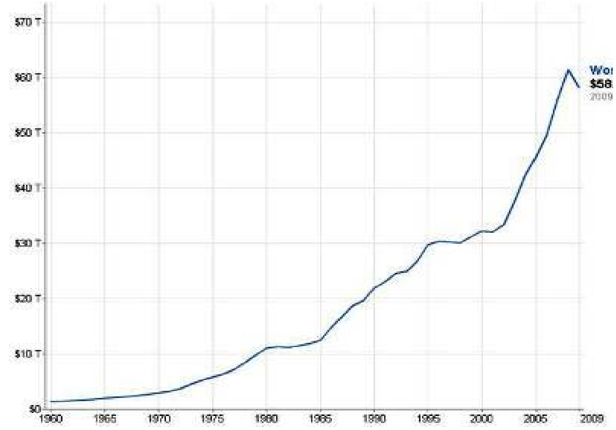
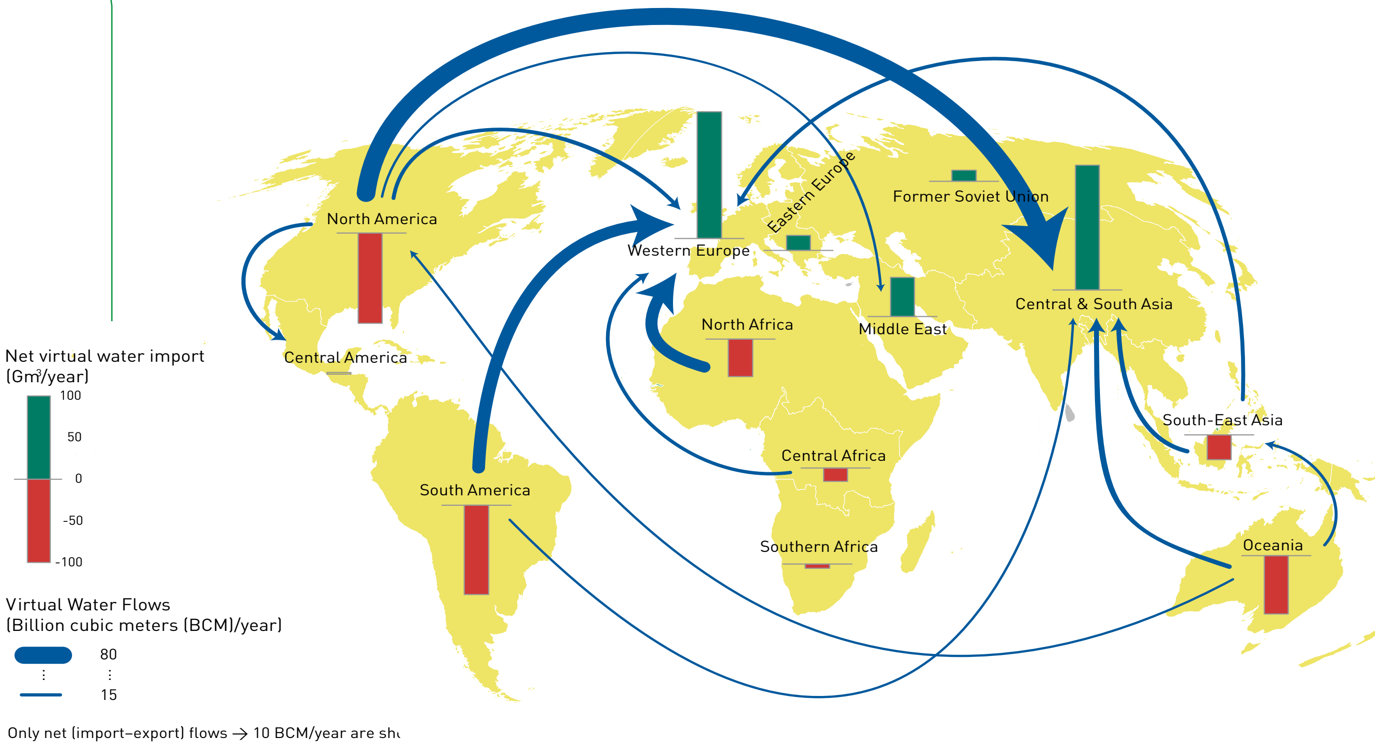


Figure 1.8 World GDP 1960-2009 at current market prices (left scale in units of $1.000 million)
Source: World Bank, 2009

A major change of the situation occurred since roughly the year 2000, as China and other major countries entered the world commodity markets as big buyers, turning markets into sellers' markets. Demand for several resources has reached the limits of short-term supply, which results in even small extra demand creating significant price volatility. Further supply side change currently appears unlikely to keep pace with predicted increases in demand. The investments in infrastructure needed for supply increase are often not sufficient.

1.4.2 Historically, growth in developed countries has used resources from other countries

Although the situation differs greatly between countries, for many wealthier countries a significant proportion of the resource use related to their economies takes place in their trading partners. For instance, when a north African country exports food to the EU, the water to grow those crops is used in north Africa for the benefit of a consumer in the EU. The same can be true of material extraction or burning of fossil fuels to provide products



for export: the product may be consumed in Japan, but the material is mined, or CO_2 released within the exporting country (for example China).

Chapter 4 of our first decoupling report describes these flows, based on a growing academic literature examining the issue. Recent trends show that developed countries appear to be increasing this form of indirect use of resources.[19] Sixteen per cent of total global water consumption is now used for exported goods and commodities.[20] Figure 1.9 illustrates the balance of imports and exports of water used in one region for consumption in another – "virtual water".

19 The indirect use of resources and resources embedded in trade are being the object of a new assessment study by the UNEP-hosted International Resource Panel, to be published in 2014.

20 15% of the water use in the agricultural sector, and 34% of the water in global industry is used in making goods for export (Chapagain and Hoekstra, 2004).

Figure 1.9: Virtual water trade balances 1997-2001.
Source: Adapted from Chapagain and Hoekstra, 2008

This economic model only works when there are sufficient countries who are not using their resources – like their freshwater supplies – to their full extent, and are willing to use them to supply others with consumption goods. As demands for consumption rise across the world, only those countries with excess supply of resources, beyond their own future national needs, may be willing to use their resources in this way. There will be fewer of these countries.

1.4.3 Declining ore grades and impacts on other resources

Depending on the metal concerned, past mining of the most attractive ores has led to declining average ore grades, as Figure 1.10 shows for several key metals. For many metals, this means that about three times as much material needs to be moved for the same quantity of metal extraction as a century ago. This brings associated increases in fossil fuel energy use, land disruption, chemical release and implications for groundwater and freshwater bodies.

Technological innovation can offset at least some of the decline in ore grades, and find and process new sources of natural resources that were previously economically inaccessible. Yet, this very rarely avoids the need for more energy, water and resource inputs to extract the same quantity of a natural resource. The tendency to process lower grades of ore to meet increasing demand is leading to a higher energy requirement per kilogram of metals, and consequentially to increased production costs (UNEP, 2013b).

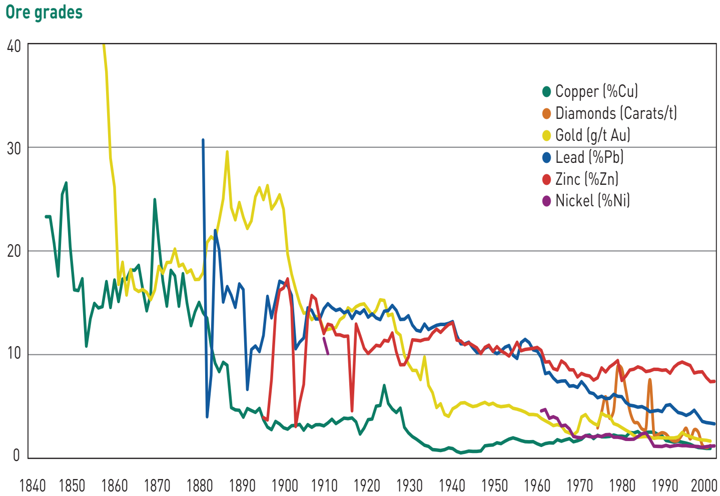


Figure 1.10: Ore grades of mines in Australia 1840-2005.
Source: Mudd, 2009

Similarly, oil production costs are rising: the cost of bringing a new oil well online doubled between 2000 and 2010. With oil production having peaked in more than 50 countries, production is now shifting to either secondary sources such as tar sands – or more extreme geographic deep-sea locations, where extraction is more costly.

1.4.4 Linkages between energy production, water, resources and food

Numerous reports (World Economic Forum, 2011; Hoff, 2011) provide evidence of the increasingly linked use of different resources in the supply of others – a trend that can exacerbate scarcity (Figure 1.11). For instance, according to the IEA, current energy policies will result in the volume of water consumed for energy production to double by 2035 mainly due to investment in biofuels, new coal plants and unconventional natural gas (Lavelle and Grose, 2013).

Currently, the water intensity of energy production, the energy intensity of water production and the energy and water intensity of resource extraction (i.e. mining) are increasing. The cost of pollution per kilogram of metals is rising as these concentrations shrink (Bardi, 2014). The average resource intensity of intensive agriculture is also rising, while extreme weather events have negatively impacted on agricultural productivity.

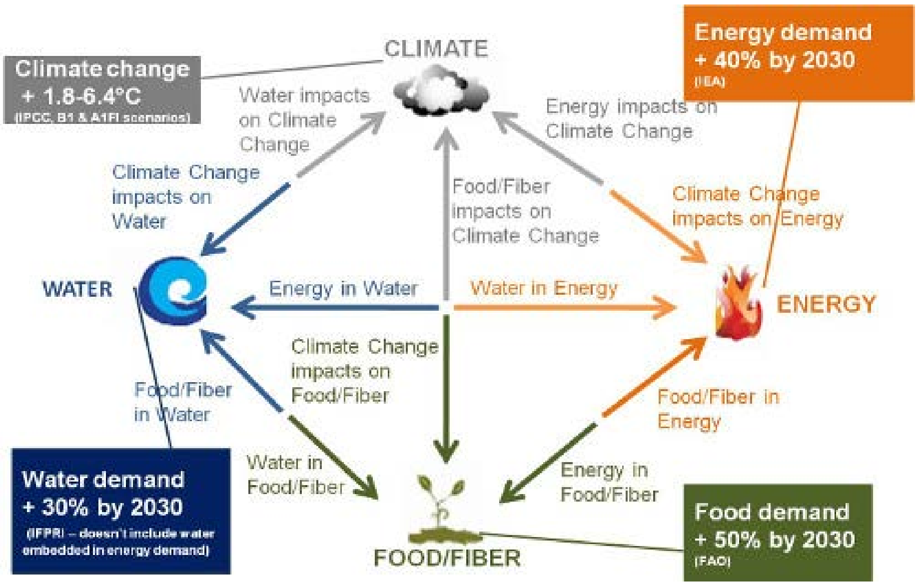


Figure 1.11 **The Climate Change, Energy, Water and Food Security Nexus**
Source: WBCSD, 2012[21]

1.4.5 Tipping points, sudden or irreversible declines

The environmental resources present an additional risk – that they may suddenly collapse in a non-linear way if put under too much stress[22]. This is because they form part of ecosystems or climate systems that consist of complex interactions and feedbacks that are difficult to understand and impossible to predict. Such effects include:

- Possible fishery collapses, illustrated by the collapse of the Newfoundland cod fishery off the coast of Canada. Another collapse was the Locos abalone in Chile, which is now almost extinct.
- Increased desertification, as land degradation worsens due to climate change and loss of biomass leading to potential collapse of grasslands, moisture retention and soil structure.
- Possible irreversible climate change (IPCC, 2013, IEA, 2011).

Damage to one part of a natural system is unlikely to just cause a linear effect, but rather is likely to lead to amplification effects across the system. At low levels of harm, the system may accommodate change (due to system resilience and support capacity), but at higher levels additional depletion may take the system over a tipping point, into collapse, that is either irreversible or recovers over very long periods of time (Diamond, 2005).

For example, irreversible climate change may occur due to the release of methane from melting permafrost (Christensen et al., 2004) and the weakening of carbon sinks (Le Quéré et al., 2007), as the Earth warms (Cox et al., 2000; Canadell et al., 2007).

1.4.6 Many of the essential resources are not accurately priced by the market

Market forces work to balance supply and demand through the price mechanism – so that higher demand typically leads

21 http://www.wbcsd.org/work-program/sector-projects/water/waterenergyfood.aspx

22 for further explanation see: Smith et al., 2010a.

to higher prices that encourage greater supply, or substitution to alternative inputs.

For many of the resources facing scarcity, the prices do not currently reflect scarcity, and so the market has little incentive to find solutions. Frequently resource use is subsidised, with the subsidy encouraging use above levels that the market would determine. This is often true for freshwater, fish, fossil fuels, emission of greenhouse gasses, soil fertility and natural resources like forests and ecosystems. This mispricing is a result of factors explored more deeply in Chapter 4. Geopolitical risks to global commodity markets, such as those when a nation restricts exports of rare earth metals in response to perceived scarcity, are unpredictable, and so also not accurately reflected in prices.

In these cases, existing market forces alone cannot provide the solutions.

2 Responding to Change

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2.1 Strategic implications of trends in resource use

The global trends in resource demand and availability appear sufficiently strong that almost all economies would benefit from adapting their form of development to changed future conditions. This applies at least as much to lower-income countries as to OECD economies. One indication of the scale of the change is an estimate that US$3 trillion per year would be needed in new investment in resource supply to meet demand (McKinsey Global Institute, 2011) if no other action was taken.

There are two wider economic implications of the changes: a changing basis of competitive advantage and risks of disruption to existing economic growth patterns.

2.1.1 A changing basis of competitive economic advantage

For centuries, nations have been concerned with securing and exploiting resources as the key to greater wealth. The trends we now observe suggest that economies should look more closely at the changing risks and challenges related to resources. They have significance for economic growth. They appear very likely to alter the relative importance of labour productivity and resource productivity as sources of growth and future economic wellbeing.

While many opportunities remain in labour productivity gains, it appears that some of the greatest opportunities for growth are to be found in increasing an economy's resource productivity (Weizsäcker et al., 1997; Hawken et al., 1999).

Leading research institutes and thinktanks such as the Wuppertal Institute, Rocky Mountain Institute, and The Natural Edge Project have highlighted for some time that as resource productivity has not been a focus in the past, many opportunities in resource productivity with higher economic returns can be taken with little capital investment, often with short payback periods. This can increase growth rates. Chapter 3 describes some examples with this potential.

McKinsey Global Institute estimates that resource productivity has the potential to earn US$2.9 trillion each year by 2030 from resource savings. This estimate rises to US$3.7 trillion per year if carbon is priced and subsidies and taxation aligned with policy goals. Both estimates are based on currently available technologies or techniques and neither cover the full range of potential areas of saving, for example, the only metal considered is steel. Even ignoring increases in prices, greater efficiency offers potential for growth by reducing costs.

There is widespread belief that the economies that move first, or fastest, will have strategic competitive advantage under the changed economic conditions. Both developed and developing countries that successfully identify and seize the opportunities for resource productivity are likely to be able to outperform global competitors and bring greater security and wealth to their populations.

In fact, there is a relationship between competitiveness and material productivity. Bleischwitz et al. (Bleischwitz et al, 2009, 2010; Steger and Bleischwitz, 2011) find a positive relationship between the material productivity of 26 economies (measured by GDP in purchasing power parity US$ per kilogram of Domestic Material Consumption, or DMC) and their Global Competitiveness Index scores based on data by the World Economic Forum.

Compared to growth through labour productivity, resource efficiency opportunities promote employment: an increase in output is likely to be accompanied by increased labour demand. This makes it particularly attractive at times of high unemployment. For instance, energy efficiency policies in California are estimated to have created nearly 1.5 million jobs from 1977 to 2007.[23] Estimates of the impact of improved resource efficiency in Germany in the years before 2004 suggest that economic benefits included the creation or saving of more than 1 million jobs (Fischer et al., 2004).

2.1.2 Potential advantages for developing countries

These trends offer newly or fast-developing countries potential advantage over OECD countries. Representatives from developing countries often claim that in their phase of development, absolute decoupling is unrealistic for resource flows and greenhouse gas emissions.

However, there are commentators who believe that developing countries have a relative advantage in decoupling, compared to more established economies, as a result of their state of development. This advantage is a result of weaker biases against resource-productive investments than are found in older economies, and described in Chapter 4. Swilling and Annecke list the following[24]:

- Firms that have dominant positions in the market will tend to resist change and protect their technologies. Emerging firms in developing economies may be less rigid because they do not have dominant positions to defend.
- Regulatory regimes in developing countries are often less restrictive or

23 There are suggestions that 50 jobs were created in the energy efficiency sector for each 1 lost in fossil fuels (Roland-Holst, 2008).

24 Adapted from Swilling and Annecke (2012, p. 101) following Montalvo (2008).

more permissive, which can reduce the protection from regulatory and financial institutions.

- The lack of embedded consumer cultures that favour the dominance of current technologies in more mature economies can make developing countries more flexible to change.
- Firms and countries can "leapfrog" stages in the development of technological capacity. Developing countries without the "baggage" of resource intensive production and consumption systems and infrastructures have an inherent potential for leapfrogging, if the associated challenges can be overcome.
- Markets in developing countries are less saturated than markets in developed countries, implying greater opportunity for products and services that meet needs in more resource-productive ways.
- Consumption habits in developing countries may not yet be so tied to mass consumption with rapid obsolescence as those in developed countries, providing greater scope for forms of consumption based on long-term, or shared, ownership of goods.

In addition, for countries that substantially rely on a particular resource as a key input into their economy, greater efficiency can bring greater benefits than in other countries – particularly in reducing the risk of drops in income from scarcity, and potential political unrest.

2.1.3 Risks of disruption to existing economic growth patterns

The other implication of trends in resources is the risk of disruption to existing economic growth patterns:

- International trade has increased dramatically over the past few decades – by an average of 7.2 per cent a year in monetary terms. This represents an ever-deeper set of interactions between the economies of countries. It brings with it the risk that scarcity or demand increases in one region affect the economic health of a distant country. When a tsunami damaged the Fukushima nuclear reactor in Japan in March 2011, one effect was that a Hitachi factory producing 60% of the world's airflow sensors was shut down, leading to disruption in vehicle production on the other side of the world: General Motors shutting a plant in Louisiana for a week, and Peugeot-Citroën slowing production at its European factories (Congressional Research Service, 2011).
- Security of supply issues and market volatility in important resources increases macroeconomic instability, for example, by reducing inflationary threats. Global food price hikes, caused, for example by regional water shortages can undermine government reforms.
- Countries that are reliant on resource imports, or on particular domestic resources, are at higher risk of disruption. For example, many lower-income nations and communities depend on fish and other seafood as a key part of their diet, providing 22 per cent and 19 per cent of animal proteins consumed in Asia and Africa respectively (Congressional Research Service, 2011). The fisheries sector employs about 40 million fishers and fish farmers, most living in developing countries (FAO; 1999), who depend on fisheries for their livelihood (FAO, 2005a).

These risks point to the need for economic strategies that reduce dependency on foreign imports, reduce risks from exposure to global markets and return greater sovereignty and choice over economic decisions to nations without creating any barriers to efficient trade. The current model of development is not sustainable in the long term. A real change of course will be needed, significantly changing technologies and consumption habits.

2.2 Decoupling as a response

2.2.1 What is decoupling?

When a country improves its resource productivity, its economy grows at a faster rate than its consumption of resources. Figure 2.1 shows this for OECD countries between 1980-2000.

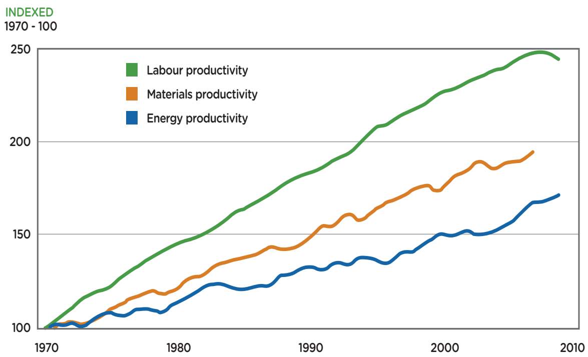

Figure 2.1 Gross Domestic Production and Domestic Material Consumption in OECD countries 1980-2000

Decision-makers in government, business and civil society have the choice to respond to the opportunities and threats from changing resource pressures through improving the resource productivity of economic activity. Improving resource productivity has not always been considered as an option for economic policy. Yet, historical evidence suggests that the resource productivity of an economy is often largely determined by policy choice (UNEP, 2011b).

Policy choices can shape the competitiveness and growth of a country, and the extent to which a country is exposed to the risks and potential disruptions from changes in resource availability. They influence the developmental path of an economy. The nature of the choice is similar to the decisions regularly made on boosting labour productivity or favouring the development of particular industries (for example biotechnology or metal production) in a country. It is, in practice, also the kind of decision over what infrastructure to provide for citizens and cities: for example, how water is supplied.

When an economy grows at a faster rate than its consumption of resources, it is called "decoupling". A successful economy (in terms of resource productivity) has decoupled its growth from its resource use. It means that the nation can produce greater economic value out of fewer resource inputs (both material and energy) per unit of value25. It stands as one indicator of how wasteful the economic activity is.

We propose to distinguish between three types of decoupling:

1. Decoupling through maturation. This type of decoupling is a "natural" process of overcoming clumsy and inefficient techniques, of building-up of infrastructures, and of actively reducing environmental pollution. This is related to the maturation process as countries shift from an extraction and production-based economy towards a service economy. For example this can happen after a period of strong investment in physical infrastructure and buildings has satisfied that need, so construction activity declines and the economy uses proportionally less construction materials.

2. Decoupling through shifting to other countries the more material intensive stages in product life cycles (burden-shifting), which happens when domestic

25 Growth is more strongly decoupled where a greater share of an economy's growth comes from resource productivity relative to labour productivity.

extraction and production is partly replaced by imported materials and products, and the domestic economy shifts towards a service economy. Although resource use may decline domestically, it still occurs elsewhere in the world where the more material intensive, often more polluting, stages in products life cycles may be taking place.– This type of decoupling is often labelled as "burden shifting", where resource-intensive activities and their environmental impacts are shifted offshore.

3. Decoupling through intentional resource productivity increase. This is what is really needed to reduce pressures on limited resources, on climate, and on the environment in general. This happens through technological innovation, infrastructures conducive to resource efficient and low material intensity manufacturing and living, and appropriate attitudes and consumption patterns, including active steps to reduce environmental harm and changes in products and services by which consumption delivers quality of life.

The first two types of decoupling are often observed, and play a role in supporting the idea of a "Kuznets curve" for local environmental pollution, and the frequent but incorrect reasoning that the appropriate policies of countries should be to grow and get prosperous in order to deal with environmental problems.

The first two typically lead to decoupling that reduces resource intensity of the economy, but only to such a small degree that total resource use still increases as the economy expands. Intentional decoupling can lead to an expanding economy that uses fewer resources, and is the main focus of this report.

In response to changes in resource demand, some countries have already intentionally moved forward with initiatives aimed at fostering decoupling. China and Germany stand as two of the clearest examples. In its eleventh Five-Year Plan, setting out the country's economy goals from 2005-10, China set a target to improve its energy efficiency by 20 per cent. The twelfth Five-Year Plan set an additional 16 per cent energy efficiency improvement goal for the period 2011-15. In 2002, Germany set a clear target of doubling material productivity of its economy by 2020, compared to 1994.

Chapter 3 illustrates that technologies and techniques are already available to greatly improve resource productivity, by providing a few of the more notable examples. Chapter 4 then reviews some of the reasons why these opportunities are not being taken up more widely.

2.2.2 Choices involved in decoupling

When a more resource-productive economy saves resources by cutting waste, it saves the costs of the resources that it has not needed. This allows policymakers to decide how the savings are used. The savings can be used to create more growth – which brings a choice about how best those savings can be allocated to meet the government's goals. For instance, governments can capture the savings from productivity gains through taxation. Then they can decide directly how they are spent.

Or they can choose not to tax, and to leave those gains to be allocated by the economy into investments or greater consumption. In both cases, policymakers in government have choices that determine whether the allocation of the savings will grow the economy on a more efficient and productive path, or alternatively, choose that it will use up the resources that have been saved. In the second case, the threats to stability mentioned above will remain.

For example, when savings are gathered by the government, they could be spent to improve the resource productivity of agriculture (and so increasing agricultural output or lessening costs of inputs), or alternatively in subsidising energy (which, on the contrary would encourage wasteful use of energy, among other effects).

When savings are not taken by taxation, but left in a market economy, evidence suggests that without policy change, savings from resource productivity gains for a particular resource may not reduce dependence on that resource to the extent expected, but that at least part of the savings from productivity gains will be used to buy more of the resource as further inputs. This is known as the "rebound effect" or, when it is particularly strong, the "Jevons paradox" [26].

2.2.3 The "'rebound effect"' from resource productivity gains

In 1865, William Stanley Jevons (Jevons, 1865) described how the dramatic resource efficiency gains coming from the invention of the steam engine two generations earlier did not reduce the total amount of coal burned for industrial processes. The opposite happened: coal consumption soared. The explanation was that more efficient use of coal induced ever more and new applications for steam power.

The greater potential production from using coal as a resource made it more popular as an input in production than before. The "Jevons paradox" is now a term used to describe similar situations of resource productivity with such large rebound effects they actually increase resource use.

The rebound effect is not only a nineteenth century phenomenon – it is seen in each country today. Figure 2.2 shows it applied to energy consumption in the USA. As each unit of energy input could produce more economic output (left-hand graph), energy consumption rose (right-hand graph). It is possible to find similar phenomena in China after the introduction of ambitious efficiency standards, or in any EU country after EU efficiency standards were implemented.

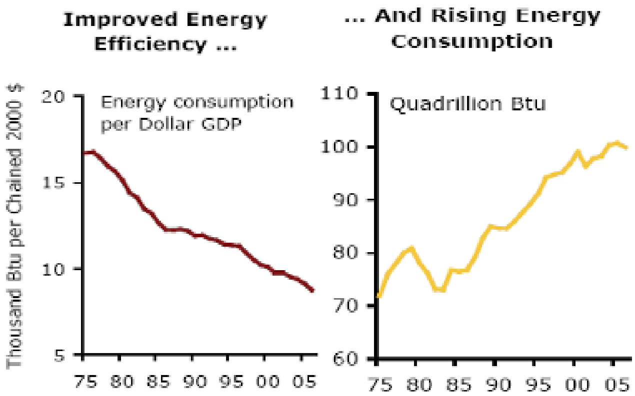

Figure 2.2 The rebound phenomenon: energy efficiency increases but so does energy consumption.
Source: Rubin and Tal, 2007

The strength of the rebound effect is different in each situation – because it is dependent on the policies in place and the strengths of the incentives for resource efficiency acting on the market economy. It can be very weak – so that almost all of the resource savings reduce exposure to risks from resource scarcity – or, very occasionally, as in the case with coal and steam engines – so strong that it even increases the absolute use of resources.

The implication of the rebound effect is that, without a change in the policy framework, at least a proportion of productivity gains will lead to absolute increases in resource use.

2.2.4 Choosing decoupling is an active choice

The implication of the rebound effect is that successful decoupling of economic growth from resource consumption

26 Since the 1990s also called the Khazzoom-Brookes Postulate, e.g. in Saunders, 1992.

will require clarity of purpose and intentional policy change. Without this, the interactions in our complex economic system appear likely to reduce the resource-saving effect of any efforts to decouple. Countries can choose where they want to reduce waste – for example in their use of energy, freshwater, material resources (including minerals at particular risk of supply disruptions) or food.

China's investment in making its economy more resource-productive has already been estimated by some to be greater than that of the US and EU combined (The Resource Efficiency Alliance, 2011). China's 2011 twelfth Five-Year Plan recognises the constraints to growth from unchecked resource depletion and sets targets for greater industrial resource efficiency and an economy that operates within the constraints of the changing physical environment.

Countries can – and have – decoupled their growth from different resources to different degrees. Decoupling can either reduce the use of resources absolutely as a country grows, or only relatively – so that the rate of increase of growth of use of resources is lower than the growth itself.

The first of these is called "absolute decoupling" and the second "relative decoupling", and is illustrated graphically in Figure 2.3, where total water abstraction for OECD countries is shown to have been absolutely decoupled from 2005 (and almost absolutely decoupled before), but water for public supply has only been relatively decoupled from growth, its absolute abstraction increasing at a rate less than GDP growth since 1990.

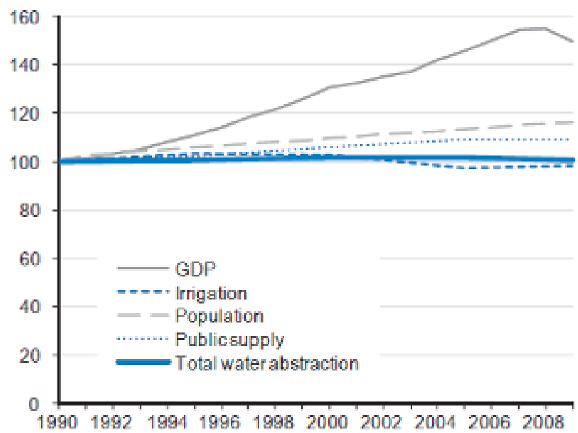

Figure 2.3 **Freshwater Abstraction by Major Use and GDP, OECD nations (OECD, 2011b, p. 78)**

It appears that any degree of decoupling is advantageous for a country when implemented wisely. However, we can also take a broader view to look at the extent of decoupling that would be necessary to reduce some of the greatest risks facing the world's economic and environmental systems from current patterns of increasing resource use.

The trends in Chapter 1 imply that to maintain stable economies and global, natural life support systems, absolute decoupling would be required.

For resources – although pressures differ greatly by resource and country – approximately a factor five improvement (Weizsäcker et al., 2009) in total resource productivity by 2050 would be required for OECD countries (resulting in just 20 per cent of today's material usage/unit of production), including also the resources embedded in the goods and services they import from other countries. This analysis is supported by the World Business Council on Sustainable Development, which points to the need for an increase in aggregate resource efficiency of factor four to 10 by 2050. This implies that each unit of production is produced using between 25 per cent and 10 per cent of its current resource inputs by 2050 (WBCSD, 2010), a much greater rate than resource productivity gains previously seen.

For example, to meet the IPCC's

recommended targets for reducing the risk of dangerous climate change, the carbon intensity of the global economy would need to have already peaked and be reduced by 7 per cent each year.[27]

(The IPCC's Fourth Assessment Report (warns that global emissions need to peak by 2015, and then reduce by 25-40 per cent by 2020 and 80 per cent by 2050 to minimise the risk of dangerous climate change. The IPCC's Fifth Assessment Report, published in October 2013, also confirms these findings) For any country growing at less than 7 per cent a year, a 7 per cent yearly improvement in carbon intensity implies absolute decoupling. This would require intentional action: the Stern Review points out that historically nations have rarely increased energy efficiency by more than 2-4 per cent per annum (which is relative decoupling) (Stern, 2006).

The implication is that countries would need to make an active choice to take effective action to absolutely decouple.

27 OECD countries would need to reduce at a faster rate to give more room to developing countries to raise living standards before they too start to achieve absolute decoupling.

3 Technological Responses Allowing Significant Decoupling[28]

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Remarkably, there exists very large untapped potential for decoupling that brings cost-savings through better resource management. Indeed, it appears to be almost ubiquitous. Technologies and techniques that bring very significant resource productivity gains are already available, right across the range of resource consuming activities.

This chapter is designed to illustrate that economies, firms and individual decision-makers can choose between future investments that are more, or less, resource productive. The chapter highlights examples of technologies and some techniques that are available or currently used to greatly increase resource productivity. They indicate that for nearly every country, it is not technological potential that is holding back resource productivity. Whatever the level of development of a country, there appear to be more resource-productive methods of production or consumption.

The Rathkerewwa Desiccated Coconut Industry (RDCI) in Maspotha, Sri Lanka is a good example. RDCI could reduce 12 per cent of energy use, 8 per cent of material use and 68 per cent of water use, while increasing the production by 8 per cent during the same period by adopting a series of recommendations on its peeling process, water treatment and fuel switching. The total investment required for implementing these recommendations was less than US$5,000 while an annual financial return of about US$300,000 was reported.[29]

28 This part of the report is based significantly on research and drafting by Dr Michael Smith (ANU) for this report and previously for the co-authored publication Factor Five and an for the Chicago Climate Exchange. It has also received research and editorial support from the members of The Natural Edge Project, namely Karlson 'Charlie' Hargroves, Cheryl Desha, Angie Reeve and David Sparks.

29 For details, see http://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Cleaner_Production/RECP_SriLanka.pdf [accessed 12th April 2014]

3.1 The widespread opportunity

An idea of the scale and diversity of the opportunity can be found by reviewing some of the available technologies for some of the key resources. The results of McKinsey Global Institute's work – shown as estimated cost curves for reduction of resource use in Figure 3.1 – illustrate this. The shaded blocks provide an indication of the areas of saving potential, based on the cost efficiency of investments in energy, land, food, water and steel.

In total, the opportunities from the technologies and techniques surveyed add up to a resource savings potential of US$2.9 trillion to US$3.7 trillion each year by 2030, on the assumptions used. Ninety per cent of the opportunities had an internal rate of return of greater than 10 per cent, if adjusted for subsidies, carbon prices and a social discount rate as a way to reflect how the investments perform for a country's economic goals, rather than only private returns.[30]

30 And 70% of the opportunities had a greater than 10% IRR at current prices.

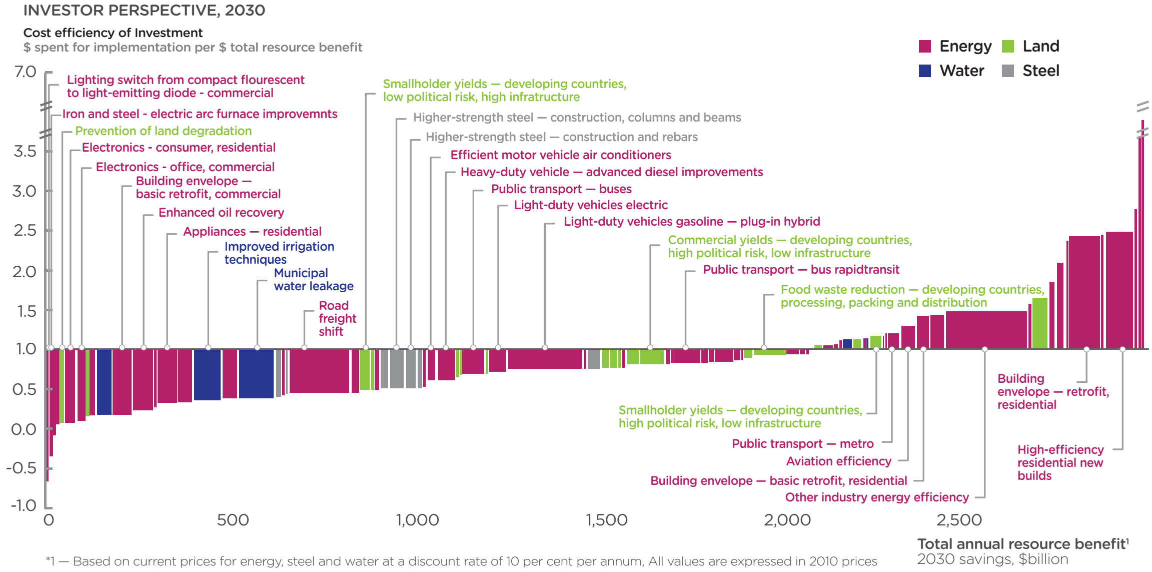


Figure 3.1 Mapping the range of opportunities for resource productivity gains.
Source: McKinsey Global Institute, 2011

Other evidence also suggests that many resource savings can be made with very short payback periods. For example, UK business are estimated to be able to save around £23 billion per year from resource efficiency measures that are either no or low cost (Hollins, 2011).

A further £33 billion per year of annual savings could be realised from expenditure with payback periods of longer than one year. The majority of these savings come from using raw materials more efficiently and generating less waste. Payback times for investments for water efficiency and waste water treatment tend to be in the vicinity of five years[31] (provided water is sold at an adequate price). Strikingly, the payback time curves all start with demand side (efficiency) measures and end up with payback times of 10 years or more for measures trying to increase water supply.

Some of the most striking results come from energy efficiency, where there has been a greater focus on efficiency since the 1970s. This chapter also picks examples of resource productivity opportunities for metals, water, soil, biotic material and resources from waste. Although some of these technologies are resource specific, many of the opportunities – like the Rathkerewwa Desiccated Coconut Company – come from actions or technologies that simultaneously improve resource productivity in more than one resource.

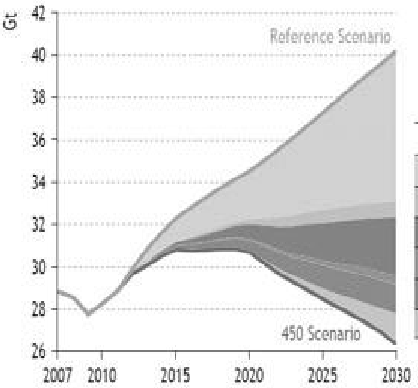
3.2 Technologies to save energy

The technical potential to reduce demand for energy through energy efficiency appears to be in the order of 50-80 per cent (factor two-five) for most technical systems[32].

- A team which included several of this report's authors researched current efforts around the world which are currently achieving between 60-80 per cent improvements in energy (and water) efficiency in sectors including: buildings, agriculture, food and hospitality, industry and transport (Weizsäcker et al., 2009).
- Another recent research study (Cullen et al., 2011) analysing energy use in buildings, vehicles and industry and applying "best practice" energy efficiency technologies found that 73 per cent of global energy use could be saved by introducing such changes.
- Research indicates that developing countries could cut their annual energy demand growth by more than half from 3.4 to 1.4 per cent over the next 12 years. This would leave energy consumption some 22 per cent lower than it would otherwise have been – an abatement equivalent to the entire energy consumption of China today. The opportunities lie in choosing more energy-efficient cars and appliances, improving insulation in buildings, and selecting lower energy-consuming lighting and production technologies. Additional annual investments in energy productivity of $170 billion through 2020 could cut global energy demand growth by at least half while generating average internal rates of return of 17 per cent (McKinsey Global Institute, 2008). Figure 3.2 illustrates the role efficiency can play in reducing energy consumption and – as shown in this figure – corresponding greenhouse gas emissions.

31 On the basis of sources including: Water Resources Group (2009).

32 Since the late 1980s, there have been a range of detailed studies providing business and governments around the world with detailed and comprehensive guidance as to which showing that existing technologies can reduce the intensity of greenhouse gas emissions between 40-80% to be achieved by 2040-2050. For further information see: Smith et al., 2007.



	Abatement ($Mt\ CO_2$)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	2 284	7 145	1 933	5 551
Power plants	233	735	66	35
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

Figure 3.2 International Energy Agency – Carbon Abatement Strategies.
(Source: IEA, 2009)

3.2.1 Technologies directly reducing fossil fuel consumption

The following section summarises a selection of technologies that can improve fossil fuel productivity in key resource-processing industries, suitable for application in developing countries.

Mining and minerals: Optimal management of crushing and grinding significant advances have been made which now enable up to 50 per cent reductions in the energy intensity of crushing and rock grinding in the mining sector (Pokrajcic and Morrison, 2009). Enabling technologies also exist to achieve up to 40 per cent reductions in the energy intensity of zinc, tin, copper, and lead smelting by using advanced furnace technology with co-generation.33

Steel: Compared to inefficient smelting processes, reductions of more than 80 per cent in greenhouse gas emissions can be achieved in the steel processing industry by using innovative processes such as switching to a state of the art electric arc furnace system that process recycled steel (including options such as improved process control, oxy-fuel burners, DC-arc furnaces, scrap preheating and post-combustion processes) and implementing options such as energy monitoring and management systems for energy recovery and distribution between processes along with preventative maintenance. Using high levels of recycled steel in electric arc furnaces not only improves energy productivity but also materials and water productivity (Liedtke and Merten, 1994).

Cement: Research shows that the energy used in current methods of Portland cement manufacture can be reduced by at least 30 per cent globally (Humphreys and Mahasenan, 2002; Kim and Worrell, 2002). However, the greatest reductions would come from the use of alumino-silicate (geopolymer) cement that can reduce the overall greenhouse gas emissions of the concrete by 80 per cent, compared to Portland cement (Duxson et al., 2007; Duxson 2008) depending on formulation variations, as it requires lower kiln temperatures and has no direct process emissions of carbon dioxide (Davidovits, 2002). The World Business Council for Sustainable Development has identified cement manufacturing as one of the six key industries on which to focus efforts on reducing energy consumption and greenhouse gas emissions.[34] Once commercialised at larger scale, geopolymer cement should cost less to produce than Portland cement and may have better durability. Other innovative cements that reduce greenhouse gas emissions per ton by 40 per cent are already in commercial use for construction.

Paper and pulp: Fossil fuel use by the USA pulp and paper industry declined by more than 50 per cent between 1972 and 2002 (AF&PA, 2004), largely through energy efficiency measures, power recovery through co-generation and increased sourcing of energy from biomass sources (IPCC, 2007). Since 1990, CO_2 emissions in the sector globally have decreased

33 See Ausmelt Technologies at *http://www.outotec.com/en/About-us/Our-technologies/Smelting/Ausmelt-smelting-and-converting/*, accessed 12 April 2014.

34 WBCSD (undated) Cement Sustainability Initiative, *http://www.wbcsdcement.org/*, accessed 12 April 2014.

by approximately 25 per cent in Europe, 20 per cent in Australia (Prosser et al., 2006), and 40 per cent in Canada through investing in similar measures.[35] The sector also has the potential in both existing and new mills to become renewable electricity exporters through the use of Black Liquor Gasification-Combined Cycle (BLGCC) technologies (Worrell and Galitsky, 2004). Black Liquor is a by-product of de-lignifying wood chips, and can be used to generate a synthesis gas (syngas) that is combusted in a gas turbine or combined cycle system with a high efficiency.

Chemicals: According to research undertaken by the Climate Group, a UK based thinktank, Bayer has now achieved 63 per cent reductions in greenhouse gas emissions profitably (Bayer, 2004). A range of technologies enable significant energy savings and greenhouse gas reductions in this sector: chemical process innovation, catalysts, co-generation and heat exchangers to capture, recover and reuse heat and power, as well as separation membrane technologies to replace energy intensive distillation processes. Use of innovative chemicals has the potential to greatly reduce resource use in other sectors of industry and society.

3.2.2 Technologies directly saving electricity in industry

Electric motors: Electric motors can account for approximately 60-80 per cent of industrial electricity use, driving pumps, fans, air compressors and materials processing and handling (Turton et al., 2002). Significant improvement in many aspects of motor design and production has resulted in the availability of "highefficiency motors". Many factors influence the comparative efficiency of motors, and it is estimated that energy consumption can be very greatly reduced through the use of high-efficiency motors, the use of a variable speed drive to precisely control the electricity frequency (Turton et al., 2002), matching design loadings, optimizing the whole system including the motor, shaft coupling, pump and throttle valve (Energy Efficiency Exchange, n.d.), and appropriate sizing. The IEA found in 2011 that using these approaches could reduce global electricity demand by 10% (Waide and Brunner, 2011). High-efficiency motors alone could potentially save 28-50% of energy use, with a typical payback period of one to three years (CADDET, 1995).

CASE STUDY – CHINA: Electric motors used in industry in China account for around 60 per cent of the country's total electricity consumption. The operational efficiency of these motors is 10-30 per cent below international best practice, depending on the industry. There is generally a low level of awareness of the potential efficiency gains with motors. Some actions are being taken, however. For example, in the second largest oil field in China, the total power consumption was 7 billion kilowatt hours (kWh) per year, of which 3.11 billion kWh were used by motors. An audit revealed that there were 14,000 motors operating with high power consumption and low efficiency, operating for on average 7,200 hours per year, revealing an enormous potential for fuel saving (Schröder and Tuncer, 2010).

To test the potential for energy and financial savings, several motors were replaced with efficient motors. The output with the new motors is only marginally higher than the previous motors (0.84 per cent higher), however the average power saving rate is 13.2 per cent. This equates to a monthly power saving of 5,910kWh and annual power saving of 70,920kWh. The investment cost for these motors was 52,500 yuan (US$7,600), and with the price of electricity being 0.45 yuan/kWh, this resulted in annual savings of 32,600 yuan (US$4,700). Hence, the payback period for recovery of the initial investment was 1.6 years. The estimated service life is 15 years, saving a total of 486,000 yuan (US$70,350). Based on the savings produced in this pilot study, there is the potential to save more than 400 million kWh of electricity per year in this oil field.

35 FPAC, available at *http://www.fpac.ca/publications/Sustainability_Report_2009-e.pdf*, accessed 12 April 2014.

Energy-efficient lighting: Globally, lighting is responsible for around 19 per cent of global electricity use, and a much higher proportion of energy use in buildings (IEA, 2006a). Additionally, electric lighting generates waste heat, which subsequently places additional load on building ventilating and cooling systems, estimated to account for up to 15-20 per cent of cooling demand (IESNA; 2001).

Light-emitting diode (LED) lamps are generally around 80 per cent more efficient than incandescent lamps (Portela et al., 2010). These new, highly efficient lighting technologies such as LED lamps are increasingly being used across the world. In developing countries, they provide good quality light to more people by coupling these efficient forms of lighting with renewable power sources (Portela et al., 2010).

This has begun to tackle the problem identified by the World Health Organization, that approximately 1.5 billion people still lack access to electricity, with the majority of these residing in south Asia or sub-Saharan Africa (Legros et al., 2009). Without access to modern electricity supplies, people rely on fuels such as kerosene, diesel and biomass for lighting (Mills, 2005), that are inefficient and highly polluting. With LEDs, photovoltaic systems, pico-hydro generators, and hand- or pedal-powered generators may be used to provide power for the efficient lamps.

CASE STUDY – NEPAL: A pico-hydro system in Nepal, that previously supplied lighting energy to three households, was instead able to provide light to 28 houses after the installation of LED lamps (Mills, 2002). In this case, increasing the end-use efficiency of the lighting source allowed more households to benefit from higher quality light at a cost equivalent to kerosene.

Energy-efficient technologies used in conjunction with design principles can significantly reduce use of energy in buildings while providing a better environment for building occupants. Effective day lighting strategies can deliver reductions in annual lighting energy consumption in the order of 10 – 60 per cent, and up to 40-80 per cent in perimeter zones (Levine et al., 2007). Savings are achieved by coupling natural daylighting strategies with simple technologies such as lighting controls, occupancy/daylight sensors, and effective task lighting. Passive design principles that effectively utilise daylight while avoiding glare and solar heat gain reduce or eliminate the need for artificial lighting and provide a pleasing lighting quality for occupants (Smith et al., 2007). Appropriate inclusion of windows and skylights in conjunction with simple technologies such as light shelves, light ducts, and light tubes, have been shown to give high performance with satisfactory payback periods (Singhal et al., 2009). These technologies reduce the need for electric lighting over the life of the building and therefore reduce both resource consumption and energy use. Adequate day lighting has also been linked to mood and productivity of occupants in offices (Abdou, 1997) and schools (Plympton et al., 2000).

Energy-efficient street and traffic lighting: Street lighting contributes significantly to city energy demand and associated greenhouse gas emissions. New and emerging lighting technologies, such as fluorescents and LEDs can dramatically reduce energy consumption, as well as reduce resource consumption through longer service lives. These newer lamps also reduce municipal expenditure for energy and maintenance of street lighting. Performance of high-efficiency lighting is predicted to further improve over time (Hansen, 2009). Combining these high-efficiency lighting technologies with emerging lighting control technologies can deliver further energy savings of 5-10 per cent, leading to total savings of 90 per cent (Commonwealth of Australia, 2011a).

CASE STUDY – USA: LED lights are now often being used in traffic light applications, providing the same level of light as traditional incandescent bulbs while reducing energy use and maintenance requirements. The City of Denver began replacing traditional incandescent traffic lights with LED signals in 1996. Approximately 20,500 traffic signals have since been retrofitted, avoiding 1,440 metric tonnes of CO_2 equivalent (CO_2e) and saving the city more than US$430,000 annually with a four-year payback period (Winer, 1998).

CASE STUDY – SOUTH AFRICA: The city of Cape Town in South Africa is currently conducting a 10-year traffic signal upgrade programme, retrofitting 120 intersections per year with LED lamps. The LED lamps consume almost 90 per cent less electricity than the lamps they replaced, yet produce the same lighting service (Soloman and Sebitosi, 2007). A total of 1,200 major traffic intersections will be retrofitted during the programme period and are expected to deliver savings of ZAR 23.8 million (US$2.9 million) due to electricity savings and reduced maintenance. The programme is estimated to have also reduced CO_2 emissions by 39,000 tonnes (Soloman and Sebitosi, 2007)).

CASE STUDY – AUSTRALIA: The city of Sydney found that one third of the city's annual electricity use came from public lighting (City of Sydney, 2014). The council investigated high-efficiency street lighting technologies as a key measure to help achieve the city's targeted energy and emissions reductions of 50 per cent. A trial to test the viability of LED street lights found substantial energy and greenhouse reductions of 40 per cent was possible, and has led to a citywide lighting retrofit (City of Sydney, 2011). The LED lights met appropriate standards and produced high-quality light while reducing electricity consumption and greenhouse gas emissions. The city then undertook a citywide lighting retrofit using LED technologies in combination with lighting controls to allow remote monitoring and control, so as to further reduce energy use.

3.2.3 Technologies for reducing fossil-fuel demand in transportation: trucks and ships

Trucking fuel efficiency: Freight trucks contribute 24 per cent of greenhouse gas emissions for the transport sector. Emissions from this sector are forecast to more than double over the next 50 years (WBCSD, 2004). The fuel efficiency of trucks can be greatly improved through a number of key measures, including improving the aerodynamics and reducing rolling resistance. The Rocky Mountain Institute estimates that 50 per cent improvements are possible for both with design innovation and current off-the-shelf technology. This is significant as for heavy trucks travelling along interstate highways at speeds over 100 kilometres per hour, the aerodynamic drag can be responsible for more than half the power requirements.

Achieving close to these theoretical limits requires a combination of modifications to the freight truck and trailer form, such as adding a full roof deflector (5-10 per cent reduction), chassis fairing (1-3 per cent reduction), sloped hood (2 per cent reduction), round corners, aero bumper (2 per cent reduction), air dam, flush headlights (0.5 per cent reduction), slanted windshield, curved windshield, side extenders (1-7 per cent reduction), skirts (plates which are mounted on the sides of trailers) and under-hood air cleaners (1-4 per cent reduction), concealed exhaust system, recessed door hinges, grab handles, aerodynamic mirrors (1-2 per cent reduction) and truck vision systems (3-4 per cent reduction) that can replace mirrors (Cummins, 2006, p. 10; Kenworth Truck Company, 2006, pp. 7-10). Similarly, for trailers, designing smooth-sided van trailers with a rounded leading edge will induce minimum drag.

The rolling resistance of the truck can be reduced through a combination of cumulative factors, such as reducing the weight of the truck (for example by using alternative floor materials and reducing the amount of steel used in the frame), optimizing tyre configuration (4-6 per cent fuel savings), tyre and axle alignment and behavioural practices (truck speed and tyre inflation). Once the power requirements of the truck have been reduced by optimizing the aerodynamic form and reducing the rolling resistance, the engine can be resized and redesigned to match this reduced capacity, further producing fuel savings. Collectively, by cascading efficiencies created through improved aerodynamism, reduced rolling resistance and downsizing and enhanced engine efficiency, improvements of 70-80 per cent are estimated to be achievable (Lovins et al., 2004).

Shipping efficiency: Shipping is a primary means of transportation for many goods as it is a relatively low-energy transport option (Macintosh, 2007). However due to the scale of the industry, shipping is responsible for 2.7-5 per cent of global greenhouse gas emissions and contributes heavily to air pollution in coastal areas (Kleiner, 2007). A range of technological innovations is being used in the sector to achieve better environmental outcomes and greater energy efficiency. New low-drag hull coatings, air floatation devices, advanced propeller technology, waste heat recovery, and the utilization of parafoils and other wind-assisted propulsion technologies are all contributing to energy and greenhouse gas reductions. Low-drag hull coatings have been trialled on more than 300 vessels around the world and delivered CO_2 savings of approximately 9 per cent (Boyd, 2012). The inclusion of an air cavity in the hull of ships aids buoyancy and reduces drag. This innovation was trialled on five vessels and resulted in greenhouse gas reductions of 7-15 per cent (Boyd, 2012). Additional improvements in associated container logistics operations, such as loading and unloading containers from cargo ships, are further efficiency gains, giving a total potential of 40-70 per cent.

CASE STUDY – VYCON: The loading and unloading of containers from cargo ships requires large amounts of energy and thus represents a significant cost involved in container transportation. Mobile cranes, powered by onboard diesel generators, are utilised to move the enormous containers between ports and container ships and then to freight trains and trucks. However, an innovation by flywheel manufacturer Vycon has cut energy consumption drastically while extending the life of mechanical parts (Pauli, 2011). Lowering the containers is energy intensive because the braking system must generate significant resistance in order to slowly lower the containers. Usually the energy from braking is directed to a bank of resistors where the energy is dissipated. Vycon realised that the kinetic energy generated by lowering the containers could be harnessed using a flywheel and stored for use during the next container lift. The design is a form of regenerative brake, which slows the descent of the container by converting its kinetic energy into rotational energy in the flywheel. This simple innovation reduced energy consumption by 30-35 per cent (Pauli, 2011). In addition, the design reduces noise and prolongs the life of generators due to the utilization of magnetic bearings. The bearing design levitates the flywheel in a magnetic field, essentially eliminating friction and mechanical wear in the system.

3.2.4 Technologies for reducing fossil-fuel demand in transportation: rail and road passengers

Transporting passengers and freight by rail is much more efficient than transporting by road, with freight estimated to be up to 66-80 per cent more efficient than trucking (Kamakaté, 2007), with significant opportunities existing to further improve efficiency. The UK Carbon Trust argues that significant efficiencies could be achieved in this sector through energy efficiency, regenerative braking, lighter rolling stock, better traffic flow and load factor management, biodiesel and hybrid or fuel cell engines and renewable electricity (UK Carbon Trust, n.d.). Large efficiency gains have already been recognized over the last few decades as locomotives have become more efficient. In the USA, the volume of freight transported by rail has almost doubled since 1980 while energy use increased only marginally (Association of American Railroads, 2009).

Although the aerodynamic performance of trains is already relatively good, it is still possible to reduce drag and friction (Jochem, 2004). Simple alterations can be quite effective. For example, during transport of coal, empty cars can contribute significantly to fuel consumption. Adding covers over empty containers during transport has been shown to reduce drag by 25 per cent due to improved aerodynamic performance (Jochem, 2004). Improved logistics may also deliver significant energy savings without need for further resource consumption (Jochem, 2004). Focusing on better traffic flow and load factor management can assist in utilizing rail infrastructure more efficiently (UK Carbon Trust, n.d.). Other management practices, such as reduced idling time can deliver savings of more than 6.3 per cent. Simple software and GPS technology can also be used to help optimize speed for maximum fuel efficiency by considering factors such as the type of locomotive, weight, gradient, and location (Association of American Railroads, 2009).

CASE STUDY – JAPAN: Japanese train manufacturer JR East Group has been applying a range of strategies to improve the energy efficiency of passenger train design since 1993. Their latest trains, the E231 series, are 50 per cent more efficient than the 103 series, which is the major metropolitan area commuter train (JR East Group, 2004). The E231 series achieves these savings mainly through lighter overall weight, effective use of braking energy, and greater motor efficiency.

3.3 Technologies saving metals and minerals

3.3.1 Steel end use in construction

Around half of global steel is currently used in construction. Three examples show the extent of potential savings:

Higher strength steel: Using steel with higher strength for re-enforcement of concrete, beams and columns saves steel. ArcelorMittal, the world's largest steel company estimates use of higher strength steel achieves a 32 per cent reduction in the weight of steel columns and 19 per cent in beams (McKinsey Global Institute, 2011). China and developing countries tend to use lower strength steel, with China using steel for reinforcement that is two thirds the strength of steel averagely used in Europe. This offers a very good opportunity as these countries' use of steel is very significant. (For example, China currently consumes 60 per cent of global steel reinforcement bar production.) Even partial global switching to higher strength steel could save 105 million tonnes of steel a year, and save 20 per cent of the costs of the use of steel (Allwood, J. and Cullen, J., 2012).

Steel use optimisation: Additionally, the mass of steel put for reinforcement in buildings and infrastructure constructions is frequently excessive, with 15-30 per cent more put into constructions than would be needed to meet building codes and design needs. This can be because simple estimations of the steel needed on the construction site do not take into account the construction's design. One solution is offsite, computer-controlled fabrication of "carpets" of reinforcement bars that are designed for the building's needs. This technology is already being commercially implemented, for example by Qube Design. Using these techniques could save 15 per cent of the mass of steel used globally for reinforcement in construction (Allwood, J. and Cullen, J., 2012).

Beam and joist redesign: Estimations from Cambridge University in the UK suggest that savings of more than 30 per cent of steel used in floor and ceiling beams for construction could come from redesign of the beams by using less steel while offering the same physical properties. This includes using beams with variable depth (or thickness) or ceiling joists made of a web of steel elements instead of a solid beam (Allwood, J. and Cullen, J., 2012).

3.3.2 Reduction in metal use

Blanking sheet metal: The pressing out (or "blanking") of metal components of different size and shape from sheet metal necessarily leaves behind pieces of sheet metal that are not wanted and too small to use for other components. Intelligent organization of the different shapes to be pressed out can realize significant metal savings.

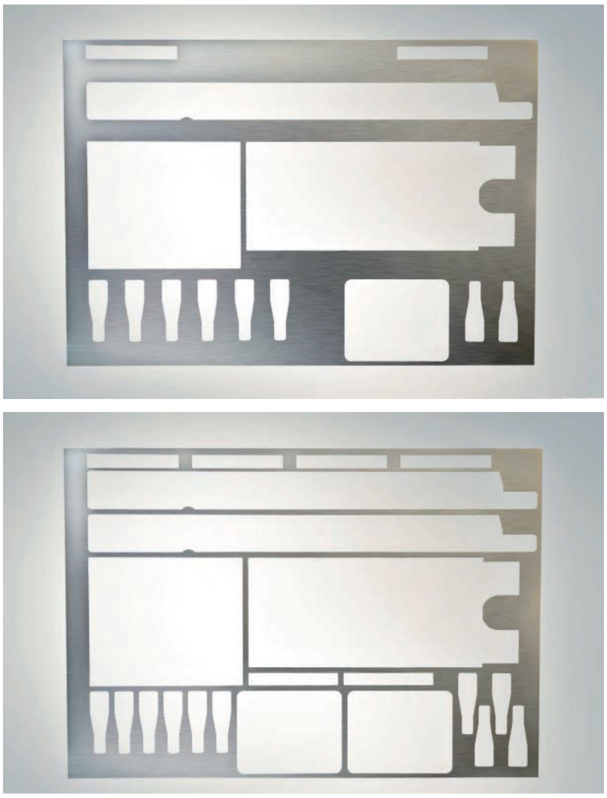


Figure 3.3 Alternative blanking patterns for metal components from sheet metal.
Source: Closing the Eco-Innovation Gap (Eco-Innovation Observatory Annual Report 2011)

CASE STUDY: DEUTSCHE MECHATRONICS.
Deutsche Mechatronics GmbH operates in Germany providing engineering services, including pressing out of sheet metal parts for external customers. It used up to 40 tonnes of sheet metal a day for almost 100 different customer orders, with a wide variety of shapes. By using computer-driven shuffling and a good production planning system, metal use could be reduced by 12 per cent.

Substitution with bamboo: Bamboo is one of the fastest growing woody plants globally, reaching maturity three times faster than any other harvestable timber, in on average three years (Jayanetti and Follet, 2003). Bamboo is used for many purposes that reduce consumption of less sustainable resources, such as for co-firing in power plants, producing bio-oil, for food, paper, clothing, furniture, wind turbine blades, sporting equipment, scaffolding and construction. It is estimated the construction sector is responsible for as much as 50 per cent of material extraction, and 50 per cent of waste generation (Edwards and Bennet, 2003). Bamboo is well-established as a viable construction material, particularly in relatively poor, rural areas. Bamboo can grow in most climatic conditions and soil types, and provides benefits while growing such as soil stabilisation; due to spreading roots, bamboo has been found to reduce soil erosion by 75 per cent within two years of being planted (INBAR, 2010). Due to a rapid growth rate, bamboo can be sustainably harvested in three- to five-year rotations (Jayanetti and Follet, 2003).

Bamboo has natural structural advantages, including its strength and light weight, such that properly constructed bamboo buildings are inherently wind and earthquake resistant (Jayanetti and Follet, 2003). Indeed, the tensile strength of bamboo is relatively high, reaching 370 megapascals, making bamboo an attractive substitute for steel (Ghavami, 2008). The ratio of tensile strength to specific weight of bamboo is six times greater than that of steel. The energy needed to produce 1m3 of bamboo per unit of stress compared with materials commonly used in construction found that steel requires 50 times for energy than bamboo. Two tons of CO_2 are emitted to produce one ton of steel, compared to bamboo, which absorbs CO_2 as it grows (Ghavami, 2005). While bamboo would normally be part of a short carbon cycle, rapidly absorbing carbon from the atmosphere and rereleasing this as the plant decomposes, the use of bamboo for construction and other durable purposes can sequester the bamboo carbon for at least several decades (Yiping et al., 2010).

CASE STUDY – CONSTRUCTION INDUSTRY: There is growing application and sophistication in the use of bamboo in the construction industry, including as flat panels able to be used as floor boards and walls, large laminated sections for use in external joinery, to reinforce concrete and to provide structural support (Ghavami, 2008). As bamboo is flexible, it can be used to create domes and other curved shapes that can be difficult to achieve with other construction materials (INBAR, 2010). Bamboo is in particular an attractive building material in developing countries as it is cheap, locally available and quick to grow. Further, only a low degree of industrialization is needed to cure and process bamboo, particularly in comparison to steel. This reduces transportation requirements and construction costs, and can enhance job prospects for local construction workers without access to training or facilities for the production and use of more industrialized construction materials (Ghavami, 2008). Furthermore, bamboo production can provide sustainable jobs and incomes, particularly in developing countries. Due to the variety of end uses, growing demand, and low-tech harvesting and processing, local producers in developing countries can cultivate, process and market the bamboo themselves to maximize their income (INBAR, 2010). Bamboo has been found to outlast steel when used to reinforce concrete (Ghavami, 2005).

CASE STUDY – INDIA: The UK based Timber Research and Development Association designed a project in India to develop and promote cost-effective bamboo based building systems through demonstration and education. To this end, the project aimed to showcase safe, secure and durable construction that would be affordable even to the poorest communities in India, and to show how to design buildings so that the life of the bamboo would be equivalent to that of other building materials. The building systems they designed were half the cost of traditional brick block or reinforced concrete, were simple to erect and incorporated all of the essential requirements for affordable shelter. At the same time, they were sustainable, stood up to wind, earthquakes and other environmental conditions, and the building design was flexible and easily adjusted to need. The use of bamboo presents the opportunity to also improve the local environment (habitat for wildlife, reduced erosion, carbon sink and protection of native forests) and to enhance the local economy through providing a local industry (bamboo cultivation and processing), jobs (bamboo harvesting, processing and building) and a food source (Jayanetti and Follet, 2003).

Information and communication technologies (ICT)[36] are continuously making astounding progress in technical efficiency and performance. The space, material and energy needed to provide a unit of ICT service have decreased by three orders of magnitude (Hilty, 2008, p. 13) (Factor 1,000) since the first personal computer, the Apple II, was sold in 1977. For this reason there are high expectations in regard to the contribution of ICT to continue to reduce its own impacts, and to further support significant energy and resource productivity improvements across our economies in the coming decades.

36 Extract from Fitcher et al., 2010.

3.3.3 Saving materials from waste streams

Reducing the material that a nation discards reduces resource wastage, which increases the resource productivity of the economy, helping to decouple its resource use.

This can be done through waste prevention and increasing recycling, which also provides an additional domestic source of supply for materials. The waste of one industry can be used as input by others if properly facilitated.

Globally, there is significant scope to lift recycling rates. Currently, however, only 25 per cent of the 4 billion tonnes of municipal waste produced each year is recovered or recycled. Only 15 per cent of all electronic waste is recycled and less than 1 per cent of rare earth metals are currently recycled. UNEP research has found that on a global scale, under a scenario of increased "green" investment, the global recycling rate in 2050 could be more than three times the level projected under business as usual, and the amount of waste destined for landfills reduced by more than 85 per cent.

Design of products to reduce waste: Reductions in waste can be found by design in the products being consumed.

CASE STUDY – PACKAGING REDUCTION: In one instance, Electrodomesticos Taurus redesigned its domestic food blender so that nearly all cardboard packaging previously used for sale was eliminated. Instead, the blender was packed in two containers that form part of the product itself, and are used for blending, chopping and making sauces. Each redesigned blender saves 130g of cardboard and its related life cycle impacts.

CASE STUDY – CARPET TILES: UK-based commercial carpet maker Desso set a goal to make all its products 100 per cent recyclable, while launching a scheme for the return of its and its competitors' carpets for recycling. Putting this goal into practice required design changes, and material substitution to use materials that can be recycled over and over again. Materials are evaluated against 19 human health and environment criteria, with the goal to use 100 per cent materials that can be constantly recycled by 2020. This required a re-engineering of the firm's supply chain. More than 60 per cent of the company's product range now contains recycled material, while the company aims to collect around 12,000 tonnes of carpets to feed into recycling during 2013.

Substituting fossil fuels with methane from landfill: Landfills generate large amounts of methane gas from decomposing organic waste. Further, methane in landfills often presents a difficult management issue as it can cause explosions and noxious odours. However, methane is a valuable fuel and can be burned in power stations and for industrial applications, and can also be liquefied, transported and distributed for purposes such as heating and cooking. Hence, capturing and beneficially using the 40-60 per cent methane in landfill gas can reduce greenhouse gas emissions as well as offset the use of other fossil fuels. (Methane itself is a significant greenhouse gas and globally emissions from waste contribute 3 per cent to total greenhouse gas emissions, IEA, 2008a) Globally, there is significant potential to capture and beneficially use methane from landfill gas. Figure 3.4 below shows an estimate of the methane emissions from landfills in the top 10 emitting countries in 2010, highlighting the potential for this technology to reduce global greenhouse gas emissions. Several of these are developing economies.

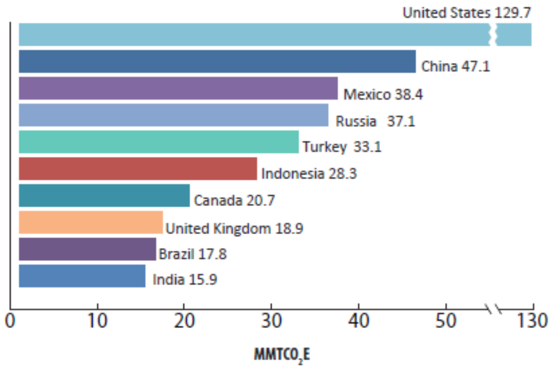


Figure 3.4 Estimate methane emissions from landfills in the top ten emitting countries, 2010
Source: Global Methane Initiative (GMI, 2011, p.2)

Developing countries such as China, Mexico, Brazil and India can benefit as waste disposal rates increase, landfill management practices improve, and energy demand grows.

CASE STUDY – USA: In the USA, landfill gas has been captured at the nation's largest landfills to meet requirements under the 1996 Clean Air Act. However even landfills not required by legislation have landfill gas capture projects due to tax incentives and voluntary projects, such that there were approximately 480 landfill sites in December 2008, representing around 27 per cent of the nation's landfills, capturing landfill gas (Bracmort et al., 2009). Methane from landfills contributes 1.8 per cent to the US total greenhouse gas emissions. It is estimated that between 60 and 90 per cent of the methane in the landfill gas can be captured and burned. The US Environmental Protection Agency (EPA) encourages the capture and use of landfill gas for energy by burning the methane in a thermal electricity generator, directly using the gas to provide heat for industrial or other purposes, or in cogeneration plants.

CASE STUDY – CHINA: The Gauantun landfill in China has been retrofitted to enable landfill gas capture and use (GMI, 2011, p. 3). Following testing and pre-feasibility investigations conducted by the US EPA, a gas collection system consisting of 150 extraction wells was converted from existing passive vents. A 500-kilowatt (kW) reciprocating engine was installed in 2007 to generate electricity for the onsite leachate treatment plant, and a second 500kW engine was added in 2008. The project is annually reducing greenhouse gas emissions by 37,100 tons of CO_2e from electricity generation and 500 tons of CO_2e through direct use. Two additional engines will be added, bringing the total electric generating capacity to 2.5 megawatts (MW). There are plans to ultimately increase the power generating capacity to 4MW by the landfill closure date (GMI, 2011).

3.4 Technologies saving freshwater and biotic resources

3.4.1 Technologies saving freshwater extraction

Within each area of potential efficiency, there is usually a wide range of options (Smith et al, 2010c), of which this chapter only gives one or two illustrative examples. For example, one map of the potential means for reducing a projected demand-supply gap in China's future water demand identified 55 levers utilizing more than 40 technologies (2030 Water Resources Group, 2009).

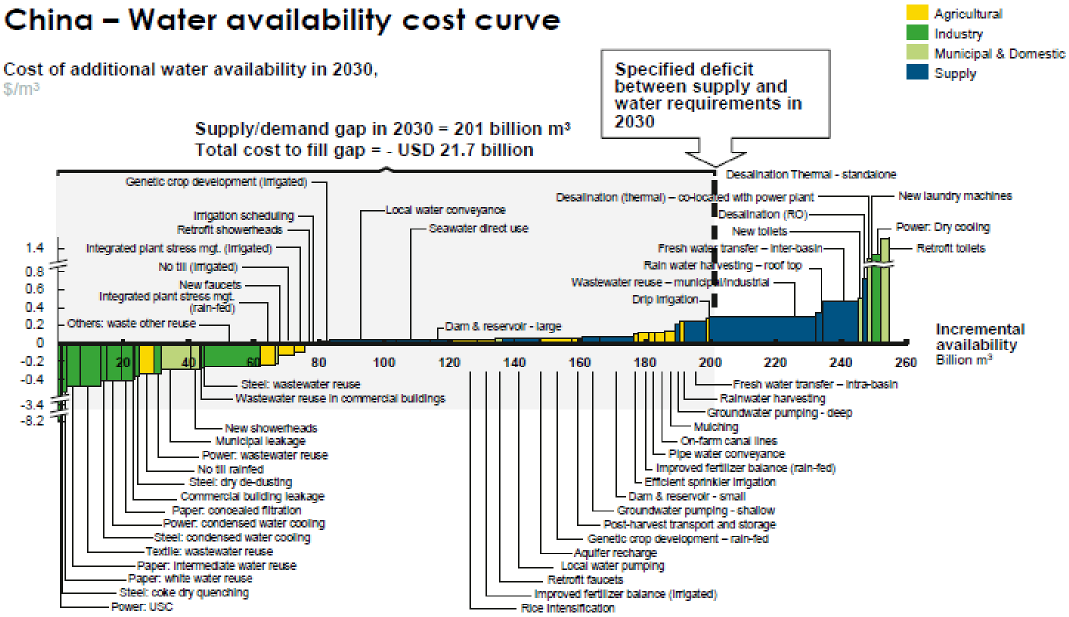


Figure 3.5 China Water Availability Cost Curve
Source: 2030 Water Resources Group, 2009, p. 77

A long list of the technologies to reduce freshwater consumption through improving water efficiency and increasing reuse and recycling of treated water can be found in Annex A, with two examples described below.

Drip irrigation: Agriculture is responsible for 70 per cent of freshwater withdrawals (Weizsäcker et al., 2009). In many countries, 90 per cent of irrigated land receives water through open channels or by intentional flooding. The waste of freshwater through these methods, through evaporation, leakage and seepage is high. Farmers in India, Israel, Jordan, Spain and the USA have shown that sub-surface drip irrigation systems that deliver water directly to crop roots can reduce water use by 30-70 per cent and raise crop yields by 20-90 per cent, depending on the crop (Postel et al., 2001). Efficiency savings can be as high as 50-80 per cent, and can be made affordable for use in the developing world (Shah and Keller, 2002) with payback periods of less than a year.

The use of freshwater on farms has halved in Israel since 1984, while the value of production has continued to climb. Drip irrigation has played a role in this, alongside the recycling of water for farming. More than 80 per cent of all water used for farming in Israel is recycled.

These low-cost solutions are seen to increase incomes of smallholders and were estimated, in 2001, to be able to profitably irrigate a tenth of India's cropland, with similar potential for China. India and China currently use this kind of technology on just 1-3 per cent of their irrigated land, with China in particular increasing the spread of this technology to arid areas (Brown, 2008).

Where drip irrigation is not appropriate, better water management still delivers benefits. Farmers in Malaysia saw a 45 per cent increase in their water productivity through a combination of better scheduling their irrigations, shoring up canals, and sowing seeds directly in the field rather than transplanting seedlings.

Reducing municipal water leakage: Estimates of the current rates of leakage of municipal water show a great variance between countries, with leakage rates of 5 per cent losses in Germany and 25 per cent in the United Kingdom. The opportunity to reduce wastage by leakage is particularly large in developing countries – India could save 26 per cent of its municipal water demand by fixing leaks (McKinsey Global Institute, 2011).

The value of water for municipal use is sufficiently high to make leak-fixing economically attractive: McKinsey Global Institute estimates that action in China could have a 22 per cent return (even taking into account the subsidised price of water) (McKinsey Global Institute, 2011). The World Bank's Water and Sanitation Programme found that more than 40 per cent of water produced in Indian cities did not produce revenue for the utilities because of leakage or failure to invoice, pointing to the sources for payback of the capital investment required for fixing leaks. Identification and location of leaks has now been made much easier by technologies that allow remote monitoring of water leakage.

3.4.2 Technologies protecting soil fertility

Currently, large-scale industrial agriculture often reduces soil fertility, diminishing soil biodiversity and humus levels, relying on flows of resources, chemicals and fossil energy to maintain productive output (Jackson and Berry, 2011). Many strategies exist to reduce resource consumption while maintaining productivity. Simple management techniques, requiring only education and costing little to implement, are being used to improve the fertility of agricultural systems while reducing resource use and maximizing the carbon sequestration potential of soils. Increasing soil organic carbon through the use of crop residues, manures and compost is an effective means of improving soil health while closing nutrient cycles and sequestering carbon (CSIRO, 2011). Practices such as cultivating perennial crops, employing winter cover crops and utilizing meadow-based rotation systems can also help maintain soil health while requiring less input of fertilizer and chemicals. Energy savings of 30 per cent exist and can be realized through better understanding of farm energy usage (CSIRO, 2011). Furthermore, agricultural systems can also be used to sequester carbon in soil organic matter (Lal, 2004).

Shifting food production systems away from monocultures to diverse local farming systems built upon biodynamic or permaculture principles that are restorative of ecological capital and maximize the reuse potential of local nutrient and energy flows will reduce resource consumption and sequester soil organic carbon, while also helping to restore food sovereignty to communities.

CASE STUDY – BIOCHAR: According to the UN Convention on Climate Change and Desertification, "pyrolysis" of agricultural residues resulting in charcoal and energy production with biochar carbon sequestration provides a tool to combine sustainable soil management, carbon sequestration and renewable energy production. While producing renewable energy from biomass, agricultural productivity, and environmental quality can be sustained and improved if the biomass is transferred to an inactive carbon pool and redistributed to agricultural fields. The uses of crop residues as potential energy source or to sequester carbon and improve soil quality can be complementary, not competing uses (UNCCD, 2008).

CASE STUDY – GRAZING METHODS: "Time-controlled grazing" has been long used as a form of pasture management. In the late 1950s, French farmer and scientist André Voisin showed that for wet and cold climates, regularly allowing grazed pasture plants adequate time to recover meant that the biomass produced in a season could be significantly greater than that produced by a constantly grazed pasture (Voisin, 1959). This involves moving stock through a number of paddocks at high stock density (Cook, 1994).

In the 1980s, Zimbabwean biologist Allan Savoury successfully adapted Voisin's ideas to grazing systems in hotter and drier climates of southern Africa. Through short duration and high-density grazing, livestock eat whatever grasses and vegetation is available, rather than just those species the livestock prefer. The combination of these changes leads to more soil biota activity, improved soil structure and hydraulic properties and increased and more active root systems of plants (Savory and Butterfield, 1988). This also means plants and grasses are able to grow longer in dry periods because more of the natural rainfall is stored in the soil and need less water from irrigation. It also means significant levels of soil carbon are stored in the soil, which as grazing pastures comprise 69 per cent of agricultural land globally (FAO and IFAD, 2006), indicates significant potential for carbon storage through use of these methods. The methods have now been applied to 30 million hectares of grazing land globally.

Figure 3.6 Traditional grazing practices on the left hand side, and time controlled grazing practices on the right hand side.
Source: Milkwood (2010)

3.4.3 Technology- saving biotic resources

Solar cookers: Two-and-a-half billion people in developing countries depend on biomass – wood, dung, charcoal and agricultural residues – to meet their cooking energy needs (IEA, 2006b). This often leads to harvesting of biomass beyond sustainable levels, leading to resource depletion, ecosystem decline and soil degradation. (It also results in the premature deaths of an estimated 1.6 million people each year from breathing elevated levels of indoor smoke, with indoor air pollution being the fourth leading cause of death in poor developing countries, WHO, 2004). Solar thermal cookers have been improved to achieve more than factor five efficiencies and are cost effective, relying on sunlight instead of biomass to cook food. Solar Cookers International operates in Kenya, providing cookers made from cardboard and aluminium foil and costing $10 each. They cook slowly, much like a Crockpot and require less than two hours of sunshine to cook a complete meal. They can also be used to pasteurize water, which saves lives (Brown, 2008, p. 154).

Reducing consumption of biomass based forest products – timber – enabling technologies (Hawken et al., 1999): Engineered timbers and timber recycling provides numerous opportunities to reduce raw timber consumption. "Engineered timber products" have about 1.8–2.4 times conventional lumber's product yield per unit of fibre, and can use younger, softer, lower quality trees. Still another important timber-saving development is modern Glulam beams, which glue together many layers of timber to replace massive solid beams which can save two thirds of the timber mass.

Reducing wastage of food: The UN Food and Agriculture Organization has estimated that between 20-30 per cent of all food produced is wasted along the value chain even before it gets to consumers. In developed countries this happens mainly in processing packaging and distribution. In developing countries it occurs mainly in storage and distribution (FAO, 2011).

Reducing food waste has consequential savings for the water, soil, nutrients and energy used in food production at earlier stages of the value chain. It offers the opportunity to improve domestic food security, as well as increased incomes (McKinsey Global Institute, 2011, p. 94).

The technologies to reduce food wastage are not seen as innovatory. Much of the savings can come from improved or widespread use of best practices (coupled with technologies) in processing, storage and transport. In developing countries this often implies the use of cold-storage systems and transport infrastructure.

Investing in natural assets: Decoupling can also involve investments in natural assets that provide services, or resource flows. The impact of building this natural asset base can be profound – as is often the case with reafforestation. Forty years ago, Niger had severe problems with drought, desertification, unsustainable farming practices and rapid population growth. It was becoming harder and taking longer for firewood and timber to be found and the farming soils' fertility was declining.

From the mid-1980s this began to change. At that time, farmers in several villages were taught to plough carefully around tree saplings when sowing crops of millet, sorghum, peanuts and beans. The growing trees, along with other simple soil and water conservation practices, stabilised topsoil erosion and so reduced crop loss. They became assets that families used to supplement incomes, provide insurance against crop failure and meet their own needs. The trees provided wood for charcoal, foliage for animal fodder and fruit for food.

Word of mouth spread the benefits until an area of 7 million hectares was replanted with trees. The average distance a woman must walk for firewood in the Zinder region of Niger has declined from 2.5 hours to half an hour. Poverty is lower, nutrition improved and communities are less vulnerable to natural disasters.

When a regional drought and locusts hit in 2005, many of the villages in the green belt of Niger reported no child deaths from malnutrition because they were able to sell wood in local markets to purchase expensive cereals that normally would have been beyond reach (Green World Recycling and Gaia, 2010).

3.4.4 Combinations of technologies

It is possible to use several technologies at the same time for related issues. Most technologies produce additive results: the savings or benefits from one technology can be added to others, to produce greater effect. Sometimes using technologies in combination will produce enhanced savings, because of favourable complementarities between technologies. In other cases, there may be negative interactions between solutions.

For example, the use of some forms of biofuels to reduce fossil fuel consumption has significant impacts on water consumption and land use. The IEA has examined the strong linkages between energy policy and water use and found that some energy policy approaches would result in demand for water usage doubling by 2035. Elsewhere, some aspects of sustainable water technologies – drip irrigation, water recycling and/or desalination, if applied widely to save freshwater, would increase the energy intensity of water supply.

However, the bulk of energy use related to water derives from heating it. Heating water through the traditional electric storage hot water system is responsible for a significant proportion of energy consumption in residential homes around the world – representing 9 per cent in the EU in 2004, 11 per cent in the USA in 2005, 25 per cent in Australia and 27 per cent in China in 2000. This means that reducing the use of hot water (or increasing the efficiency of hot water use) can simultaneously reduce water and energy use.

The IPCC estimates that: "Energy requirements for domestic water heating can be reduced by at least 90 per cent, through a range of cost effective options, including: reducing consumption of hot water; improving thermal properties of hot water systems; recovering lost heat; and selecting low energy consumption hot water systems, such as solar thermal or heat pumps."(Levine et al., 2007).

An idea of the relative scale of the potential energy savings (and also greenhouse gas emission savings) is given by the estimate that savings of 15 per cent in hot water heating across Australia would offset the entire energy use to supply water to the urban water sector (Kenway et al., 2008).

The interaction between technologies or techniques to decouple different resources from economic growth has implications for the choice of technologies. It implies that, where possible, technological options that are complementary, rather than conflicting, will better achieve decoupling goals.

For example, literature points to the possibility to achieve the same levels of decoupling of greenhouse gas emission reduction through using mitigation strategies with water and food security co-benefits, as could be achieved by investments in first-generation biofuels, carbon capture and storage or expansion of nuclear electricity generation.

This can mainly be achieved through end-use energy efficiency, water efficiency, reducing wastage of food, increased renewable electricity generation and decoupling of growth from non-CO2 greenhouse gases. Table 1 below very briefly describes the range of options that would deliver these outcomes:

1) Improve Industrial Process Energy Efficiency–For instance shifting to Electric Arc Furnace Steel manufacturing. (IEA, 2006)	**9) Energy/Water/Materials/Waste Nexus** - Product stewardship, materials efficiency, recycling, methane capture from landfill (Bahor, 2009)
2) Improve Industrial Technologies Energy Efficiency– Upgrade and optimise industrial and commercial technologies eg: electric motor driven systems such as pumps and fans and compressed air (IEA, 2011)	**10)** Decarbonising water supply and treatment through reducing water leakage water efficiency, demand management, methane to electricity from sewerage treatment plants. Investing in solar power generation structures on top of the water behind hydroelectric dams to generate electricity and reduce water losses due to evaporation from dam water.
3) Reduce Waste Heat Loss and + Waste Heat and Power Recovery (including cogeneration) (Romm, 2008)	**11)** Significantly reduce 1.3 billion tonnes of annual global food waste (a 1/3 of global food production), currently responsible for 3.3 billion tonnes of CO_2 equivalent emissions. (FAO, 2013)
4) Energy efficient street, traffic and neon signage lighting, such as LED, cuts energy usage by 85%	**12)** Increased soil carbon storage in grazing systems through time controlled grazing principally in the South – Africa, Australia and South America
5) End Use Fuel Efficiency #5 – Non-passenger vehicle freight transport (Trucks and Rail) (Mui, 2007)	**13) Decarbonising the Electricity Sector** - Transitioning to 80-100% renewables by 2030-2050 through the use of additional renewable technologies including wind power at sea, solar thermal and geothermal in non-arid areas. (Elliston B, et al 2012), (IPCC, 2012), (IEA, 2011, 2009)
6) End Use Fuel Efficiency #6 – Fuel Efficient air transport and alternatives to air transport (videoconferencing + very fast trains) (Mui, 2007)	**14)** Smart grid technologies to enable plug-in hybrid or fully electric renewable transportation vehicles (cars, vans, motorbikes, trucks, buses) powered by renewable energy sources through vehicle to grid technologies. (Romm, 2008, IEA, 2009 and 2011 and Went et al, 2008)
7) End Use Energy Efficiency #7 – Doubling of building efficiency. Eg: Increasing building albedo reducing air-conditioning loads.	**15)** Reducing Non-CO_2 Greenhouse gas emissions. (Reilly, 2008)
8) End Use Efficiency #10 – Designing products to be more energy and water efficient.	**16)** Behaviour Change (Romm, 2008)

4 What currently holds back decoupling?

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4.1 Introduction

Despite the opportunities for organizations and economies to profit from being more resource-productive, technologies and techniques that improve resource productivity are not spreading as widely as might be expected. As a result, the rate of increase in resource productivity is much lower than the estimates of technological potential. It initially appears strange that profits from productivity gains are being lost and that chances to avoid future economic and environmental costs are going unused. What blocks many of these beneficial technologies from being used more widely?

The answers appear surprising. Some of the barriers appear "soft" compared to the size of the benefits on offer. In this respect, the blocks to decoupling are similar to the barriers that hold back economic development in general: they are the kind of factors that explain why some economies function better than others, or why some firms are more successful than others.

4.2 Growth, development and transition

To understand the barriers, we have to look at the relationship between innovation, growth and transition.

The adoption of technologies and techniques is part of the dynamic process of change in an economy, and is an essential part of economic growth. For growth to happen, old ways of doing things are replaced with better ways of doing things, old products superseded by better (or at least cheaper) ones – with the net effect being that more can be produced, costs can be saved, investments can be

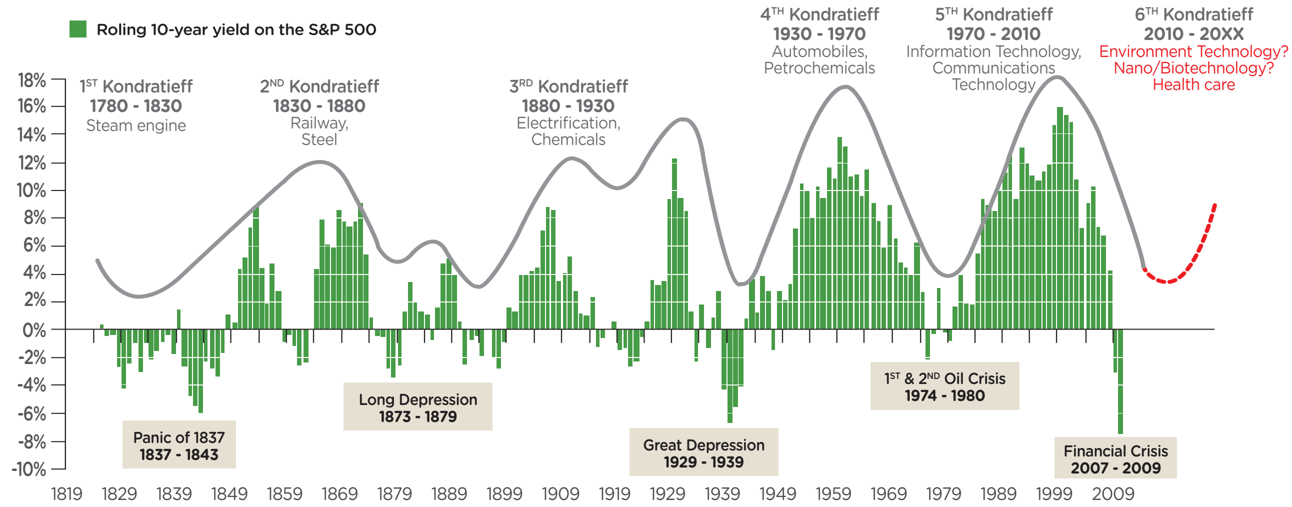


Figure 4.1 Kondratiev cycles.
Source: Allianz Global Investors "The Sixth Kondratieff" – long waves of prosperity, 2010 (Allianz Global Investors, 2010)

made and people can raise their standard of living by consuming more.

This description of the process of growth, or development, was popularized by Joseph Schumpeter in the 1940s, whose thoughts are now found across the world in economic text books and who is renowned for the evocative phrase "gales of creative destruction" to convey the way in which new ways replace the old to create growth. It is a view of growth which has formed the backbone of liberal economic policy recommendations across the world, with liberalization of markets (for trade in goods, labour or capital) being justified by the belief that increased market competition will push aside less productive firms and bring greater rewards for innovators, leading to growth through the expansion of more productive firms.

It means that a growing economy is an economy undergoing a transition, even when this may not be as apparent as it is in developing countries. It is an economy whose stock of investments (including skills) is changing. Even in countries where change is not so visible, economies grow through day-to-day changes as firms succeed and fail and employees change jobs. For example in the UK, 28 per cent of private sector jobs are lost every year, and around the same number created (Anyadike-Danes et al., 2011).

4.3 Cycles of Growth and Transition

A vivid visualisation of the relationship between economic transition and economic growth is given by "Kondratiev cycles" (Freeman and Louçã, 2001). Economic growth has been observed by some economists to come in long waves of prosperity, each driven by the spread of new technologies and structural economic change.

From this perspective, the declines in growth are periods where growth has slowed as the old economic structures exhaust their growth potential. Figure 4.1 illustrates these.

After the downturn in the global economy in 2008, a new cycle of growth could be expected. This raises the question: "If a growing economy is in transition – where is it in transition to?"

We start from the assumption that a well-functioning economy will naturally direct investments to the areas that deliver highest returns for society. As information about future challenges became available, it would be factored immediately into investment, production and consumption decisions. Considering, the trends in global resources and environmental resource degradation, evidence suggests that a well-functioning economy would naturally be placing greater investments in innovations in resource productivity. That implies that decoupling would naturally be one of the drivers of the next period of growth in successful economies.

In practice, whether, where and how it occurs may depend on national decision-makers' abilities to overcome biases that act as barriers and brakes on transition. Countries that can overcome those barriers can lead the next wave of transition, gain advantage over their competitors and secure economic growth.

We can envisage the extent to which decoupling actually takes place in any country as a result of the interplay between:

- The innovative capacity of an economy; and
- Biases in the economic and political systems which hold back innovation in resource productivity

Together these factors determine whether the kind of technologies described in Chapter 3 become widespread.

4.4 Innovative capacity

The ability of an economy (or a firm) to improve its resource efficiency is promoted or constrained by its ability to innovate in general. The capacity to innovate differs greatly across countries, and is seen in the academic literature on innovation to be closely linked to a combination of interacting factors. These factors include: the extent of knowledge, the speed with which it is replaced by new knowledge, the networking of actors who can learn from each other, the availability of finance, and the right incentives (Lundvall, 2007).

These factors are now seen by mainstream economists to be the produce of formal and informal rules in a country - institutional arrangements that are themselves dependent on culture, norms and leadership. These differ greatly between countries:

"Developing counties often lack these market and regulatory institutions. Indeed, an important part of development is precisely the creation of these institutionalised capabilities ..." – (Commission on Growth and Development, 2008, p. 4.)

Yet, it is worth noting that the rate of change in developing countries – and the rate of growth – is often much higher than in more developed countries, with a great variation between countries. As Section 2.1.2 notes, for innovation in resource productivity, middle and lower-income countries may have advantages which can more than compensate the weakness of these institutions, not least because some institutions can also hold back change.

4.5 Bias in innovation investment decisions

There are factors that have been identified as holding back the widespread adoption of innovation for decoupling. These are also factors that bias investment decisions away from investment in more resource-productive innovations.

The starting point for investment theories is that firms invest in the most advantageous investments out of the alternatives available. This is often also believed to be the case for government investment decisions. In practice, this usually means investing in the opportunities that maximize financial return over the timescale sought for investment. The relative return on investments is what matters: investments in resource productivity can be profitable and still not widely taken up, because other alternative investments are seen as more advantageous, and investment funds are limited.

Any factors that bias the decision-making process for investments will distort the natural functioning of the economy to invest in the areas with the highest returns for the economy. There are several of these biases.

Much of the literature on the topic finds that the biases that hold back decoupling are the factors that reduce the appropriable private financial returns to investment in resource productivity compared to other possible investments (OECD, 2011c). The barriers are often found in:

1. The factors which influence the prices and costs that determine financial returns for alternative investments. Influences on the effective prices of raw materials, energy, capital and labour are all key factors. Subsidies and taxation are clear examples.

This is not the whole story. Nearly all decisions about future investments have to be made in the face of uncertainty. No investor really knows what the future will hold, nor has full knowledge of all the alternatives available and how they could perform. Bearing this in mind, decision-making can be described as the choice of investment that the decision-maker perceives to be most advantageous when faced with uncertainty. There are many factors that influence this perception. They include:

2. The characteristics of the decision maker (e.g. their attitude towards risk);

3. The knowledge at the front of their mind when deciding, and

4. The situation in which the decision-maker decides – their institutional and cultural context.

The institutional and cultural context is important: it includes the views of peer-group members, the incentive structures within a workplace, received wisdom about what is good practice, codes of conduct, social norms and the regulatory framework for investments. This context influences:

- How the decision-maker judges what is advantageous (for example, how short-term payback should be, or whether reputational risk matters);
- How the decision-maker resolves uncertainty about future conditions (for example, whether they take current market prices as indicative of future prices, or accept majority views about changed future states of the world, resource scarcity and future government policy);
- How the decision-maker resolves uncertainty about the performance of unfamiliar technologies (which do not have a known track record of performance), and
- Constraints on the ability of a decision-maker to act (including hierarchical organizational structures that are risk-averse, such as credit committees in banks, or management boards, or other blocks to innovation, including financial and technical capacity).

When any of these factors has a bias against resource productive investments, they can lead to investments in resource productivity that would naturally take place being held back. In the following sub-section, we gather the main factors that lead to bias against decoupling into two categories:

- The legacy policy framework, resulting from past decisions by government;
- Biases against change, or "inertia".

4.6 The legacy policy framework

Both sides in the debate about the appropriate role and size of the state in the economy acknowledge the profound effect that government policy has on the choices market actors take. It is the policy framework that determines the rules and practices that allow a market to operate efficiently. The way in which those rules are set changes the relative advantage of different types of investments.

"[M]ature markets rely on deep institutional underpinnings, institutions that define property rights, enforce contracts, convey prices and bridge informational gaps between buyers and sellers," – Commission on Growth and Development 2008 (Commission on Growth and Development, 2008, p. 4; quoted in Swilling and Annecke, 2012, p. 91.).

Additionally for the majority of high-income countries, the state's influence through taxation is high, with tax levels between 25 per cent and 45 per cent of GDP (Heritage Foundation, 2013). Taxes influence market prices by changing those prices and the relative rewards from investments. In other countries, taxation can be much lower.

Governments have further influence in the economy through choice in the spending of the taxation revenues and other sources of funding. Government spending is often significantly higher than the level of taxation revenues, particularly for lower-income countries, with very many countries spending at 35-45 per cent of GDP (Heritage Foundation, 2013).

As a result, the playing field on which investments compete is the result, or legacy, of the policy decisions made in the past by governments. The policy framework has a significant effect on the relative effective prices of economic inputs. This is not just through fiscal policy. All policies which affect economic decisions play a role, not only taxation, subsidization and direct market regulation, but many others, including industrial policy, employment, innovation, environment, energy and consumer policy. These indirectly influence prices and investment returns, and remove or create non-price barriers or disadvantages.

The cumulative effect of the wide range of government policies is sufficient to have a very strong influence on the relative attractiveness of investments, and shape the direction of investment and innovation in an economy. The nature of investments determines the development path of an economy. Government policies have a key role in deciding the nature of the development path of an economy – for example, which sectors grow fastest, or whether it is more or less resource-productive.

Even relatively small changes in government policy can have a large effect on the relative advantage of investments: they can remove legal or organizational blocks holding back innovation, or make investments financially attractive to mainstream investors. In the 1980s, few would have imagined that changes in the energy policy of many countries could be a driver for investments in renewable energy reaching US$300bn a year in 2011. On a worldwide basis, investments in new renewable-power capacity exceeded that for fossil fuels by US$30 billion in 2008, for the first time (Senator the Hon. Penny Wong, 2010).

We highlight the legacy of past decisions because mainstream economic policy aiming to increase growth has, for a long time, tended to look primarily at growth from labour productivity gains. The resulting policy framework has helped economies realize significant growth related to labour productivity. Although resources are one of the essential inputs into an economy, like a skilled labour force, consideration of resources has been as a way to avoid risks to growth (e.g. from shortages), rather than an opportunity for growth. Figure 4.2 illustrates the result of this trend with the example of the oldest 15 EU countries – a policy framework that successfully promoted labour productivity. This framework does not appear suitable for a changed situation where resource productivity offers greater returns to society.

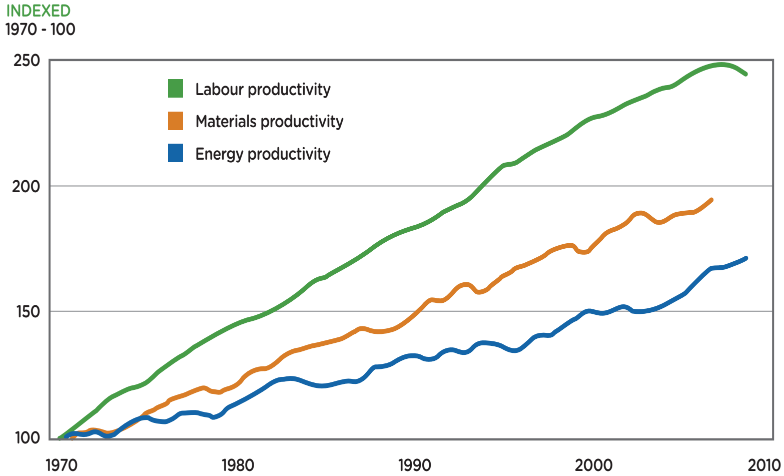


Figure 4.2 Resource Productivity, Labour Productivity and Energy Productivity.
Source: EEA, 2011

The literature is very clear on a number of areas where current policy structures coming out of past government decisions steer economies away from resource productivity:

- Subsidies of up to US$1.1 trillion each year for resources (McKinsey Global Institute, 2011). These subsidies encourage the wasteful use of resources by reducing the savings from investments to use the resources more efficiently.
- Taxation of people's work through labour taxes are relatively higher than the tax burden on resources (and energy) in many countries. As labour and resources are often alternative inputs into economic growth, this favours resource consumption rather than increased employment. Taking the economy as a whole, it encourages development of an economy that is more resource intensive. Together with distortions from subsidization of resources, taxation reduces the return on investment in resource efficient technologies and techniques.
- Regulatory frameworks for markets have often been created in ways that discourage long-term management of resources, but rather promote their wasteful early use. Clear examples are:
    - Market regulations which have worked well for old technologies, but which disadvantage the entry of new technologies. Even quite small issues can have significant effects on the entry and spread of new technologies. For instance, in some developed country energy markets, bidding systems for electricity supply have taken place one day in advance of electricity delivery. This has put operators of wind turbines at a disadvantage, because they can only reliably predict their electricity output 3 hours in advance (OECD, 2010a).
    - The absence, or uncertainty, of individual property rights or control (for example for a fish stock, or forest) that creates competition for resources between individuals which may conflict with the collective goal of maximising the value over time of the resource.
    - The economic value of many resources is not valued properly in market prices. In particular, services provided by ecosystems are often not valued, and so the capital value of an ecosystem as an economic asset is overlooked. Similarly, costs from environmental damage and costs related to increased material scarcity are not included in the costs of manufacturing or products. This is frequently because the costs or risks fall on someone other than the person using or consuming the benefits from the resource: they are "externalities". They can do so indirectly, through impacts on environmental systems, or with time lags. Effects can be incremental or uncertain in their

magnitude. As a result, this usually means that investments in ecosystems services that offer good returns for productivity of the economy (as a whole) do not offer attractive financial returns. They also promote excessive use of resources or activities that damage the unpriced resource, and hold back growth of the consumer market for less environmentally damaging products and services.

- Past regulation of market activity has frequently focused on short-term direct effects, and so has produced significant unintended consequences negatively affecting resource productivity. The absence of policy to limit this kind of effect is as much a legacy as the existence of a system of subsidies.
- Policies have also often left what are called "agency problems" or "landlord-tenant" problems, in which the person who stands to benefit from an investment to reduce resource consumption is not in a position to be sure to get a return on their investment, because they do not have sufficient legal rights over that investment. The clearest "landlord tenant" example occurs when a building tenant would save on energy bills through energy efficiency measures, but may not have the rights to invest in the building, and cannot be sure to recover the value of those investments if they move out of the building.

4.7 Biases against investment in innovation

There are also various ways in which current economic structures create biases against innovation. These very often apply to innovation in resource productivity. We can categorise four types of biases from the literature: physical and technological; behavioural; organisational, and institutional (European Commission, 2011a). Some examples of each of these categories illustrate the wide nature of biases:

4.7.1 Physical and technological biases

- Established technologies tend to have a price advantage over innovations, as continued development of the established technology over time, and its production at commercial scale tend to reduce production costs.
- Many technologies are used in conjunction with existing physical infrastructure, giving existing technologies a significant advantage over alternative technologies that would require different infrastructure (e.g. the lack of electric vehicles' recharging points compared to the large number of refuelling stations for oil powered vehicles).
- Rather similarly, many technologies function well because they are part of networks, with widespread use of a common technology (the advantage of communication technologies is their ability to communicate with the technologies that other people already have). New technologies that compete to offer a similar service, but are not widely networked, are at a disadvantage.

4.7.2 Behavioural biases

- People have a general tendency to keep to existing habits, social norms, or past behaviour – for example in purchasing choices, transport choices or waste disposal habits. Experimental evidence also suggests that we naturally value what we currently have more than we did before we possessed it (Kahnemann et al., 1990, as cited e.g. by Moseley and Stoker, 2013). People – and so the firms they work in – tend to be risk-averse, which can constrain the ability of firms, consumers and societies to adopt new innovations (OECD, 2011d).

- Behaviours are often tied to the use of existing technologies, creating a barrier to the uptake of new technologies that would require a change in habits for their widespread use. Individual behavioural patterns are also strongly influenced by peer groups – and so the social norms and context, which can also act to lock-in behavioural patterns (Thomas and Sharp, 2013), unless these social norms are changing. This affects demand for innovation, and can be particularly challenging for efforts to shift from personal ownership to a service based approach for appliances, vehicles and other consumer goods (Healy et al., 2011 or for a more accessible overview of habits Duhigg, 2012).
- Social norms do change, and are influenced by effective leadership, example and marketing: all of which can either work to promote continuation of current patterns or move to change them.

4.7.3 Organisational – including biases against finance for resource productivity

- Organisations often define working relationships between people in ways that create additional rigidity in habits. For example, the success of workers is often judged on how they perform in a pre-defined role, which hinders innovation in that role. The organisational structures can create incentives against risk-taking (and so innovation).
- Additionally, existing accounting practices and flows of information within the firm can mean that financial directors making investment decisions do not receive information from staff (in operations) who know of the potential of resource efficiency.
- Organisations have often invested in existing capital (equipment, machinery, stocks, workers' skills and networks). Innovation may be beneficial, but can simultaneously make the existing capital redundant or less valuable. Resistance to this capital destruction often biases decisions.
- Both the skill set of the workforce and business models continue to be strongly based on existing techniques or previous training, which holds back to spread of new ideas (for example, in the spread of efficient construction techniques).

Many of these factors are found in the finance sector, and this creates particular issues for changes in the pattern of economic investments. Due to the internal incentives and controls found in many banks and financing organisations, positive financing decisions tend to be made in areas familiar to the professional expertise of staff. The lack of track record for the investment performance of new technologies also makes them appear more risky, and places them at a severe disadvantage when investment decisions are made (Hudson et al., 2013).

These barriers to financing are a considerable hindrance to resource productivity. McKinsey Global Institute estimate that to meet the world's future consumption demands through resource efficient technologies would require $3.1 trillion of investment a year globally (McKinsey Global Institute, 2011). This is only fractionally higher than the $3 trillion a year that would be required for capital investment to meet future demand for steel, water, agricultural products and energy in the absence of decoupling. But it would require a shift of financing capital into areas which will be new to many of the financiers controlling funds. This adds to an already considerable challenge – both estimates of capital needs are more than $1 trillion higher than the volumes that have, in practice, been invested in resources in recent years.

4.7.4 Other institutional norms, including short-term incentives

Institutional norms are the patterns, rules, laws and codes of conduct that shape and constrain our activities[37]. They structure social and economic interactions, and can vary between areas of economic activity, cultures and over time. (Organisational norms, and some behavioural biases can also be seen as subsets of institutional norms.)

- One widely found norm which disadvantages investments in innovation and resource productivity are incentives that reward short-term financial gain. These promote investments by firms in a series of short-term actions, whilst long-term economic success and stability requires a longer-term perspective. For example, the relatively new institution of quarterly reporting of profits on stock markets leads to incentives for the management of listed companies to focus on the short term.

As many of the issues with resources are longer-term issues, the widespread institutional focus on short-term returns raises a significant bias against investments in resource productivity.

4.8 Inertia in political systems and systems lock-in

Political systems have their own inertia, which often act as a brake on policy reform, or block it entirely. The close interaction in nearly all countries between political decision-making and economic interests can lead to what is called "systems lock-in" because the policy framework is difficult to change without change to economic interests and vice-versa. Political processes can therefore act as barriers to decoupling, because:

- Frequently, policy is formed in response to the interests of leading economic groupings. Where these groupings are biased towards the current arrangements that have given them market power, they tend to engage strongly to preserve existing policy. This can be the case even as underlying conditions change (like resource availability). Although recommended policy for economic success is one that promotes employment overall, rather than protecting specific jobs, political pressure often lead to the protection of existing jobs.
- Segmented policy-making governmental structures –different ministers or departments favouring different specific interest groups leads to policy inconsistency, with the effect of some policies being cancelled out by the indirect effect of others. This weakens incentives for investment (McKinsey Global Institute, 2011, p. 120).
- This inconsistency, lack of clear direction and past records of changes in policy creates unpredictability and uncertainty about future investment return on lasting policy change.
- The institutions through which policies are made often reflect existing norms, and change is often resisted, within the institutions (for example government departments) or industrial organisations shaping policy (Ekins and Salmons, 2010, p. 132).
- Political decision-making involves the balancing of conflicting information about the impacts of future changes. Where economic interests are at stake,

37 See, for example North, 1991.

groups are likely to contest evidence showing the need for change. Where there is some degree of scientific uncertainty about the future (as is inevitable) this can be used to discredit unfavourable information. Even evidence gathered by governments seeking to promote innovation may be sceptically received and scrutinised for bias. The rejection of, or unwillingness to hear, information demonstrating the benefits of change is a key barrier to achieving policy change – as success in policy reform often involves political and economic actors perception of their own self-interest to alter (Ekins and Salmons, 2010, pp. 133-134).

- Policymaking procedures are often lengthy, and can have additional lead-in times before policy is expected to take effect – leading to lags in the policy framework in reaction to new information.

The existence of systems lock-in is believed to be a strong explanatory feature in the decline of countries that held on too long to past industrial structures that were uncompetitive in a changing world, and in the starker examples of the decline of whole civilisations. Jared Diamond has pointed to an inability to change practices and social organisation when conditions change, as one of the drivers of collapse of past civilisations faced with changing conditions, for example, of the Maya of central America, or the Easter Islanders (Diamond, 2005). Often these declines appear to have come when societies have not realised the impacts of resource exploitation until it is too late and the ecological system has been pushed past an irreversible threshold, creating non-linear harm (Diamond, 2005).

Another illustration of these effects comes in the (often) relatively slow spread of renewable energies in the face of the risks of climate change. Market prices in energy generation are strongly determined by existing, slow-changing regulation, economies of scale of past generation technologies, distribution network infrastructure, weak expression of consumer preferences and unfamiliarity and incorrect perception of the potential of new technology. For instance, a strong argument is made that renewable energy cannot be the major part of a nation's energy supply, because renewable energy sources are too intermittent and cannot be guaranteed to meet both overnight baseload electricity demand. In practice, solutions for that exist (Diesendorf, 2007) by using a mix of sources (Tickell, 2005) and in practice, already by 2008, renewable distributed energy accounted for one quarter of California's installed capacity, one third of Sweden's energy and half of Norway's, with Denmark generating 20 per cent of its electricity from wind (Smith and Hargroves, 2008). Nevertheless, the carbon intensity[38] of the global economy does not appear to have changed since the oil price shocks of the 1970s. (Figure 4.3)

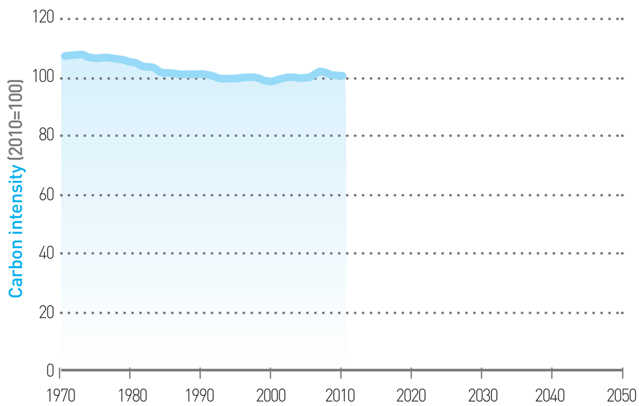


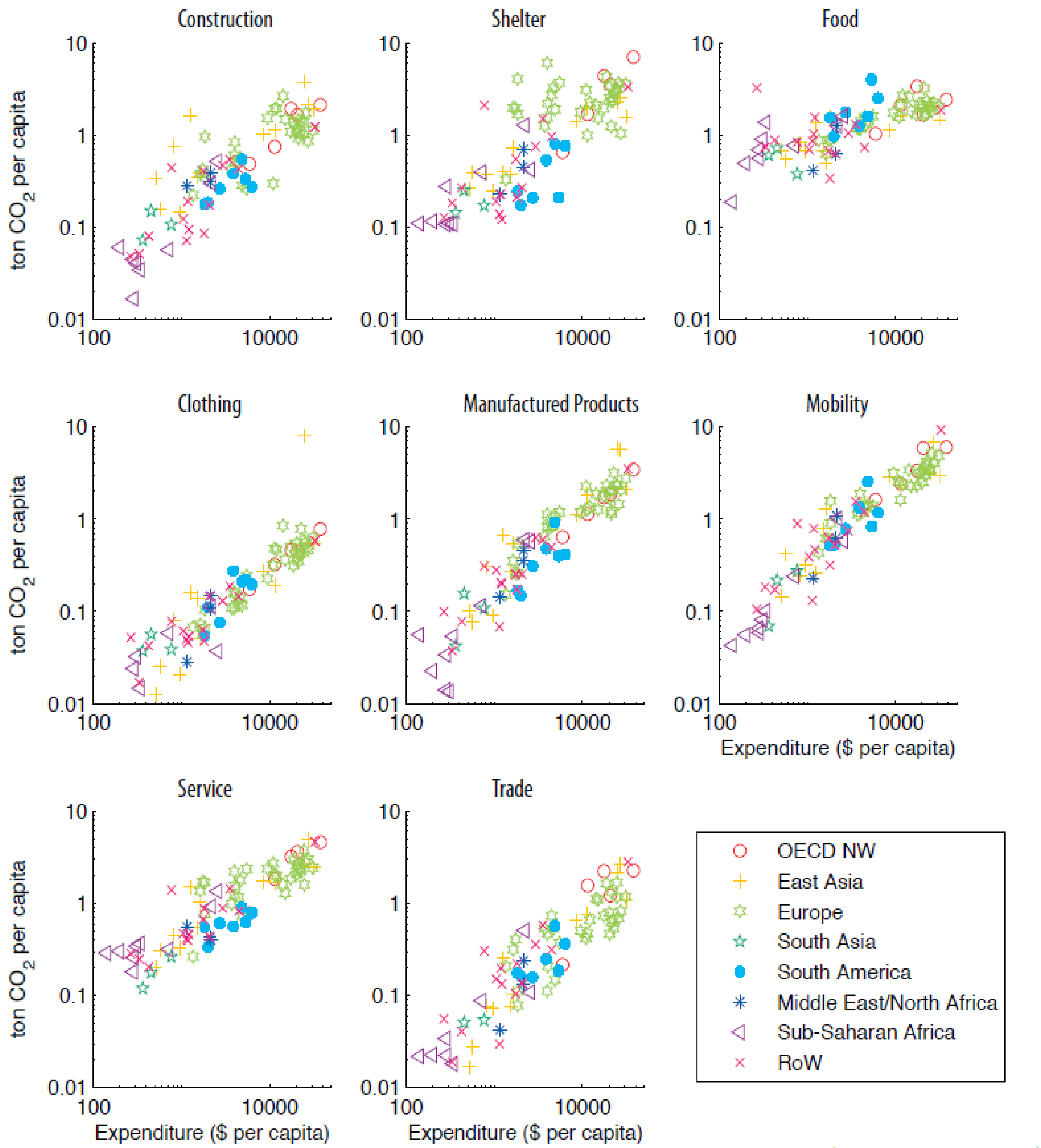
Figure 4.3 The lack of progress in reducing carbon intensity since 1985, shown by the IEA Energy Sector Carbon Intensity Index, 2012 data.
Source: IEA, 2013

The historic trend of greenhouse gas emissions being strongly coupled with rising energy consumption, which are also correlated with rising levels of per capita GDP appears only rarely to have been broken in any sector of the economy, as

38 This is the number of tonnes of CO_2 emitted for each unit of energy supplied (data from IEA, 2013).

the International Rersource Panel's 2010 Report on the Environmental Impacts of Consumption and Production has shown. Some of its key findings are encapsulated in Figure 4.4, which shows the correlation between per capita consumption levels and per capita carbon footprints. The most disappointing graph from the point of view of decoupling may be that of "services", which are often quoted as the way out of overconsumption of resources. But even here, carbon emissions relentlessly rise with expenditures.

Note: *OECD NW stands for the "New World" countries in the OECD, i.e. Australia, Canada, Mexico, New Zealand and the US. "RoW" represents various aggregate regions.*



(Hertwich and Peters 2009)

Figure 4.4 Carbon footprints (per capita CO_2 equivalents, 2001) of different consumption categories, plotted against per capita expenditures in the respective countries.
Source: UNEP 2010, Fig. 4.6, p. 55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5 Deepening understanding about the nature of decoupling

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A decision-maker judging progress in the resource productivity of their economy needs to take care over three issues. It is possible for statistics on the rate of decoupling in a country to give a better picture of exposure to resource constraints than may be the case, if used without some deeper understanding.

Many countries show relative decoupling as they grow economically, even without policies promoting resource productivity. This does not mean that their economic structures are reducing their future risk from resource scarcity. The paragraphs below explain why[39].

39 They are issues because decoupling can be measured in different ways, and each way shows something different. For more information on forms of measurement see Chapter X of the International Resource Panel's first Decoupling report (UNEP, 2011a).

5.1 Burden shifting – or 'decoupling through trade'

A country can appear to be decoupling, even when it is not. If it is replacing its domestic extraction and production of a resource with extraction and production elsewhere in the world, through imports, its economy is not changing its reliance on resources. This is often labelled as burden shifting, and often appears as countries shift from an extraction and production based economy towards an economy with a higher share of services.

As globalisation of trade proceeds, this increases, with materials that make up products increasingly coming from diverse sources around the world. In 1996 less than 20 per cent of consumption in G8 countries was met by material imports, by 2008 this share had risen close to 29 per cent.

The effect of this trade on measures of decoupling can be significant, because these frequently look at domestic resource use by mass. If extraction of ore moves from the domestic economy, with processed material imported instead, the statistical effect may be very great: to produce one ton of gold, typically 1 million tons of gold ores are mined (Schmidt-Bleek, 1994), so when these ores are included in the metrics of resource used, the apparent change in decoupling from offshoring gold extraction would be significant.

There is a similar effect for many products: it is common for 10 times more material resource to be used as input in the production process than eventually ends up in the final product. So importing a product, rather than the resources to make it reduces domestic resource use.

This can give the false impression of the changing relationship with dependence on natural resources. For example:

> "Between 1980 and 2008, Japanese material consumption decreased by over 20% while the economy expanded by 96%. When including unused domestic extraction and estimated indirect flows from trade, the decrease in material consumption appears more modest - 1% between 1980 and 2008. [And] in Germany domestic material consumption decreased by over 10% between 1996 and 2008, but accounting for unused extraction and indirect flows cuts this progress in half." (OECD, 2009).

This burden-shifting can hide dependence or depletion of existing sources of resources. The importing country is still vulnerable to changes in the market or supply for the resources, and is still contributing to any future scarcity. When its economy is viewed to include all the value chains by which its consumption is produced (e.g. from primary resource extraction upwards) its degree of resource productivity increase is smaller.

This is illustrated by three examples: freshwater abstraction, fish and biofuels:

- There is evidence that many OECD countries remain more reliant on adequate freshwater supplies than their domestic water use suggests, with the size of imports of goods produced with other countries' water – shown in Figure 1.9 – suggesting that the decoupling illustrated by Figure 2.3 is actually significantly lower. Annex C also illustrates the scale of trade in "virtual water": water used in the production of traded products.
- Trade in fish has also resulted in a shift of resource depletion from domestic to global resource stocks, so that measures of the health of many countries' domestic fish stocks does not give a true picture of the depletion of the fish stocks on which they rely. About 77 per cent of fish consumed worldwide is supplied from open oceans and from developing countries. Yet developed countries account for 81 per cent of imports of fish-based products and thus fish consumption (UN, 2006).
- An emerging area of burden-shifting comes from the rising use of biodiesel and biofuels by the European Union (Directive 2009/30/EC, Art. 7b). Our report "Assessing Biofuels" (UNEP, 2009) showed some OECD nation's transport biofuels policy is shifting environmental burdens from OECD nations onto poorer developing nations in ways that are not sustainable.

5.2 Understanding the drivers behind decoupling

Countries tend to change their resource productivity naturally as they develop because their demand for resources changes. Early industrialisation and consumption growth tend to be accompanied by the construction of a new infrastructure: such as buildings and roads that are resource-intensive. Once these are built the resource intensity of economic activity naturally reduces, which shows up as a resource productivity increase. This does show that the next stage of this country's ongoing development will be less resource-intensive, but it does not indicate that its economy is structured in a way that it will continue to become more and more resource-productive.

Where this economic "maturation" is the driver for apparently increased resource productivity, it does not indicate that the country's economy is becoming any less wasteful, or necessarily that it is less vulnerable to resource supply shocks.

5.3 Decoupling what matters

Some resources matter more to one economy's stability and success than others. Some resources are likely to have greater imbalances between demand and supply than others: several countries have drawn up lists of priority materials for their economic policy, usually based on the importance of those materials and the perception of risk in their supply.

When considering changes in resource productivity, decision-makers need to look as closely as they can at the productivity changes in the resources which matter most to them. Aggregate figures for resource use – which are frequently the most available – may not reflect the possibilities for decoupling economic growth from some particularly important resources.

Decision-making is also helped by considering the linkages between the increase in productivity of one resource and the effect on the economy's productivity in the use of other resources. For example, improving resource productivity for metal in a production processes is almost certain to improve the energy efficiency of an economy, due to the amount of energy that would be used in the production of the saved metal, as well as in the efficiency of the production process itself.

Knowing about these linkages gives decision makers more options on how they could decouple growth from resource use. (In the example above, energy use and related emissions can be decoupled from growth by reduction of metal inputs). Where the use of resources has indirect impacts on other resources – including fossil fuel use, freshwater, or "environmental resources" like soil fertility and healthy air – increasing resource productivity can also be a way to reduce those negative impacts. Our report on priority products and materials (UNEP, 2010a) looks at the inter-relation between resource use and environmental impacts.

This could particularly be relevant for EU countries, which are increasingly importing goods whose production places intensive pressure on the environment (greenhouse gas and other industrial emissions, water pollution) from newly industrialising or developing countries.

At the same time, action can be taken to reduce the impact of resource use on environmental resources even without decreasing the level of resources used. This can be done in many ways, including reducing toxic emissions or substituting dangerous chemicals with less harmful chemicals. This is the usual realm of environment policy, and can lead to decoupling of economic growth from these negative environmental impacts. As illustrated in Figure 5.1, it can be called impact decoupling. It is particularly relevant where some activities have specific toxic or harmful effects on health and the environment.

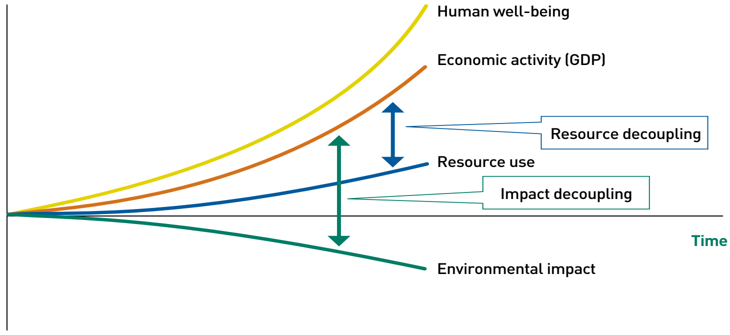

Figure 5.1 Conceptual and stylised representation of resource decoupling and impact decoupling graph (UNEP, 2011b, Figure 1 page xiiii)

This kind of "impact decoupling" can be particularly important for lower-income countries.

- In "low-income" economies, the livelihoods of many of the poorest people are directly dependent on local environmental ecosystem services – whether it be fertile soils, clean water, or biomass-based energy sources. It has been estimated that services provided by forests (for example for fuel wood provision) account for 7.3 per cent of India's overall GDP, but that they account for 57 per cent of the effective household income of those living below the poverty line and relying on activities like subsistence farming (Sukhdev et al., 2008).
- The World Bank has estimated that economic damage, productivity losses and public health impacts from environmental degradation costs Tunisia 2.1 per cent of its GDP, 3.7 per cent of Morocco's GDP and 5 per cent of GDP in Egypt (World Bank, 2010a).
- A range of studies now shows that such negative environmental impacts are having both direct and indirect impacts on economies and economic growth (Brown, 2008). Such "costs of inaction" to reduce environmental impacts will continue to mount if decoupling is not achieved quickly. OECD studies of the costs of inaction related to water and air pollution, biodiversity loss, climate change and natural disasters show that such costs are significant (OECD, 2008b), and are set to rise sharply by 2030 (OECD, 2008a).

Historically, it has – for obvious reasons – been environmental resources that have mattered most:

> *The great Empires of Assyria, Babylon, Carthage and Persia were destroyed by floods and deserts let loose in the wake of forest destruction. Erosion following forest destruction and soil depletion has been one of the most powerfully destructive forces in bringing about the downfall of civilisations and wiping out human existence from large tracts of the Earth's surface.*
>
> **Richard ST. Barbe Baker, 'I Planted Trees', 1944 (St. Barbe Baker, 1994)**

Figure 5.1 also illustrates that human wellbeing can be relatively decoupled from GDP and recognises that wellbeing is not only determined by the goods and services which are measured by GDP. (GDP is a constructed metric that measures only a subset of the activity which contributes to wellbeing, much of which is not traded or priced.) Policymakers aiming at increasing wellbeing of their citizens rather than GDP find that they have more options for achieving significant decoupling.

This is a significant feature of sustainability debates in prospering OECD countries, but also in other countries such as Bhutan and in Latin America, where the key word is "buen vivir" (good living).[40] The possibilities to decouple wellbeing from resource use have been analysed and proposed by Tim Jackson (Jackson, 2009), among others, while decisions to adopt complementary metrics of economic progress, in addition to GDP, have also become more common in OECD countries in recent years[41].

40 The concept of 'Buenvivir' has been included in the Constitutions of Ecuador and Bolivia. See also the Declaration of Cochabamba (WPCCC, 2010).

41 See for example the EU Beyond GDP Initiative: http://www.beyond-gdp.eu/index.html, the Commission on the Measurement of Economic Performance and Social Progress: http://www.stiglitz-sen-fitoussi.fr/en/index.htm, or the Office for National Statistics: http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/index.html

Neither of these important discussions is the focus this report.

Yet looking at the comparison between one other measure of progress and resource use can help show the possibilities for countries at different stages of development. Figure 5.2 shows the inter-relation of per capita domestic material use (DMC) (in tons/capita, on the horizontal axis), and the Human Developing Index (HDI, on the vertical axis) by country from 1980 to 2000.

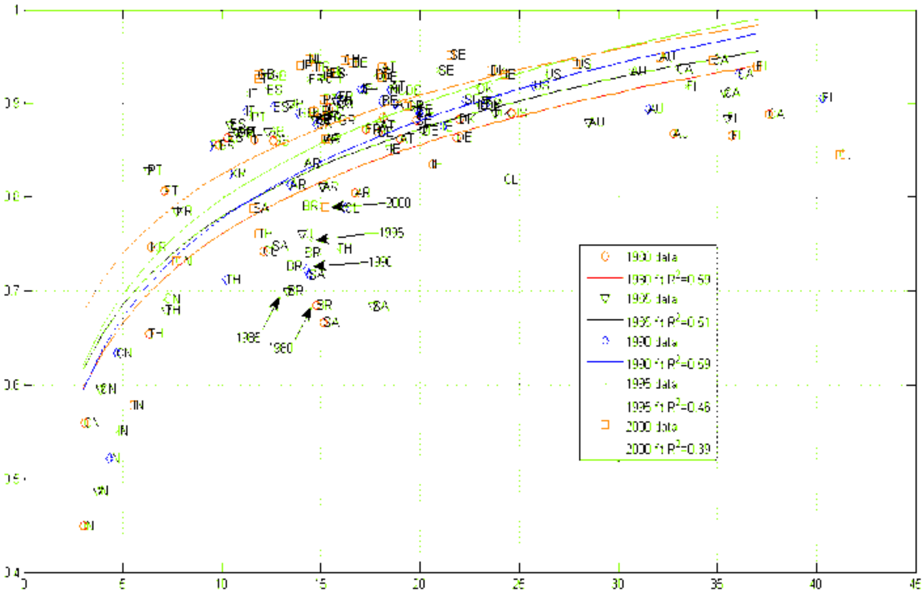

Figure 5.2 Comparison of per capita domestic material use and the Human Development Index
Source: Fischer-Kowalski, M. (2007)

There is a growing research body (Farley, 2005; WWF, 2008, Steimberg & Roberts, 2010) claiming that additional increases in material consumption no longer translate into proportionate increases in life quality (at least as expressed by the HDI) in for the 69 countries classed as high-income (38 OECD and non-OECD 31).

At the other end of the scale, there is a group of 40 low-income countries (basically in Africa, Asia and Latin America) for which any increments in consumption are immediately translated into higher HDI. These countries account for 12 per cent of the global population and have a huge demand for goods and services, because the greater part of their populations live below the poverty line. Absolute decoupling of growth from resource use in these countries would not be possible in the way that it would be for high-income countries. Improvements in resource productivity can directly contribute to economic growth, while impact decoupling may be particularly important to avoid waste of essential environmental resources.

In the intermediate level, there is a third group of 105 emergent countries (57 low to medium-income and 48 high to medium-income) representing 70 per cent of the world population. These countries do seem to have the possibility to use resource productivity gains to increase their HDI, as well as improving their economies.

6 Facilitating Transition: Removing barriers to decoupling

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6.1 Decoupling can happen

There is enough evidence to suggest that decoupling can be achieved. Most countries have already made investments that bring some degree of resource and impact decoupling. Several have reoriented their economic strategies to do more. There is now a wealth of experience with the measures that help facilitate decoupling.

Some of the investments already made in decoupling are so much part of the existing economy that they demonstrate how easily decoupling fits within existing economic structures. The recycling sector is one example. Recycling industries globally employ formally 1.5 million people and an estimate suggests that up to 15 million people are engaged in informal waste collection for their livelihood in developing countries (Medina, 2008). Recycling's global annual turnover exceeds US$160 billion dollars and processes more than 600 million tonnes of commodities annually (Oliver, 2008; BIR, n.d.).

However, the biases and barriers mentioned in Chapter 4 stand in the way of an economy's transition towards greater resource productivity. Their presence means that the most productive investments for future conditions do not necessarily take place.

To achieve the pace of decoupling required for economic success and stable environmental quality additional leadership from policymakers and others would be required. This chapter looks at examples of actions already taken across the world on decoupling, to illustrate the variety of ways in which decision-makers can facilitate change.

There are parallels between achievement of decoupling and the crucial role that states have frequently played in stimulating innovation in other areas. The public sector already plays a greater role in facilitating and steering innovation than is often acknowledged. Commentators have noted that to tackle the barriers to financing of innovation, developed states often take risks financing breakthrough innovations which the private sector is not set up to invest in. (This has included the technologies that led to the iPhone (Mazzucato, 2013). In several cases, government authorities have driven the industrialisation of nations, as seen in the past in Japan (Johnson, 1982) and in the "developmental states" seen more recently in other Asian (e.g. China, Singapore) nations and some South American and African countries (for an overview see Swilling and Annecke, 2012, chapter 4).

More specifically related to resources, there are many examples of successful decoupling where public sector leadership has overcome barriers to change. The case studies below illustrate aspects of decoupling.

6.2 Case studies of decoupling

6.2.1 Decoupling economic growth from freshwater extraction

There are multiple benefits from water resource productivity improvements, including lower business and household costs and delayed need for new and expensive water infrastructure. It is important to improve water quality and ensure access of unpolluted clean water to all people and the environment. Greater water productivity improvements also help rural, urban and coastal communities adapt to the likelihood of near-future reduced water availability in many parts of the world due to climate change. Also the more efficient use of water for agriculture and cities enables more water to become available for restoring environmental flows for river ecosystems and wetlands.

Readily available sources of freshwater are already under significant stress: freshwater lakes are shrinking; rivers are drying up and often fail to reach the ocean, while groundwater resources are already overused in many regions. Increasing rates of pollution loads caused by the major water use sectors (domestic, agriculture and industries) are already limiting available water resources for sustainable economic growth and other water services in many river basins. Many "dead zones" now exist around many of the major river deltas of the world, where marine life cannot be supported due to depleted oxygen levels. A study has recorded 405 dead zones worldwide, representing a more than 100 per cent increase in the last five years. These situations have increased the rates of physical water scarcity in many river basins.

Under an average economic growth scenario and if no efficiency gains are assumed, global demand to withdraw water would outstrip currently accessible, reliable water resources – including return flows – by 40 per cent by 2030. To meet expected growth in demand, the annual pace for supply additions over the next 20 years would have to be almost triple the rate at which it expanded over the past two decades.

6.2.2 Decoupling in Australia

From 2001 to 2009, Australia has reduced water consumption by around 40 per cent, while GDP has grown by more than 30 per cent, as Figure 6.1 shows. Usage in agriculture decreased from 12,200 to 7,000 Gigalitres (GL) from 2004-05 to 2008-09. Brisbane has achieved a 50 per cent per capita reduction in potable water usage from 2005-10. This came at negligible cost as most of the reduction was achieved through highly cost-effective investments in water efficiency and demand management.

This has allowed the use of scarce water in higher value sectors, like industry and manufacturing, resulting in significant improvements in water productivity – an increase of economic return from AU$50 million to AU$95 million per GL of water. There is still significant potential to improve water productivity through greater uptake of drip irrigation and irrigation scheduling techniques as well as higher use of treated recycled water.

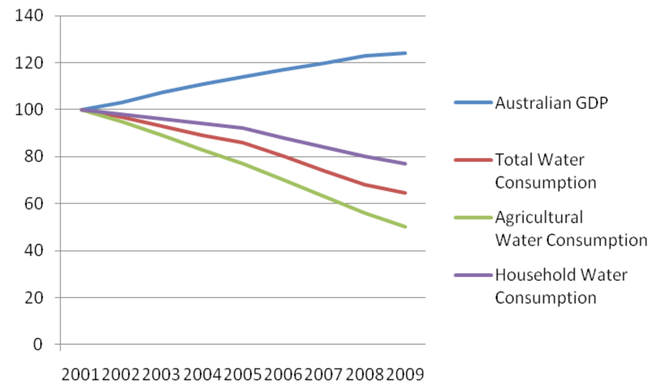

Figure 6.1 Australia - Absolute Decoupling of Economic Growth from Freshwater Abstraction [100 = 2001 levels]

6.2.3 Decoupling in Singapore

Singapore has achieved economic growth rates of in excess of 10 per cent over the last 40 years with the economy growing 25-fold in one of the fastest transitions from "developing" to a "leading first world" country in history. Its population has grown by a factor of 2.5 in that period to 4.4 million people. Yet water use has only increased five-fold, or a two-fold per capita increase. This represents a factor five decoupling (Figure 6.2). The average Singapore home now uses four times less water than a US home of comparable income. Singapore's water utility focused on reducing the demand for water by improving efficiency, cutting waste and expanding alternative sources of freshwater supply. Wasted water has been reduced (Khoo, 2005) to 5 per cent by 2002 compared to 40 per cent and 60 per cent for other Asian urban centres. This has allowed Singapore to cut its imports of water from Malaysia by 60 per cent and to commit to ending those imports entirely by 2060 through additional demand management and alternative water supply management options (PUB, 2009).

Singapore is one of the most striking successes, though other cities have also demonstrated the economic benefits of a focus on absolutely decoupling economic growth from freshwater extraction. Jerusalem, Los Angeles and San Diego, Austin, Melbourne and Sydney have all achieved significant reductions in water demand over the last two decades (Postel, 1997).

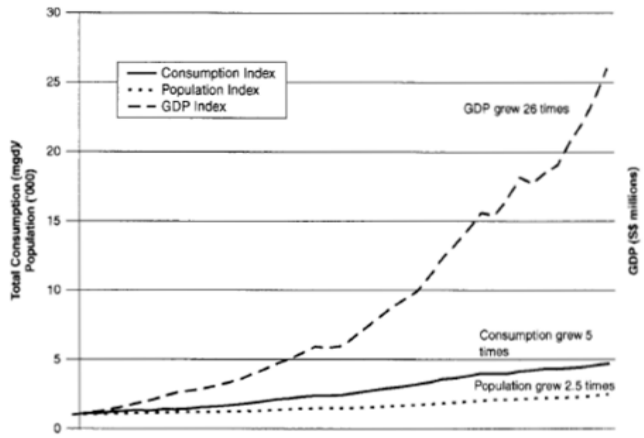

Figure 6.2 Singapore GDP, population and total water consumption growth (1965-2007) [1965 =1]
(Source: Khoo, T, C., 2008)

However, in general, countries have mixed records in water efficiency and productivity. Most countries have dysfunctional water supply infrastructure, with high levels of leakages ranging between 20-80 per cent. More than $18 billion worth of water is considered as non-revenue water per year worldwide, mainly due to leakage, private water sources, illegal connections and dysfunctional meters. Non-revenue water proportions range from as low as 15 per cent to more than 70 per cent of water withdrawals. The record on water productivity also varies by countries and by sectors.

Low levels of water efficiency and productivity are largely attributable to distortions in the water markets, capital availability and regulatory issues, as well as technological and infrastructure-related challenges. Current water prices often do not fully reflect resource scarcity or environmental costs. In many countries, the price of bulk or "upstream" water (particularly for agricultural use) has been largely static in real terms because the increasing costs of abstraction have not been passed on to end users. In 2011, direct subsidies of between US$200-300 billion supported water prices globally.

The successful transitions towards more efficient water uses were found in both in developed and developing countries. Key success factors appeared to be: existence of integrated water and/or environmental policies and structural and technological transformations toward low water-intensive economies. In all cases, investments in improved technologies and innovations were among the key drivers of water efficiency and productivity. For example, the use of freshwater on farms has halved in Israel since 1984, while the value of production has continued to climb, with the adoption of drip irrigation.

6.2.4 Decoupling economic growth from air pollution

Across the world, we find stories of successful absolute decoupling of air pollution from economic growth, in developing and developed economies.

At a regional level, Mexico City has shown the possibility to decouple growth from pollution of clean air. In 1992, it was the most polluted city on the planet with ozone levels thought to cause 1,000 deaths and 35,000 hospitalisations a year. Since then, lead in the air has dropped by 90 per cent and suspended particles – pieces of dust, soot or chemicals that lodge in lungs and cause asthma, emphysema or cancer – have been cut 70 per cent. Carbon monoxide and other pollutants also have been greatly reduced.

In central and southern Chile, the air quality in cities deteriorated as a result of emissions generated by the massive use of firewood as an energy source in homes. This problem was addressed by the government, which deployed a programme for exchange of the wood combustion equipment by greener technologies under the framework of the Atmospheric Decontamination Plan approved in 1995. The programme's objective was to exchange at least 12,000 pieces of equipment during its implementation period (2008-10), and it reduced emissions by 30 per cent (UNEP and Mercosur, 2011).

Over the three decades from 1970 to 2000, the majority of OECD countries achieved absolute decoupling of economic growth from all major air pollutants. A leading example of this has been global and regional efforts to decouple economic growth from sulphur dioxide pollution through first the 1983 "Helsinki protocol" and the UNECE Second Sulphur protocol in 1994. The Second Sulphur protocol committed nations to targets of 50 per cent reductions by the year 2000, 70 per cent by 2005, and 80 per cent by 2010 (UNECE, 1994). The environmental objective of the protocol – eventually to bring sulphur depositions in Europe within the critical loads of receiving ecosystems – is a fundamental principle of ecological sustainability. The emission reduction required was of the order of a factor of five, or 80 per cent. Initial perceptions were that it would be incredibly costly, but the arrival of cost effective low-sulphur fuel and a range of supporting technologies altered the cost situation such that the goal was attainable for significantly less cost than anticipated, $90 per ton rather than the anticipated $1,000-1,500 per ton (Hodges, 1997). When the costs of sulphur to health and the environment are monetised and taken into account, this phase-out has had negligible net impact on short-term economic performance (Figure 6.3).

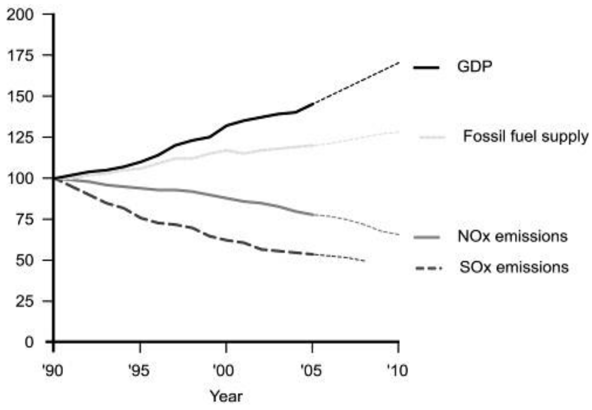

Figure 6.3 OECD: Air pollutants recede while the economy keeps growing (OECD, 2008c, p. 16)

6.3 Decoupling resource use across a whole economy

6.3.1 The challenges for decoupling

Most industrialised countries have experienced very strong decoupling of economic growth from local pollution. Here we have consistently seen "absolute decoupling" – meaning a net reduction of environmental damage as incomes increase.

On the other hand, for resource consumption, we have mostly seen only "relative decoupling", meaning that resource consumption per unit of economic production has decreased, but the overall use of resources in their economies has still increased. This is particularly the case if the resource use embodied in traded products consumed in an importing country is considered.

This suggests that future efforts to facilitate decoupling of resource consumption from economic growth may need to learn from the successes and failures of past attempts.

Successful decoupling of some environmental harm from resource use (sometimes absolutely, and sometimes on a local scale with burden-shifting) was driven by environmental policies, mainly from the 1970s onwards, starting with OECD countries. The key features which allowed this to happen were: a sufficiently strong political constituency to drive regulatory change, sufficient alternatives to highly polluting technologies and sufficient capacity of governments to control the technologies emitting pollution.

Decoupling economic growth from resource use generally has more additional challenges. One of those challenges comes from the extent of the globalisation of our economies that has brought so many economic benefits. Where goods and services are traded across borders, the boundaries of "the economy" are no longer defined by national boundaries – but by the extent of the network of contributors to the supply chain, the consumers of the goods or services, and even the people who receive the waste products at the end of their life. Physical goods, the resource intensive parts of economies, are usually widely traded, and supply and consumption networks can span many countries.

This implies that for many resources, the rebound effect described in section 2.2.3 appears likely to occur on a global scale. In interconnected resource markets, savings in resources in one country may lead to some degree of increase in use of those same resources in others. In the absence of international agreements, governments in any single country have the scope of their action to reduce rebound effects significantly limited (although not eliminated) by the geographic limitation of their regulatory powers to their own borders.

Where the resources in question are globally traded and can be used in production or consumed very widely – like many biotic resources, fossil fuels and many minerals (though not those used in very specialist applications) – this makes decoupling challenging. This contrasts with more local resources, which can include freshwater.

Secondly, the interaction seen between the economic system and the political system, mentioned as a barrier to innovation in section 4.8, appears particularly strong as a bias against policy reform in favour of resource productivity. This seems likely to be due to the absence of strong political coalitions arguing in favour of resource productivity: many of the negative impacts of resource scarcity are less visible (because they are indirect, come later [as with greenhouse gas emissions] or are further away, geographically) than direct damage to human health or the neighbourhood environment. This also stands in contrast to some of the successes with decoupling environmental impacts. Although many individuals and firms would benefit from being in a more resource-productive economy, most of them do not have resource efficiency gains at the front of their minds, reducing the chances that they are sufficiently motivated to group together to push for change. Many of the firms that would stand to gain most from a shift to a more resource-efficient economy are still small, and not politically active.

Yet for the level of improvements in resource productivity that would be needed to meet the challenge of global resource trends, economies would require dynamic technological innovation in resource productivity. Innovation would be needed at a rate currently only seen in the most innovative sectors of successful economies. It would need innovation in many firms and behavioural change of individuals.

6.3.2 Multi-level perspective on transition

There is a growing level of academic literature exploring how economies with biases against innovation can make structural changes and choose to develop and innovate towards a particular goal. This is based on analysis of past economic and societal transitions (for example, the industrial revolution) and can provide some useful ways to think about how to facilitate decoupling. In this context, decoupling is seen as a process of transition to an economy that is sufficiently resource-productive to be sustainable.

Much of the literature draws on the work analysing structural and institutional barriers and biases like those described in Chapter 4. It views the economy and innovation as part of a complex system, inter-related with political, cultural, ecological and technological aspects of society. So it goes beyond ideas that transition comes about by a strong state commanding a change in behaviours from firms and citizens. This is a more realistic reflection of the way in which, in most countries, external political influence determines policy choice, as much as policy choices determine economic and societal behaviours.

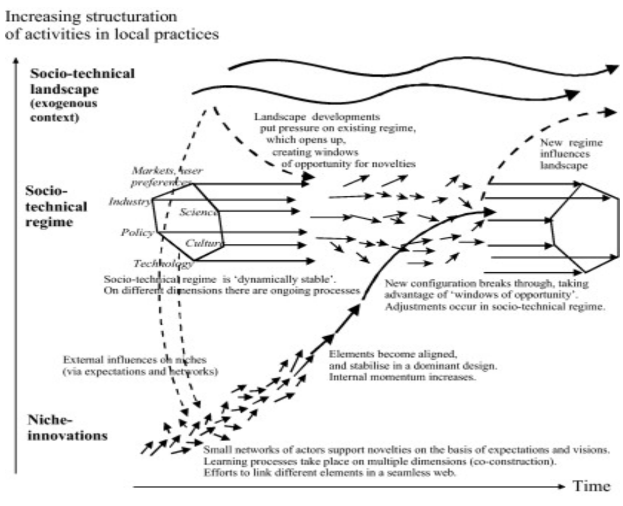

Figure 6.4 The Multi-Level Perspective of transition processes

One approach, called the Multi-Level Perspective[42], conceptualises three different levels of society that interact to facilitate or prevent decoupling, shown in Fugure 6.4. The key aspects of this thinking are:

42 For a more detailed description of the Multi-Level Perspective see Grin et al. (2010)

- Innovations can evolve on a small scale in niches, where there are favourable conditions for innovation.
- Whether these niche innovations manage to become widespread is partly dependent on the opportunities created by the mainstream "socio-technical regime", which is the set of technologies, policies, business models, consumption patterns and other forms of social organisation.
- This socio-technical regime is itself shaped by the "landscape" of physical, ecological and technological and cultural fundamentals current at the time – sometimes referred to as "megatrends", such as increasing climate change.
- The interactions between these different levels are sufficiently complex to make it hard to predict exactly the degree of change which will result from an innovation, or a new policy.
- Transition comes about due to action by innovative individuals, organisations or coalitions of people who are acting within broader societal institutions or structures. How much room they have to act depends on the conditions provided by those societal institutions.
- Due to the bias against change in these existing structures and institutions, significant change is unlikely to be able to be made in one part of the political-economic set up, without some other change taking place elsewhere. So transition is a process of co-evolution: with changes occurring simultaneously in at least a couple of the economic, political, cultural, technological and ecological areas.
- Transition will only come about by a very large number of changes, taking place at different levels over an extended period of time. At some stage, these may reach a tipping point, at which change escalates and becomes irreversible.
- A transition is very unlikely to naturally occur, but is shaped or directed (although not controlled) by individuals or identifiable groups of people organised to have sufficient influence on their part of the socioeconomic regime, or on niche innovation. Some refer to this as the "core adaptive leadership" of the transition (Heifetz, 1994).

This has implications for decoupling, and the widespread uptake of resource-productive technologies. It gives one framework for considering which actions would be needed by decision makers to unlock greater resource productivity gains:

- Because it is rare that any decision-maker within the political or economic system will have the independent power to effect radical change without other simultaneous changes, the Multi-Level Perspective suggests that facilitating decoupling would first need the creation of conditions in the economy which then support many smaller changes in the transition to resource productivity.
- This points to a role for many individuals to bring about change within their sphere of influence: people inside and outside government, whether in innovation, consumption patterns, business models or political and governance institutions. Such people are referred to as "change agents" in the literature.

Strands of academic research looking at political economy, behaviours and transition identify some factors that would promote transition:

- The need for a clear goal for the transition, agreed by sufficient people, or change agents, supporting change, so that many actions contribute to a shared goal.

- The need for a widely accepted narrative of the future, giving the reasons and routes for transition (Ostrom and Walker, 2003). Updating the mainstream economic narrative43, in the light of changes in resource use and its constraints, may be essential to the success of decoupling. Annex A mentions some issues in this respect.
- For the promotion of decoupling through resource productivity gains, policymakers concerned with resource and environmental limits need to broaden their goals: expanding their main focus from preventing harm to creating the conditions that encourage investment in resource productivity. This does not mean that policy to prevent environmental harm is any less crucial – it has remained essential in many respects. It means that an additional, broader goal for policy has been added to the strategies of forward-thinking economics and environmental ministries.

6.4 Creating the conditions for decoupling

To create the conditions for widespread investments in resource productivity, policymakers can take steps to increase innovation capacity, remove hindrances to innovation and reduce biases against resource productive investments. This can improve the functioning of economies, so that investments are made in the areas and innovations that bring the greatest future return to a country's economic goals. How much policymakers can do in practice is related to their resources, technical capacity and strength of political support.

The creation of favourable conditions can be made incrementally: the cumulative effect of many small changes affecting conditions for investment appears the most likely way in which the conditions for decoupling would be created. Creating the right conditions invites systemic changes, often of a long-term nature.

A central aspect of establishing favourable conditions for decoupling is the enhancement or creation of the market incentives that reward innovation in resource productivity. This provides dynamic ways of reducing future costs, as measures doing this tend to provide a continual incentive to reduce resource consumption, promoting new technology, and permitting maximum flexibility in achieving resource efficiency and emissions reductions (Harrington and Morgenstern, 2004).

They have the potential to encourage engineers, managers, and investors to think of innovative strategies, including complex systems design, in pursuit of better returns on investments by continually saving resources, rather than requiring policymakers to periodically attempt to gather similar levels of knowledge on technical possibilities and make policy decisions on that basis. Market signals can bring about changes in technology, products, and individual behaviour across value chains without the need for interventions by policy makers at each level of that value chain. Where other conditions for innovation are already in place, the link between one policy and a strong upswing in innovation can sometimes been seen. (Figure 6.5).

43 The prevailing narrative for economic development is based on the unlimited use of fossil fuels and material resources. This narrative dates from at least the time of Adam Smith, at a time when the world's population was less than 1 billion and the industrial revolution was just about to begin.

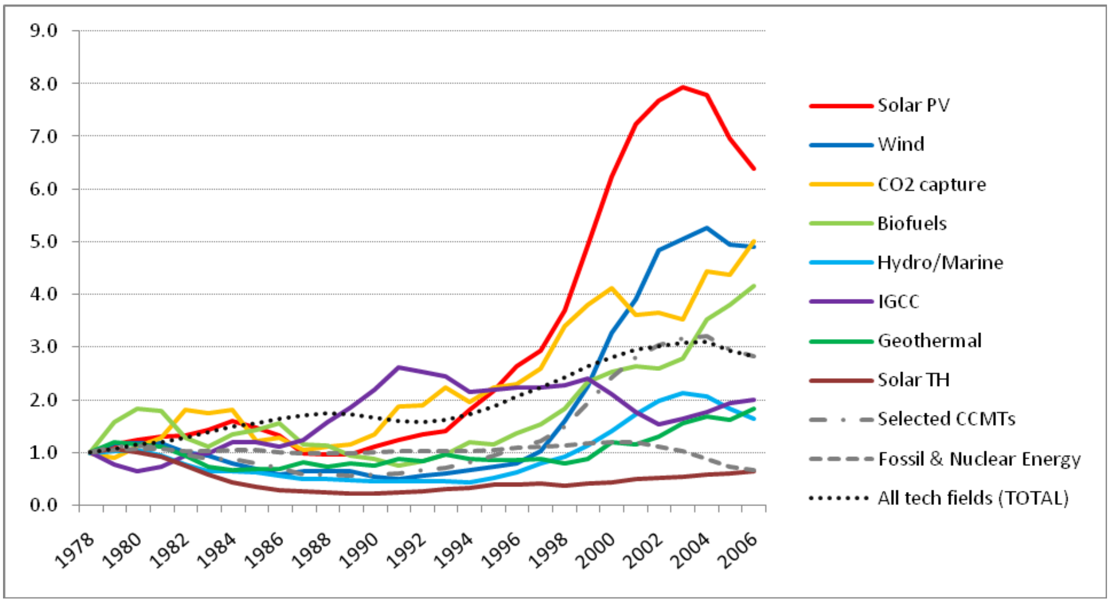

Figure 6.5 Growth rates of patents relating to renewable energy technologies compared with other energy technologies. 3-year moving average, indexed on 1978=1.0) (Haščič et al., 2010, p. 12). The jump was prompted in part by the feed-in-tariffs law in Germany (see chapter 7.6.1)

6.4.1 Many policy makers have a crucial role

Prices tend to be the strongest language for influencing firms and individuals and helping them consider less wasteful alternatives of reaching the same desired goals. Yet as the barriers to innovation in resource productivity are widespread – and often connected to each other – success in decoupling would need many policy changes. This presents an opportunity to forward-thinking policymakers across different policy areas. It also indicates a key role for influential political and economic forces to shape policies where they have influence. It would need to include actions:

- In the areas of economic affairs and development, fiscal affairs, transport, trade, planning and infrastructure, science and technology, and education. These are central to resource productivity. This means that resource policies unavoidably require the attention of the top ranks of our political leadership to help policy coordination.
- That take many different forms of measures, such as voluntary agreements, labelling, research and development, fiscal change, institution building, market development, public procurement and education.[44]
- That address resource and environmental issues at different phases of a product life cycle, e.g. during manufacturing, during use or relating to disposal.

For example, in the specific field of the sustainable energy transformation, the World Business Council for Sustainable Development has offered a tabulation giving an overview of the range of policy measures to be used:

44 For Europe (including Turkey), there is a good overview from EEA (2011); Another useful source: GTZ, CSCP and Wuppertal Institute (2006).

Type	Category	Examples
Economic Instruments	Subsidies	Gasoline subsidies Feed-in tariffs Fiscal incentives Direct subsidies to R&D Loan softening/guarantees Subsidies for public transport for the poor
	Taxes	Gasoline taxes R&D tax credits Carbon taxes
	Permit trading	Carbon trading market Renewable energy credit trading
	Public procurement/ investments	Green procurement Public investment in R&D infrastructure Government funding of demonstration projects Government-sponsored R&D, national laboratories National/State-funded or -run venture capitalism Public investment in education and training Government investments in science and technology parks
Command-and-control measures	Standards and regulations	Standards for biofuel blending Energy-efficiency standards Renewable energy obligations Cooking stove standards
	Goals and targets	Sectoral energy intensity targets Greenhouse gas mitigation targets Energy access targets
Cooperation	Domestic	Promotion of collaborative RD&D Public-private partnerships and knowledge exchange
	International	Official development assistance (ODA) for energy access and clean technologies Trade preferences for specific technology clusters Bilateral and plurilateral agreements on technology cooperation

Figure 6.6: An overview of instruments driving the economy towards sustainable energy use (WBCSD, 2011)

Chapter 7 provides examples of some types of the policy measures that have been used to create the conditions for resource productive investments.

6.4.2 Creation of policy mixes

As suggested by the Multi-level Perspective, simultaneous changes to different, related barriers to innovation are likely to be needed to make significant progress. The way in which the set of policy measures are used in combination can make a significant difference to the outcome.

The OECD's research in this area, based on many years of experience, has found that a portfolio policy approach utilising a variety of government mechanisms and policies is the most effective strategy to underpin decoupling of economic growth and environmental pressures and ensure minimal negative effects to existing businesses' competitiveness from transition. They write that:

> Significant environmental improvement can be achieved at relatively low cost to the economy and with little negative social impact if the right mix of policies is used. The necessary policies and technological solutions to tackle the key environmental challenges are both available and affordable. (...) Even for a single environmental problem, an instrument mix may be needed given the often complex and inter-connected nature of many environmental challenges, the often large number and variety of sources exerting pressure on the environment, and the many market and information failures. Instrument mixes need to be carefully constructed

> to ensure that they achieve a given environmental goal in an effective and economically efficient manner, while providing consumers and producers with flexibility in how they meet the targets, so as to enable innovation. Social or equity impacts should be addressed. Instrument mixes should provide clear, short- and long-term policy signals to support appropriate investment decisions. The policy instruments used in a mix should be complementary and reinforcing, rather than duplicative or conflicting. (OECD, 2008a, p. 432).

Creating conditions that deliver the pace of productivity gains which result in absolute decoupling may require new ways of thinking. When considering the instruments to include in a policy mix, policymakers are likely to need to think about the appropriate timeframes guiding their goals, and the scope of the impact they are seeking:

6.4.3 Long-term thinking

One of the barriers that seems to create biases in decision-making against more productive investments is the pervasiveness of decisions based on short-term impacts.

Whether in finance, business or politics, this is very often because the decision-maker will be rewarded (financially or by political success) on the basis of short-term, direct impacts. Yet, for those decision-makers looking to provide leadership, and longer-term success for their countries or firms, adopting wider ways of thinking would be important.

Countries are likely to fare best with long-term targets and with incentives that will make ever more intelligent and efficient use of natural resources continuously profitable. A policy of a long-term vision and of incremental signals could be the recipe for stimulating innovation in the direction of truly sustainable development and avoiding capital destruction from unpredicted obsolescence and associated political resistance to policy change.

Taking a long-term perspective can help in the identification of trends that make incremental differences year-on-year, but which present serious challenges or opportunities for the future. For example, Figure 6.7 shows that the share of primary goods among Latin America's exports is still growing and has even exceeded 50 per cent. The use of resources in Latin America is neither sustainable nor efficient. It may take some time until resource-exporting countries move towards higher value levels of production and resource efficiency.

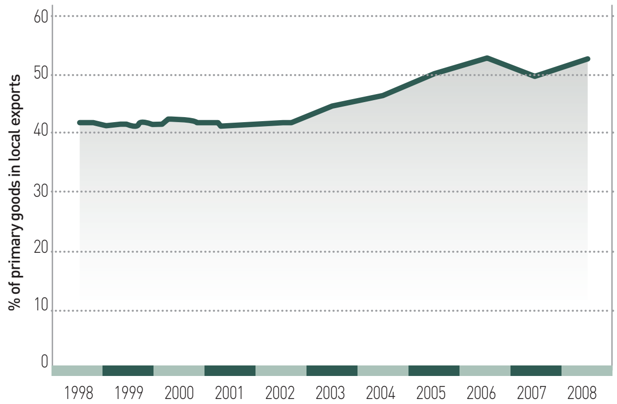

Figure 6.7 The share of primary goods in Latin American exports is still growing, indicating that the continent may not be on a sustainable path, according to UNEP (UNEP and Mercosur, 2011)

6.4.4 Selecting the scope

When selecting a mix of policy instruments for a particular goal, policymakers have choices over the breadth of the firms, individuals or institutional arrangements which they want to target. For example, a policy mix could target a particular locality, or the firms involved in the production and consumption of a particular product.

When considering the scope of action, there is a need for a whole systems approach (see Stasinopoulos et al., 2009). This is valuable for designing policy attempting to influence separate stages of the use of resources inside complex economic and environmental systems. For example, although it is important to ensure that automobiles are designed to be more energy efficient, this is only part of the wider system. The entire transport infrastructure, the philosophy of logistics, and the shape and spread of human settlements influence the amount of energy and other resources spent on transportation. Policy changes that take this into account can find mutually reinforcing policies and new ways to introduce policies that can bring economic and environmental benefits. Other considerations, relevant to scope are:

- The evolution of innovations may need to be promoted in niches, where favourable conditions can be created, before it spreads to the mainstream. Practically, this may suggest leadership by businesses, citizens and policymakers acting together on certain value chains, which can serve as niches, or in certain geographic or urban locations.
- Wisely choosing the scope, or boundaries, of the part of the economy to be influenced is important to the outcome. One of the most important factors is the strength of economic exchange between people of firms. Firms in a supply chain based in one country supplying parts for a product that is manufactured in another are usually much more closely related than firms in the same geographic area involved in the production of entirely different goods. This implies that considering value chains of economic activity may often be a good starting point for policy decisions. In other cases, people and firms sharing infrastructure, common services and governance structures may be the most helpful way to draw boundaries of action. This is often the case for cities, which are also the location for most economic activity. Our report on City-Level Decoupling examines the crucial role of decoupling policies in cities (UNEP, 2013c).
- While pollution prevention has been mostly addressing manufacturers and the service industry, resource policies are also addressing consumers, inviting them to consider arranging their daily habits, homes, vehicles and nutrition to consume less non-renewable resources.
- Resource-saving policies must consider the impacts and influences upstream in the production and consumption chain, while earlier environmental policies tended to focus on reducing pollution at "the end of the pipe". Life cycle-thinking and management can help avoid too much burden-shifting around the globe and encourage greater resource productivity throughout the system.

6.5 Life -cycle thinking

Measures to remove disadvantages against resource-productive investments have to be based on clear identification of which investments are more resource-productive and which are less. Getting to the right decision on a policy mix will probably involve consideration of the indirect impacts of a change on resources at each of the life cycle stages: from use of resources or environmental harm from extraction, up to waste disposal at the end of life.

Methodologies already exist to help policymakers consider these influences all along the supply chain from production through to consumption. Using these methodologies can allow policies to be shaped and coordinated to provide consistent incentives for innovation in resource productivity, and so stimulate these savings where the opportunities are most cost-effective.

Among the different life cycle based methodologies, Life Cycle Assessment (LCA) (ISO 14040:2006) is currently widely adopted[45] to assess environmental impacts associated with all the stages of a product's life from cradle-to-grave (i.e. from raw material extraction through to materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). It aims to avoid impacts and inefficiencies throughout the entire life cycle. LCA can help avoid a narrow outlook on environmental concerns by compiling an inventory of relevant energy and material inputs and environmental releases, evaluating the potential impacts associated with identified inputs and releases and interpreting the results to help make a more informed decision. Figure 6.8 indicates the fundamental phases of LCA.

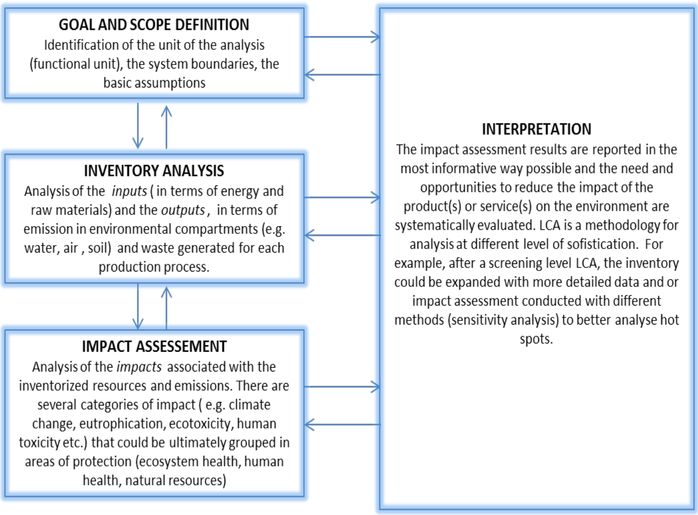

Figure 6.8 The Phases of Life Cycle Assessment

Due to its comprehensiveness, LCA is the basis for designing resource efficient processes and products, enhancing the eco-design of a product and process and adopting the "whole systems approach". The key to the whole systems approach is identifying the right problems to solve along the product life cycle, well before design begins (Stasinopolous et al., 2009).

Significant efforts are ongoing at international level towards harmonisation of life cycle assessment methods in order to ensure robustness and comparability (e.g. the ILCD Handbook of the European Commission and the methodology for Product Environmental Footprint[46]). Since 2002, UNEP and the Society for Environmental Toxicology and Chemistry (SETAC) have launched, together with a number of governments and industry associations or companies, a Life Cycle Initiative[47] aimed at promoting wider adoption of life cycle thinking and overcoming barriers to implementation.

Life cycle thinking has been more and more integrated into investments firms make, and the way they design products, joining with environmental management systems to comprehensively assess impacts over product life cycles (Sala et al., 2012).

The life cycle analysis includes assessment of the results from changes (to policy stimulus, or investments). Often, the basis for this part of the analysis is a widely used analysis framework called the DPSIR method (Driving Forces, Pressures, States, Impacts, Responses), symbolised in Figure 6.9. By clarifying the cause-effect chain between drivers of resource pressures and the foreseeable impacts of resource scarcities, it can help in identifying policy responses addressing drivers, pressures, states and impacts. The DPSIR framework has been successfully used for policy formation for managing pollutants (Figure 6.9), water (Kristensen et al., 2004), and energy (EEA, 2008) and can be used for policy for decoupling.

45 Other Life cycle based methodologies are e.g SLCA (social Life cycle assessment), LCC (life cycle costing) and LCSA (Life Cycle Sustainability Assessment).

46 International Reference Life Cycle Data System (ILCD) Handbook, available from: http://publications.jrc.ec.europa.eu/repository/handle/111111111/25589; Product environmental footprint (PEF), available from: http://ec.europa.eu/environment/eussd/smgp/product_footprint.htm.

47 http://www.lifecycleinitiative.org/

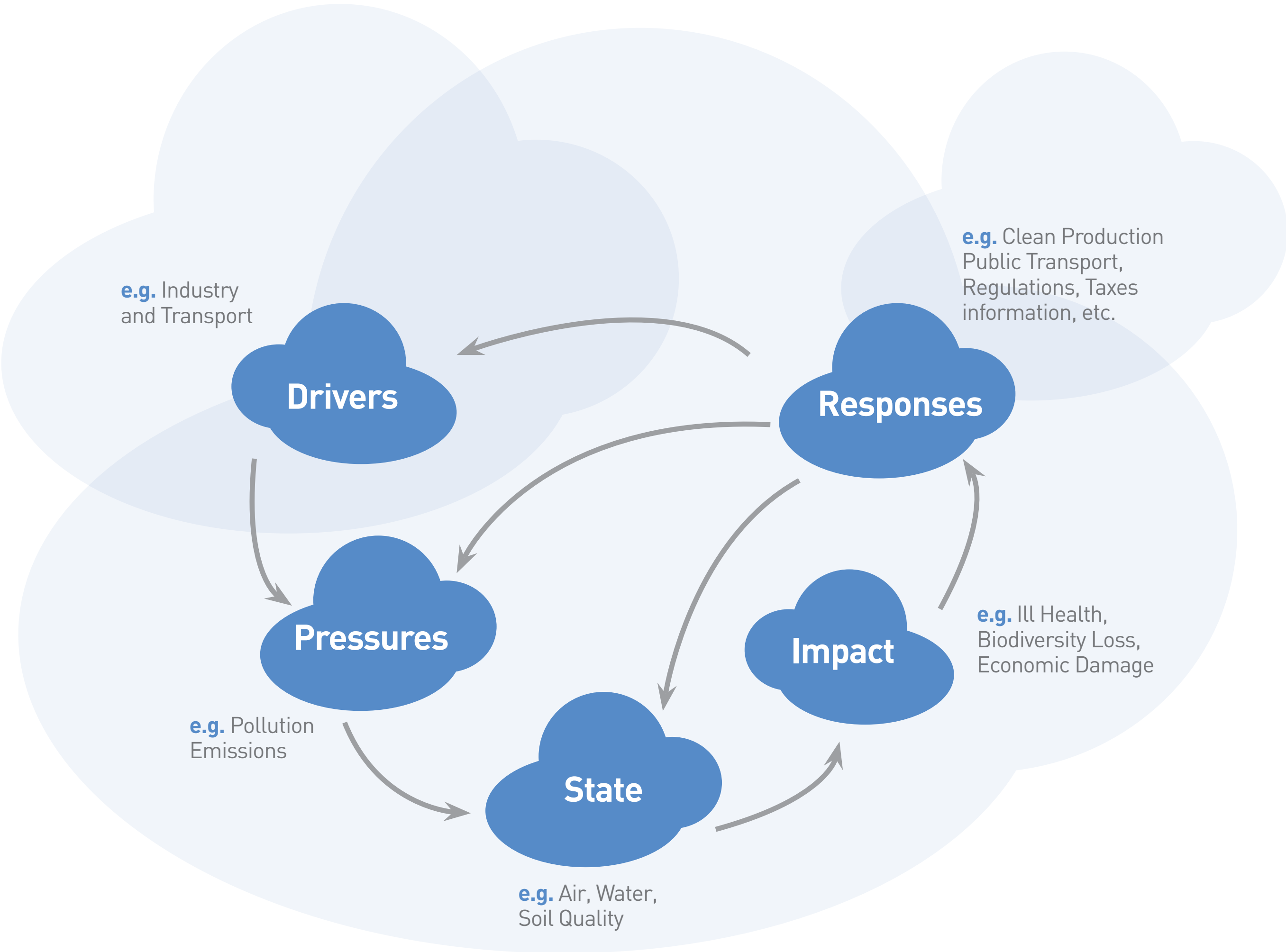

Figure 6.9 **The DPSIR Framework, depicted here from a publication on air pollution control of the European Environment Agency (EEA, 1997, Fig. 1)**

7 An overview of policies that have promoted decoupling

This chapter provides an overview of some of the types of policy measures that have been used to facilitate greater resource productivity. Between them, they give examples that contribute to tackling a range of the barriers and biases holding back transition to more resource-productive economies:

- Reducing investment uncertainty and political lock-in, and changing unhelpful public decision making structures: Section 7.1 on Strategies
- Increasing innovation capacity: Section 7.2
- Adjusting government pricing instruments to align market resource prices with decoupling: Section 7.3, 7.4 and 7.5
- Creating new market structures: Section 7.6
- Restricting harmful activities or products, and strengthening markets for innovation: Section 7.7 on Bans and Requirements, and Section 7.8 on measures increasing demand
- Overcoming behavioural lock-in and social norms: Section 7.9

7.1 Strategies

Strategies can be seen as policy instruments in themselves, and not only packaging, bundling together other policies. They can perform several functions to reduce barriers to decoupling:

7.1.1 Reducing uncertainty and providing direction

For people to adapt today to the challenges of tomorrow, clear signals about the way the future will look are crucial. When policymakers can provide a credible direction for change, they can reduce uncertainty around investments in resource productivity and so remove a bias against decoupling.

The reduction of this uncertainty is one of the central roles of strategies. Strategies are frequently used to create visions and goals for the future and provide clear routes to achieve those goals through credible mechanisms and measures. In this role, the formation of a strategy is a policy instrument, one that changes expectations about the future.

- One example is the Republic of Korea's Framework Act for Low Carbon Green Growth, which introduces goals and measures to foster green technology and industries, to create new green jobs, reduce energy dependency and prepare for future risks in resource markets (Republic of South Korea, 2010).
- Clear, achievable goals are one factor in driving change. The regular Five-Year Plans produced by China contain such targets. For instance, the eleventh plan in 2006 made a commitment of increasing national energy productivity by 20 per cent, which is a stunning commitment for a five-year period, and it was achieved. The twelfth Five-Year Plan adopted early 2011 added another 16 per cent energy efficiency increase (and 17 per cent "carbon efficiency" increase, consistent with the goal of reducing carbon intensity by 40-45 per cent until 2020, based on 2005 levels) (People's Republic of China, 2011).
- In Latin America, countries such as Guyana (Republic of Guyana, 2010) have adopted polices specially oriented to sustainable consumption and production (SCP). In November 2011, Brazil launched its SCP plan, which prioritises education for sustainable consumption, sustainable construction, environmental agenda in public administration, retail and consumption, sustainable procurement and increased recycling of solid waste. Besides this plan, Brazil has already implemented the National Plans for Solid Waste (2010), for Climate Change (2008), and for Water (2007) (World Bank, 2010b).
- Hundreds of other plans exist at international, national and city levels, all converging into the objective of making better and more efficient use of scarce natural resources. They contain thousands of actions relate to specific topics, most prominently water, climate and the recovery of mineral resources from waste.

The effectiveness of a strategy in delivering predictability depends on its degree of credibility and clarity, and the degree of political support behind it. This often means that the process by which the strategy is produced or agreed can have an impact on its success. Sufficient cooperation between government and industry must be part of the formation of the policy framework, if it is to be seen as credible and relevant.

Strategies have other important roles, particularly creating policy coherence and justifying the creation of new institutional structures.

7.1.2 Creating policy coherence

To create the conditions for resource decoupling, governments and law-making parliaments would have to utilise the entire arsenal of instruments from different policy areas – and this creates problems of coherence. Coordination reduces costs and increase benefits from complementarity between polices. It can mitigate the conflicting indirect effects of some existing policies, particularly taxation and regulatory policy on investments, which are often strong biases against innovation in resource productivity.

- For instance, Portugal implemented major energy policy reform since 2004 on both renewable energy and energy efficiency. This has led to Portugal increasing the share of renewables (including hydroelectric power) in total energy supply to 50 per cent by 2010 (Eurostat, 2012). The increase in share of renewable was made easier by reductions in total energy demand through energy efficiency.

- The EU adopted a Roadmap to a Resource-Efficient Europe for the transition to a more resource-efficient economy (European Commission, 2011 a-c) which forms one leg of the EU's economic strategy for 2020. It is one of a wide range of EU documents aiming to decouple growth from resource use and environmental pressures (European Commission 2001a, b, 2004a, 2005a-c, 2008a; Decision No 1600/2002/EC; Giljum et al., 2005). It includes policies related to energy, climate change, research and innovation, industry, transport, agriculture, fisheries and the environment. Policy mechanisms to implement the strategy include legislation, market-based instruments and refocusing of funding instruments.
- California has significantly decoupled GDP growth from electricity and water demand through institutional and policy coherence dealing with the linkages between energy and water supply.

The process of formation of strategies can bring together the decision-makers responsible for different areas of policy and provide the incentives and the interactions that help create greater coordination and coherence between policies.

7.1.3 Creation of new institutional structures

Implementation of strategies often requires changes to institutions to bring the necessary capabilities and powers together. It can be an opportunity for government reform. By finding agreement on a shared goal for the future, strategies are able to facilitate creation of the new institutional structures that are needed to move towards that goal.

For example, the cornerstone of New Zealand's green planning effort, the Resource Management Act of 1991, has a single purpose that applies to all activities on land, air, water and the coast – the sustainable management of the nation's natural resources. Accordingly, New Zealand radically restructured its government institutions and revamped its laws to create well-defined environmental policy and management roles. This included an innovative system of regional government with new boundaries based on watersheds. In 2010, New Zealand further developed a framework for resource efficiency, based on a review of international activities dealing with resource efficiency (Government of New Zealand, 2010).

Similarly, a policy feature important for good water management is the spatial organisation of implementation action according to catchment areas. France introduced this system in 1964 with six water basin agencies. These agencies are public institutions under the supervision of the Ministry in charge of the Environment and of the Finance Ministry. They bring together stakeholders (representatives of water users and of local authorities) at the basin level in a "water parliament", deciding upon a pluri-annual intervention programme geared toward developing water resources and reducing pollution. They also decide upon the water use charges and wastewater discharge charges, and upon contributions to financing of the infrastructures (waste water treatment facilities, dams, etc). A law adopted in 2006 consolidated the rules for determining the charge base and caps their rates. Charges accrue from water use, private homes waste water discharge, agricultural and industrial water discharges, (from agriculture with a standard in relation to the number of animals), and diffuse pollution, chiefly from pesticides. Revenues are used for maintenance and modernisation of the system, for the protection of aquatic zones and for water storage in times of low water. In 2009, the total revenue from the charges was more than €2 billion, with pollution charges contributing the biggest part. New Zealand has more or less copied the watershed management. Similar arrangements exist in the USA and other countries (Deli Priscoli, n.d.).

7.1.4 Advisory strategies

Additionally, strategy documents can be advisory: describing the measures that would need to be put in place, and so helping overcome institutional biases in favour of existing policy mixes or economic structures. Their strength and persuasiveness comes from the possibility to take a long-term view, use of science and analysis of problems and solutions, and often the participation of influential political or scientific people and organisations in their formation. The forums forming these strategies are sometimes able to work outside national institutional structures (such as the divide between ministerial responsibilities) and by doing so, find solutions that will facilitate change. This can be particularly important for crosscutting strategies, like those associated with decoupling. Examples include:

- The 2001 OECD Environmental Strategy for the First Decade of the 21st Century (OECD, 2001a). One of the early decoupling strategies.
- The World Bank, together with the World Economic Forum and the International Energy Agency, launched an initiative in 2008 to support resource efficiency in cities, called "Slim Cities Initiative".
- After the global financial meltdown of 2008, UNEP conceptualised the escape from the crisis through the Global Green New Deal (Barbier, 2009) and later the Green Economy Initiative (UNEP, 2011c). Both contain the strategic increase of resource productivity as a core element. The Green Economy Report documents the advantages and means for investing in 10 central sectors of the economy in order to shift development onto a resource-efficient, low-carbon path that factors in future resource demand/supply imbalances.
- The OECD's 2011 Green Growth Strategy (OECD, 2011a), which shows how reducing unsustainable pressures on the quality and quantity of natural resources reinforces economic growth.
- Decoupling has been adopted as a key framework and extensively promoted by the UN Economic and Social Commission for Asia and the Pacific.

7.2 Innovation enabling policies

The second area of measures to facilitate greater resource productivity are instruments that increase or facilitate an economy's capacity to innovate. Neither the innovation capacity, nor the measures, must necessarily be specifically aimed at increasing resource productivity. In many developing countries, creation of the generic innovation capacity is the starting point. There are two kinds, which are often related:

- Policies which boost the capacity to innovate;
- Policies which facilitate change and the spread of innovation by reducing the downsides of innovation.

7.2.1 Policies increasing capacity to innovate

In economies with developed innovation systems, those systems may still not be highly capable in resource productivity: they may lack researchers with the right knowledge, the networks, the technological capacity and the institutions (e.g. long-term funding) which would support innovation in resource productivity.

The measures can directly support research, stimulate demand, remove blocks to supply, or take many other forms. They include: promoting skills, creating networks, exchanging international experience, infrastructure planning to support innovation, and capacity building and education curriculum reform (Desha and Hargroves, 2012).

7.2.2 Policies reducing the downsides of change

An increase in the pace of innovation implies faster economic change which often results in greater disruption of existing economic structures and skill sets. Policies which help workers and entrepreneurs change at the pace of innovation will be needed to reduce social costs from change, and so enable political acceptance. These include policies supporting redundant workers to find new jobs and reskilling.

7.3 Policies directly affecting resource prices

One of the central conditions for encouraging resource-productive investments in market economies is the relative price of resources. For a market economy to make a transition in the direction which society wants, the price signals need to align with the strategic goals of the society. This has the potential to redefine the agenda of firms and individuals such that their investment and purchase decisions made in their own interest are in line with society's.

This contrasts with widespread desires that resources should be free, or very cheap. For example, in the world's farming communities, there is a belief that water should be offered as a free good, or a free public service, to all in need of it. If resources really were costless – which they would be were they inexhaustible and ubiquitous, and cost nothing to extract or harvest – then they should be free. This would be the ideal situation in many respects. However, when there are costs from resource consumption, limits to resources, indirect harm to others, or costs of provision, having prices lower than the real costs encourages waste, discourages productivity and, as Chapter 1 shows, leads to accumulation of negative impacts.

So, for example, in its Water for Growth and Development Framework, the South African Department of Water Affairs and Forestry concurred with the economic view that social welfare is maximised when all costs are reflected in prices, a concept sometimes referred to as "full cost pricing". It recognised that when prices are artificially low, consumption tends to be excessive and that it is important to use pricing as a means for consumers to appreciate the true value of water. Hopefully, this will effect changes in its consumption and achieve efficiency gains that will enable water system managers to postpone the need for new capital outlays.

A policy change that rectifies price distortions at one point in the production chain passes through that benefit to other aspects of production and consumption of a product, not only addressing manufacturers and service providers, but also consumers.

Box 2: Example of price change: the response to the 1970s energy crises

The 1970s oil shocks provided an example of how economies can successfully develop through different resource use patterns.

- After the oil shock, the OECD nations taken together decreased energy intensity of their economies by 20 per cent from 1973-85. For the same period, in countries belonging to the IEA, GDP grew by nearly 32 per cent, but energy use by only 5 per cent. In the US, GDP rose by 27 per cent, oil consumption fell by 17 per cent, net oil imports fell by 50 per cent. Between 1977-85, USA GDP grew 3 per cent a year, yet oil use fell 2 per cent a year, achieving a reduction in oil intensity of 5.2 per cent per year. This was enabled by end-use efficiency technological innovations and policy reforms. For instance, for US automobiles, 96 per cent of their efficiency gains came from more efficient design, with 4 per cent from smaller size.
- California (the world's eighth largest economy) has shown how feasible it is to continue these trends by decoupling GDP from fossil fuel electricity use per capita since the late 1970s. Figure 7.1 shows the success story. Since 1978, the Californian Public Utility Commission made licences for new power plants dependent on the proof that new power was economically more favourable than helping customers to save energy. Utilities helping their customers on efficiency earned the benefit of saving investment capital for new plants and were allowed to charge higher kilowatt prices as long as customers paid less on a monthly basis. The scheme saved California more than US$56 billion in electricity and natural gas costs (The Climate Group, n.d.). More recently, California has passed legislation committing to source 33 per cent of its power by 2020 from renewable energy.

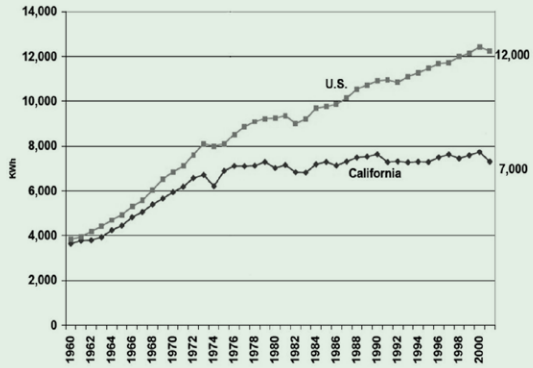

Figure 7.1 Comparison of Electricity Usage Per Capita between the USA and California from 1960 - 2000

- The oil crises and the low prices of the sugar in the 1970s pushed Brazil to the beginning of a new strategy to deal with fuels. Brazil developed biofuels from sugarcane, seen in the country as a very successful programme. The ProAlcool was set up in 1975 when energy supply became a main priority. The objective was to slow down fuel imports while maintaining economic growth, by producing ethanol by biomass (sugarcane cassava and sorghum) to substitute gasoline. Sugarcane was the chosen substrate for ethanol production due to its great adaptation to the Brazilian soil and weather condition. The anhydrous alcohols (up to 20 per cent) were mixed with gasoline (Soccol et al., 2005). As one would expect, any large-scale programme of this kind comes with downsides, notably regarding the environment. Brazilian authors Luiz Martinelli and Solange Filoso write about soil erosion, deterioration of aquatic systems, nitrogen pollution, destruction of riparian ecosystems and air pollution from sugarcane burning (Martinelli and Filoso, 2008). They also mention social troubles such as misery and deaths of cane cutters.

Unless the state has the power to set prices itself, the policies that directly affect resource prices can be price–based (charges, fees, taxes, or removal of subsidies) or rights–based (tradable permits, auctioned user rights)[48], the latter of which usually require setting up of new market institutions.

48 For a general treatment of MBI's see: European Commission (2007). For an analysis of price vs. rights instruments relating to resource efficiency in fisheries see Economic Instruments.Tthe rights approach for fisheries is addressed in Le Gallic, B. (2004).

7.4 Price-based instruments: fees and charges, taxes and subsidies

7.4.1 Fees or charges

Fees or charges are generally paid for the use of natural resources or for services in this context. Examples are water fees, wastewater charges, pollution charges, and waste collection charges. They are compulsory, and their purpose is to recover the costs (operating or capital, or both) of providing a service. The proceeds of the fees or charges do not typically end up in the government's general budget – rather, they end up with the service provider, public or private.

Cost-covering fees can indicate to consumers the real price of the sustainable provision of the respective resource. This was made explicit in the US Environmental Protection Agency's Water Conservation Plan guidelines (EPA, 1998a), stating that water costing and pricing is also seen as a conservation strategy conveying the information about the value of a reliable provision of clean water.

In South Africa, the types of charging for water can include: repeal of discounts to industry as an establishment incentive; increasing block tariffs; seasonal rates, higher tariffs during dry seasons and droughts and excess use charges. In the agriculture sector despite average increases in excess of 20 per cent per annum since the new pricing strategy was introduced.

7.4.2 Taxes

In contrast, taxes are primarily defined as revenue-raising instruments. They are compulsory payments to the government, appearing as revenues in the budget. Taxes are a central symbol of the social contract. In the words of Adam Smith (Smith, 1776, p. 704): "Every tax, however, is, to the person who pays it, a badge, not of slavery, but of liberty." Taxes are needed to finance public goods and services countries consider necessary, such as infrastructures, the legal system, public administration, external defence and internal security, social security or basic education.

While usually designed as revenue-raising instruments, the choice of which tax to use has hugely important side effects, only one of which is usually debated. They have a – usually intended – redistributive effect, frequently from the wealthier to the poorer segments of society.

But taxes can also have a strong incentive effect, inducing taxpayers to reduce habits leading to high tax payments. Where a tax takes the price of an economic resource further away from its true cost (for example, by increasing labour costs), its incentive effect is distortionary and it adds inefficiency to the economy.

7.4.3 Subsidies

A subsidy is a fiscal benefit (such as a tax exemption or rebate) or financial aid (such as a cash grant or soft loan) provided by a government intending to support an activity considered desirable, such as food production, strategic industries or products, or exports. The basic characteristic of all subsidies is to reduce the market price of an item below its true cost of supply. A case in point is water supplies for poor families and for agriculture.

Very often, subsidies support continued inefficient use of resources, not resource productivity. Partly, this comes out of their primary motive, which is as a tool of income support. As a UNEP report (UNEP DTIE, 2008, p.12) on energy puts it:

> "... studies demonstrate that, globally, subsidies are large and that non-OECD countries account for the bulk of them, (and) ... suggest that the majority of energy

subsidies in non-OECD countries benefit consumers, by lowering the price they pay."

The size and impact can be very large. The World Energy Outlook of the IEA 2012 concluded: "In 2011, fossil-fuel consumption subsidies worldwide are estimated to have totalled $523 billion, $111 billion higher than in 2010." (IEA, 2012, p. 69).

Water subsidies also have the main purpose of holding water prices down, notably in agriculture. Figure 7.2 indicates the extent to which, for some OECD countries, subsidies play a role in creating low water prices (while the costs of supply remain the same).

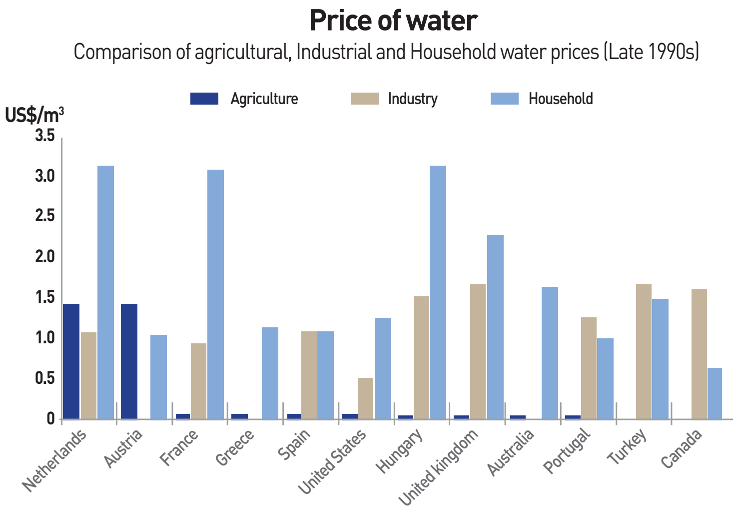

Figure 7.2 Water prices for agriculture, industry, and households in 12 OECD countries In 2001, only The Netherlands and Austria had realistic water prices for farms (Jones, 2003)

Subsidies supporting the continued inefficient use of resources are often called "perverse subsidies" (Kent and Myers, 2011) because their dynamic effects run counter to productivity goals.

Road transport is heavily subsidised, perhaps by US$250 billion, half of which can safely be considered "perverse subsidies" - i.e. harmful to the environment and to the economy (Kjellingbro and Skotte, 2005, p. 102). Subsidies for the use of pesticides, fertilisers and fishing vessels are further examples of perverse subsidies.

Other subsidies promote investment in resource-efficient production and services. Financial grants or credits can facilitate acquisition investments in resource efficient of technologies by businesses or households. The World Energy Outlook 2011 (IEA, 2011) has its special focus on energy efficiency and lists some schemes, chiefly in OECD countries, for subsidising buildings and industries to boost energy efficiency.

7.5 Reform of taxes and subsidies

The G20 has committed to phasing out inefficient fossil fuel subsidies (so reducing fossil fuel consumption) as a way to deliver growth, reduce budget deficits and reduce environmental harm (G20, 2009).

Much of the literature discussing reform of taxation changing resource prices covers the topic under the heading of Environmental Fiscal Reform (EFR) as the issue has been widely discussed by sustainability policymakers. The rationale for EFR is well set out in a report by the World Bank (World Bank, 2005) endorsed by UNEP, UNDP, OECD, the European Commission, and others.

The main motive for the tax or subsidy reform can be to reduce incentives for environmental harm, but often it is that funds can be raised to allow the corresponding reduction of other taxes. This was the case in Germany which introduced a relevant tax reform from 1999-2003 in five consecutive steps, eventually shifting some €18 billion annually from indirect labour charges to taxes on energy – and so leading to an estimated gain of 250,000 jobs (Knigge and Görlach, 2005).

The suitability of tax reform in this context at country level will vary according to the level of development, resource endowments, and institutional capacity.

7.5.1 Benefits of reform

Reform can bring several net benefits:

- Tax and subsidy reforms can be used to correct the inadequacies of current pricing systems, to contribute to internalising external costs associated with the extraction, processing and use of natural resources. For rapidly industrialising economies, EFR can play an important role in leapfrogging to promote resource efficiency and control industrial pollution. For industrialised countries, EFR can bring about the consumption and production patterns for sustainability.
- Perverse subsidies also represent a large and often growing direct drain on public finances, depriving other sectors of the economy of budgetary resources. Reform of explicit subsidies (IEEP et al., 2007) yields fiscal benefits at times of budgetary constraint. For example, Indonesia removed pesticide subsidies in 1986 and saved US$100 million per year in the process. In its place it developed "integrated pesticide management" (Gallagher, 1999).
- They are usually equally motivated by other fiscal goals, for example the tax revenues can be used for financing technology development or resource productivity programmes where not used to lower other "distorting taxes", such as labour taxes (Ekins and Speck, 2011; OECD, 2010b; Cour des Comptes, 2011; Jaeger, 2011).
- The administrative costs of eco-taxes tend to be considerably lower than those of value-added taxes or certain income taxes, which economic and political elites often manage to evade.
- For developing countries, what is perhaps particularly important is creating fiscal revenue from the extraction of their natural resources by foreign-owned interests. Extraction taxes can also serve as an incentive to overcome the often careless and wasteful methods of extraction. Where these taxes are linked to pollution, the taxes can also be an appropriate way of stopping deleterious trends of deteriorating air and water quality (UNEP, 2004; UNEP and ECLAC, 2003).

Figure 7.3 summarises assumed benefits from EFR.

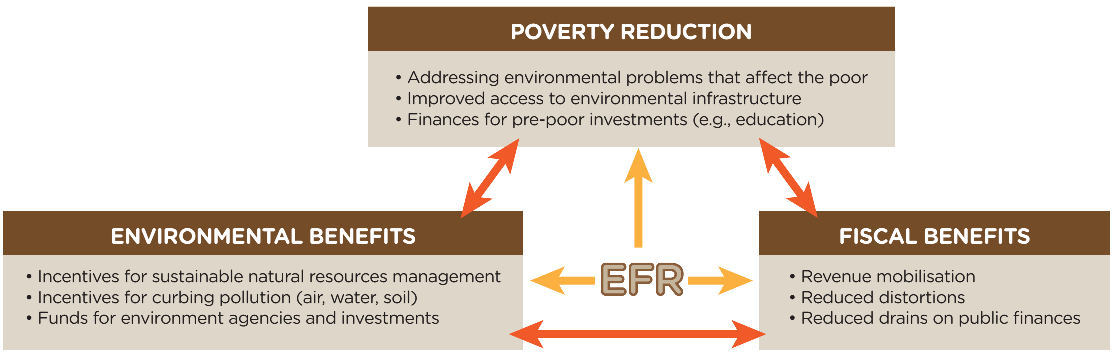

Figure 7.3 Assumed benefits from an Environmental Fiscal Reform (EFR).
Source: World Bank, 2005, p. 18

7.5.2 Challenges for reform

A growing number of lower-income countries have embarked on tax and subsidy reform as part of their poverty reduction strategies, combining it with preferential water and energy tariffs for the needs of the poorest. However, in many countries, the reform of environmental harmful subsidies will remain a challenge for the foreseeable future, due to the complexity of the subsidy landscape, and the political unpopularity of subsidy reform by those currently receiving them.

Some subsidies involve an explicit and transparent financial transfer from government to producers or consumers, such as a cash payment per unit of production or consumption, while other subsidies are hidden. By definition, however, explicit and hidden subsidies are significantly different in terms of their effects on public finances. In fact, governments like to hide subsidies (keep them "off-budget") primarily for political motives. For this reason, notwithstanding the existence of official annual subsidies reports, it is not easy to determine the level of subsidies.

In the context of the EU's Sustainable Development Strategy of 2006, the Institute for European Environmental Policy and partners came up with a decision tree to help reform subsidies by removing such aspects that act as barriers to transition to greater resource productivity. The tool they proposed in 2009 (IEEP et al., 2009a) is shown in Figure 7.4.

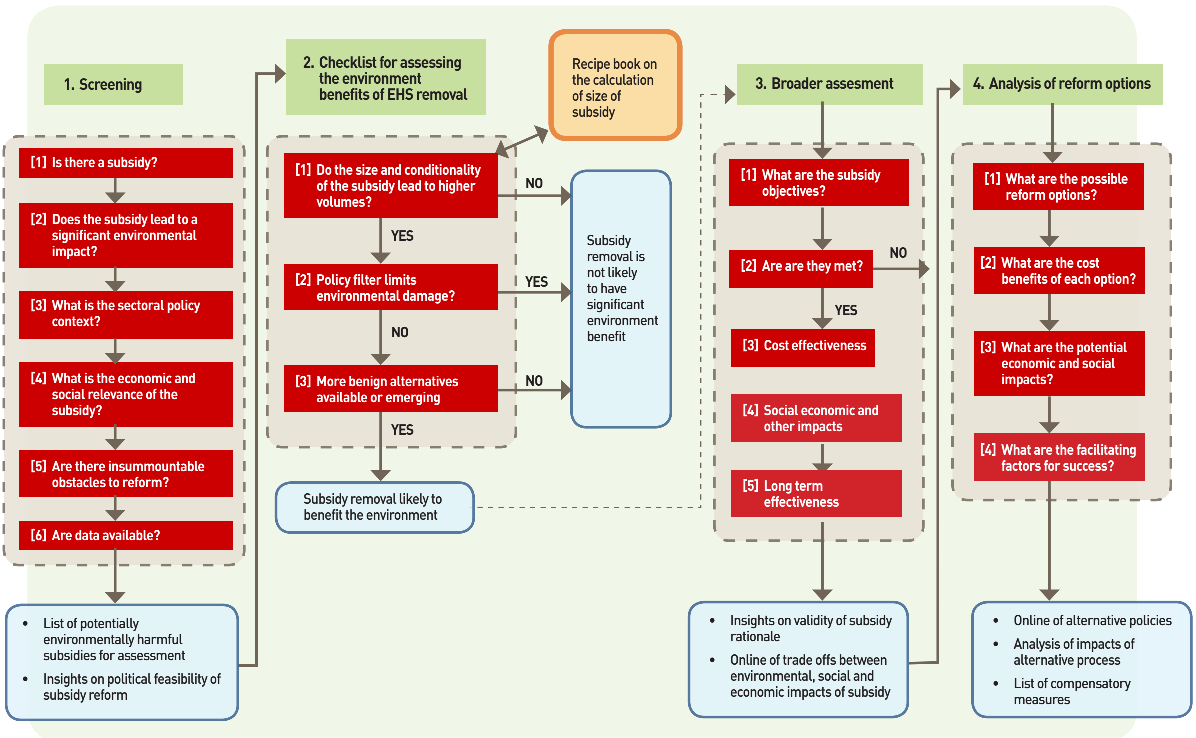

Figure 7.4 The Environmentally Harmful Subsidies reform tool, or decision tree (IEEP et al., 2009b, p. 7)

Whenever prices are changed, special attention is needed in the impacts on the very poor. There, the question remains whether it helps the poor more if they are induced by low energy prices to continue wasting energy, or if they receive direct support payments leaving them with the decision whether to waste energy, or save it through efficiency and spend the savings on other things.

7.5.3 Finding an appropriate level of taxes

Almost all of the literature on optimal levels of taxation, starting with Arthur Cecil Pigou (Pigou, 1920), assumes that taxes for resources, or pollution, should be fixed at an "optimal" rate, corresponding to the "external" cost of the societal or environmental impacts caused by the use of the respective commodities. Through this they are designed to correct the typical market failures in resource prices, and to integrate negative "externalities" into the cost of products and services (externalities being damages and costs to society that are not felt by those causing them). Despite the obvious difficulties of determining external cost49, Pigou and his followers' considerations currently define the political debate on levels of taxes that raise the price of energy, water and minerals consumption.

Despite the academic literature, the vast majority of existing taxes on polluting emissions, energy or – rarely – on other raw materials (Commonwealth Secretariat and ICMM, 2009), are designed primarily to raise revenue. So far, they are generally set at modest levels (partly to avoid migration of polluters to convenient tax havens). The ICMM, an association of mining companies, recommends a long-term view of taxes on resource extraction with a view to maximise revenues, meaning to maximise resource extraction over time (Commonwealth Secretariat and ICMM, 2009, p.11).

When the decision-maker's goal is to create the conditions that facilitate greater resource-productive investments, the estimation of the appropriate level of taxation will usually need to take into account a wider range of factors, rather than the "optimality" of taxation. This can include looking at the role that prices play in overcoming barriers to transition, and so taking account the extent of those barriers – for example the impact of subsidies on the effective price of the resource, and at the other factors creating bias in the economy.

Figure 7.5 gives an indication of the size of environmental taxation in Europe, with Europe being the continent of highest eco-taxes worldwide. South Korea is now the country with one of the highest level of resource and environmental taxation: roughly 10 per cent of fiscal revenues, compared with about 6 per cent in typical EU countries and 3 per cent in the USA.

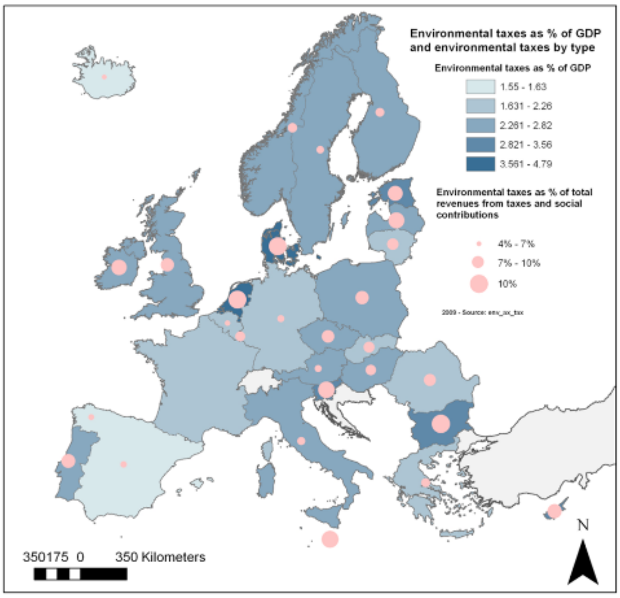

Figure 7.5 Total environmental tax revenue, EU-27 (% of GDP and Total social contributions), 1999-2009,
Source: Eurostat, 2011e

49 For carbon dioxide emissions, damage assessments differ by several orders of magnitude. And for Russia, externalities might even look positive: (Shuster, 2009)

7.5.4 Induced changes

Taxes reforms are often introduced gradually, to give time to adjust. Often, the announcement of future changes in taxes alone induces more resource-efficient behaviours, as firms and people adjust in anticipation. This is called the signalling effect.

Existing cautious examples of a gradual approach include the German wastewater charges that were announced in 1976. Four years before being actually collected, they had their strongest steering effect during the announcement period when the charge was still zero. Also the British "escalator" tax on transport fuels, introduced in 1993, and the German ecological tax reform of 1999 were progressive, meaning that year-by-year the duty increased by small amounts. In all cases, the announcement of further steps had a major effect both on manufacturers and on customer behaviour.

Our first decoupling report offered evidence of the effect the step-wise introduction of fuel taxes had in Britain and Germany and compared the situation with that of the USA and Canada. Figure 7.6 taken from that report shows the evidence.

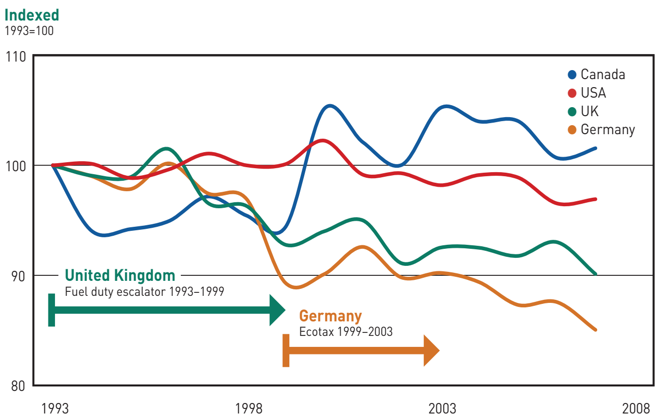

Figure 7.6 **CO_2 emissions from fossil fuel consumption (the UK introduced the fuel duty escalator in 1993, and Germany its Environmental Tax Reform in 1999, adding to a hefty levy on petrol from 1992 to co-finance the cost of the country's unification). One result has been notable decoupling of fuel use from GDP (not shown on the graph) as GDP rose at rates similar to those of the USA and Canada, whose petrol consumption more or less remained high and stable, UNEP, 2011b, p. 70)**

7.6 Creating new market institutions

One of the biases against change towards resource productivity is slow change in the rules, regulatory framework and social norms that shape economic interactions in the market. There have now been many examples where new institutional arrangements have been created by policymakers create market decisions that take into account the challenges facing society. The two examples in this section illustrate the potential: both of these are rights-based market institutions which influence prices, and hence investment choices.

7.6.1 Feed- in tariffs (FIT)

Feed-in tariffs (FIT), introduced since the turn of the century, offer cost-covering compensation to renewable energy producers. They provide secured returns on investments through long-term contracts to help new technologies overcome the biases towards existing technologies.

FITs typically include three key provisions: 1) guaranteed grid access; 2) long-term contracts (15-25 years) for the electricity produced; 3) purchase prices based on the cost of generation. Often the compensation is reduced over time reflecting reducing average costs reductions of producing the respective renewable energy.

Germany was the first country to offer FITs, for wind energy, solar power, small scale hydro and biomass-based gas and power. The legislative instrument is the Renewable Energies Act, adopted in 2000 and modified several times since. It has been copied or adapted in roughly 60 countries (both in the developed and developing world) and has boosted investments in renewable energies worldwide (World Future Council, 2009; Couture and Gagnon, 2010; Couture et al., 2010; Kreycik et al., 2011).

A detailed analysis by the European Commission concluded that "well-adapted feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity" (European Commission, 2008b). This conclusion has been supported by a number of analyses, including by the IEA (IEA, 2008b). Most FIT-related activity in 2010 focused on revisions to existing policies in response to strong markets that exceeded expectations, particularly in the case of photovoltaic. New FIT policies were implemented in several developing/transition countries in 2010 and early 2011.

They have proved very effective at moving venture capital into renewable energies (Figure 7.7), and also patent applications for technical innovations in the field, both of which appear to be stimulated.

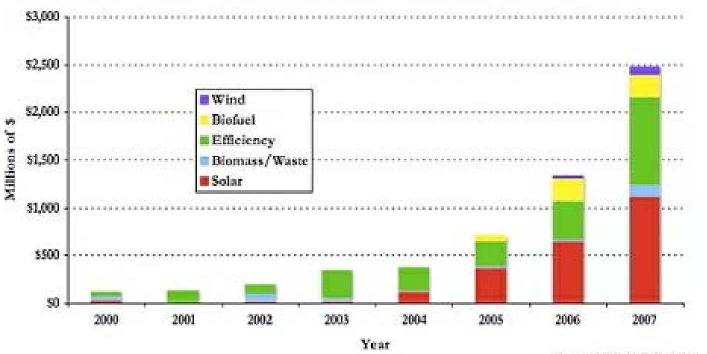

Figure 7.7 **Venture capital investments in efficiency and renewable energies after the adoption in 2000 of the first feed-in tariffs law (Knol, Beta, 2012)**

7.6.2 Tradable permits

Tradable pollution permits are rights to resource depletion or pollution that can be bought or sold in artificially created markets.

Now frequently discussed for encouraging management of carbon emissions, there are many incarnations of tradable permits.

Emission-trading schemes started long ago with local and national pollution control. A survey (OECD; 1999) found nine applications in air pollution control, 75 applications in fisheries, three applications in managing water resources, five applications in controlling water pollution and five applications in land-use control50 For example, they are used for landfill permits (in Britain's Landfill Allowances Trading System), fishing quotas (e.g. Canada, New Zealand and Norway), grazing rights (Australia), water supplies, and several undesired pollutants such as salt, volatile organic compounds or nutrients causing water eutrophication (e.g. in Chesapeake Bay, USA).

The concept of tradable pollution emission permits was first developed by the Canadian economist John Dales (Dales, 1968) in a book published in 1968. In effect, tradable permits turn pollution from a free good into a costly production factor. Usually, the government issues only a limited number of permits consistent with the desired level of emissions (a cap). The owners of the permits may keep them and release the level of pollutants matching their permits, or change their emissions and sell, or buy, permits to match (the trade). Tradable permit systems are therefore often called cap and trade systems. The decision whether to carry out measures to reduce pollution or buy additional permits on the permit market is based on a comparison between the marginal abatement cost (the cost of reducing an additional unit of pollution) and the market price for pollution permits. This situation creates an incentive to reduce emissions.

The price given to pollution is determined through supply and demand in the emission permit market. That price may alter the production decisions of companies and, to the extent that they are able to pass on the additional costs to final goods prices, also affects the consumption choices of consumers.

50 For a theoretical and practical essay see Tietenberg, 2006.

There are various advantages and disadvantages of tradable permits for polluting emissions:

- Often permits are allocated free of charge, too generously, depending on historical emissions. This has been the case for the European Emissions Trading System (ETS) for CO_2 and other greenhouse gas emissions, where over-allocation, exacerbated by an economic downturn, led permit prices to collapse to insignificant levels, thus annihilating the intended steering effect. However, governments can also sell the permits in periodic auctions, leading to considerable revenues for the state and, in practice, a stronger stimulus to polluters to reduce emissions.
- One evident challenge of emission permits is measuring the pollutants. Another is high transaction costs, and a need for administrative capacity for the state. In fact, most emission trading schemes define a fairly large minimum size of a company obliged to participate in permit trading.
- Speculation can distort and disrupt the artificial markets, if allowed to. The ETS, mentioned above, has additionally suffered from massive, and jerky, movements up and down.
    - A linking directive of the EU allowed participating installations to offset large parts of their obligations abroad, using the three "flexible mechanisms" of the Kyoto protocol, Joint Implementation, the Clean Development Mechanism (CDM), and International Emissions Trading. All this served as an invitation to a new breed of speculators and to very unpredictable fluctuations, frustrating all those who made long-term investments in carbon-saving technologies and installations.
    - The flexible mechanisms have led to another kind of downside, namely quite odd and partly perverse incentives such as the acceptance under the CDM of cheap destruction of by-products of ozone-depleting substances (Kaniaru et al., 2007)[51], or carbon offsets for big pig farms in developing countries (because they "replaced" cattle farming with heavier greenhouse gas impacts), or forest monocultures after destruction of virgin forests.

7.7 Bans, prohibitions and mandated requirements

For many decades and in many countries, some of the most important policy measures used for resource productivity (mainly energy efficiency) and the reduction of environmental harm were implemented by regulation that limited behaviour with the threat of legal sanctions if the regulation was ignored. For example, after the oil price shocks in 1973 and 1979, several countries started adopting mandatory requirements to drive energy efficiency, in particular around the energy performance of buildings[52].

This form of policy measures can limit products, or processes, or, alternatively require different processes, technologies of products to be used. They include products standards, efficiency standards, and emissions limits (into water, or air, for example). They can take many forms, and have different layers of complexity – with some combining different standards to be met with various forms of activity to meet the standards.

51 The authors describe very perverse incentives creating windfall profits to manufacturers of chlorodifluoromethane (HCFC-22) with a global warming potential 1700 times higher per weight than CO_2, and its byproduct HFC-23, 14000 times more dangerous than CO_2. Companies offering cheaply to destroy HFC-23, massively cash in as they "reduce" global warming. HFC-23 destruction has over years accounted for roughly 50% of the ETS market, leading to artificially low prices for CO_2 permits. A journalistic account of the story can be found in: The Economist, (2010).

52 For a good overview: World Energy Council, 2008.

Some can specify an environmental goal (such as an environmental ambient pollution level) as the framing for the level of change to be met.

Figure 7.8 lists and describes the most relevant types of standards

Type	Description
Emission standards	Specify the maximum level of permitted emission in quantitative terms (perfomance-based standards).
Ambient standards	Set minimum desired level of air, water or soil quality that must be maintained.
Technology standards	Specify wwhich kind of technology must be used, e.g. by prescribing or forbidding certain technologies, or by referring to the best available technologies.
Management and process standards	Specify certain behaviours and activities, e.g. refular monitoring or maintainance activities or the set-up of take-back-schemes.
Product standards	Specify certain product characteristics, e.g. on chemical residues in products or energy efficiency characteristics.

Figure 7.8 Different types of environmental norms and standards (GTZ, CSCP and Wuppertal Institute, 2006, p. I-1)

They are adopted by public authorities which then inspect, monitor, and enforce compliance to these standards, punishing violations with formal legal sanctions. Partly for this reason, these policy measures are sometimes called "command and control" measures.[53]

Direct regulatory requirements can be very effective at driving change. They often have clarity of purpose and outcome, and can send clear signals on what changes are sought (Harrington and Morgenstern, 2004). The threat of legal sanctions can be (but is not always) a strong motivation to change, the effectiveness of which depends on the credibility of the public authorities enforcing the regulation and the impact of the penalty.

Although often regarded as primarily a way to directly reach a public goal, this type of instrument plays a key role in creating the conditions for investment in resource-productive technologies:

- When they prohibit some of the existing (poorly performing) technologies, they create new demand for alternative, more resource-productive technologies, and reward innovators. It is very unusual that they bring an end to the economic activity that is being regulated – instead stimulating change to alternative products that deliver the same function, or alternative methods to produce the same product. They remove the less resource-productive (or more environmentally harmful) products or technologies from the market, cutting competition, and opening markets for more resource-productive products. This can be essential to overcome biases that have created conditions where the less-productive technology is cheaper than the more resource-productive alternatives.
- When they mandate particular standards, behaviours or processes, they also create demand for (more or less) innovative technologies, skills or organisational methods.

The effects of direct regulation depend on many factors, including how trade patterns change, skill capabilities and demand changes. One disadvantage can be that the standards are naturally "static": they usually provide incentives for reaching a particular goal (like an emission level), but no incentives for innovating beyond that.

This can be mitigated by mechanisms that periodically review and reset the standards.

53 The term 'command and control' is actually much newer than the old term of environmental regulation. It was anti-regulatory feelings since 1980 that led to the new label of 'command and control', a term stemming from the US military language. See: Short, 2007.

Usually this review takes into account what is now economically and technologically possible. The most comprehensive scheme example of this is the Japanese Top Runner Programme, which identifies the most energy-efficient household appliances and vehicles and uses the results to define the future standard for the whole industry (Hamamoto, 2011).

7.8 Other ways to stimulate demand for resource productivity

Another type of measures that decision-makers have to create the conditions for decoupling is the wide range of additional ways to stimulate demand for resource-productive technologies. This includes measures that stimulate increased demand for products that have been produced with more resource-productive technologies (or which are simply more resource productive – e.g. energy efficient) themselves. Greater demand for such technologies makes further investment in resource productivity more attractive, and helps counter biases.

There are several distinct groups of policy instruments, which have often been used effectively together, or with the other instruments mentioned in this chapter as part of policy mixes.

7.8.1 Labelling

Labelling programmes and schemes have been developed since the 1970s, for products that are less resource-intensive and less harmful to the environment. Labels are typically applied to retail products.

These 'eco-labels' have two purposes: to allow consumers to act on their preferences by providing them with information on characteristics of the products (or services) which are not otherwise apparent; and to educate consumers about the resource or environmental issue, and so change their consumption preferences.

For example, Japan's Ecomark seeks to "disseminate information on the environmental aspects of products and to encourage consumers to choose environmentally sound products". Similarly, Singapore's Green Label specifically seeks to "promote green consumerism and increase environmental awareness".

They can cover different resources: New Zealand and Australia have adopted a mandatory Water Efficiency Labelling Scheme covering showerheads, washing machines, dishwashers and toilets (Commonwealth of Australia, 2011b). The US EPA's mandatory Ozone Depleting Substances label warns consumers of products manufactured with ozone-depleting substances. The German "Blue Angel", incorporating UNEP's logo, is awarded to hundreds of very different products and typically has a short explanation on it, such as "energy efficient" or "100% recycled". They can apply to the products' performance when it is used (e.g. its energy efficiency) or its impacts over its production phase (e.g. whether it is fished from sustainable sources), or whole life-cycle.

In a typical eco-labelling programme or scheme, product categories and eco-labelling criteria are determined by a credible independent organisation with assistance from technical research staff or technical advisers.

The design of the label has been found to be very important for the way in which consumers react to it – and can influence the outcome of labelling as a policy measure. For example, the EU introduced a seven-step label for energy efficiency, which is seen in Figure 7.9. This format of label has since been adopted in many countries around the world. There is some evidence to suggest that a 2010 redesign of the EU label weakened the effects it would have on consumer choice (Heinzle and Wuestenhagen, 2012).

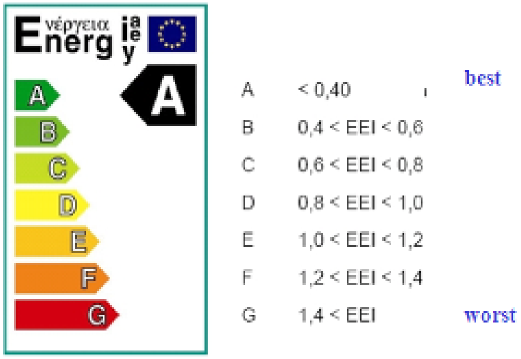

Figure 7.9 The pre-2010 EU energy efficiency label shows highest efficiency (A) to lowest (G), with specified ranges for different appliances. The label shown above is for a highest efficiency refrigerator

Many countries use labelling schemes. A review in 1998 by the US EPA found more than 25 schemes in Asia, Europe and North America (EPA; 1998b). A list of labels in the EU is kept online.[54] The International Standards Organisation (ISO) has drawn up a group of standards specifically governing environmental labelling. The ISO 14020 family covers three types of labelling schemes: 1) environmental labelling (i.e. eco-labels), 2) self-declaration claims and 3) environmental declarations (e.g. report cards/information labels provided by the producer).

7.8.2 Indicative norms and standards

Non-retail schemes describing the resource use of products or technologies help commercial buyers select more efficient products. These include forest certification schemes (such as the Forest Stewardship labelling programme, and also help boost markets, so rewarding resource-productive investments.

Standards reduce uncertainty about innovative products or processes by providing a benchmark for performance. They also communicate new norms, or standard practices, which also help people move away from past norms.

54 *http://ec.europa.eu/ecat/, accessed 12th April 2014.*

Industrial norms and standards, used for a long time to secure quality, compatibility and safety, are increasingly being used for environmental and resources efficiency purposes. Since 1996, the ISO has used the ISO 14000 series for environmental performance (ISO 14040:2006; ISO 14044:2006), mostly focusing on pollution control.

Some standards go beyond products, services or technologies. They can extend to a systematic, strategic and practical management approach: compliance with the standard provides assurance that good practice is being followed. The use of standards in this context can help adoption of norms that include maximisation of resource productivity within business models. The European EMAS (for resource and environmental management), the German DIN EN 15.000 series (energy efficiency standards for buildings and many industrial operations) and the ISO 50001 energy management standard (ISO 50001:2011) are examples. Frequent updating serves of these standards let them keep pace with technological progress, in line with the "best available technology" principle.

7.8.3 Green procurement

The purchasing power of public organisations is considerable and can be harnessed to drive markets to produce ever-more resource-efficient products and services. It works by providing a sufficiently large niche market to reward innovators who bring their resource efficient products or services to commercial scale. The presence of the market encourages investments in commercialisation of technology, which can then also break into the private sector markets where there is a natural advantage for existing products, or where innovators are unsure of market demand.

Green procurement involves inciting or obliging public administrations to purchase goods and services that are recognised for high resource efficiency and/or low pollution. Typical targets for green public procurement are buildings, office equipment, appliances, and vehicles. The International Green Purchasing Network was created in 1997 in Japan. In 2010 it published a report on policies and programmes to enhance green business growth (IPGN, 2010). In Asia, Europe, America, Australia and New Zealand, green purchasing has gained wide acceptance and is being promoted under different names.[55]

Green procurement is not limited to the public sector. Major private companies committing themselves to the resource or environmental goals have and can also drive markets.

7.8.4 Linking eco-labels and procurement

The impact of linking the use of government procurement and eco-labelling is a clear demonstration of how policies create greater results, more cheaply, where they are designed to be mutually reinforcing. Where environmental labels are used by a government procurement programme, it typically increases the market presence of the labelled products and enhances the credibility of the labelling programme. This has been the case with the Energy Star-labelled office equipment programme. Initially, the US government mandated that all federal offices stock Energy Star-labelled office equipment[56], but as the demand for these products grew it became evident that not only were government agencies buying these products, but so too were private organisations.

55 The IGPN has an interactive web and CD-ROM based package starter kit, *http://www.igpn.org/focus_on/kit/index.html*. The International Council of Local Environmental Initiatives, with a membership of more than 1000 cities ran 'Procura+' a Sustainable Procurement Campaign with a systematic exchange of experience and other practical assistance: *http://www.procuraplus.org/*. The European Union is strongly supporting public procurement and has issued a handbook on the subject: European Commission, 2004b.

56 Through Executive Order 12845 - "Requiring Agencies to Purchase Energy Efficient Computer Equipment".

7.9 Changing consumption behaviours

The removal of behavioural biases against resource-productive innovations is another important area where policy instruments can be used. This report has taken the spread of technological innovation (and some techniques) as its entry point into the wide, and interlinked, changes that would be needed for absolute decoupling. Removal or reduction of behavioural biases plays an important part in facilitating greater spread of these technological innovations.

But change in behaviours and consumption patterns can also increase the resource efficiency of the economy in other ways – mainly by reducing wasteful consumption and disposal. For example, the average OECD household wastes 40 per cent of the food purchased. This is a significant waste, and cost. It also compounds losses in the production, processing, transportation, and retail steps in the supply chain that provided that food, as well as creating a final waste problem. Changing behaviour by the final consumer to reduce waste food often does not need technical innovation, but may require innovative policy instruments.

A key aspect of successful behaviour change programmes is meaningful community engagement to identify perceptions related to the particular behaviour. A leading methodology for undertaking the design and delivery of community behaviour change programmes is Community Based Social Marketing (CBSM). Developed by Doug McKenzie-Mohr, CBSM is based upon social science research which demonstrates that behaviour change is most effectively achieved through initiatives delivered at the community level which focus on removing significant "barriers" (i.e. impediments or challenges) to a behaviour occurring, while at the same time enhancing the "benefits" (i.e. incentives) for that behaviour (McKenzie-Mohr, 2007).

Measures to change people and firms' behaviours around wastage during consumption and at the end of life of products or goods is a key part of several decoupling strategies. Behavioural change in separation of waste for recycling is often needed, for example. For instance:

- China in 2009 adopted the Circular Economy Promotion Law, the first in the world using the term "circular economy" in its title. The "circular economy" is being implemented at three levels: at the regional level, it is "big circulation" and includes lifestyle change to deliver people's desires from fewer natural resources and energy and greater efficiency at company levels (Chang, 2009).
- Japan has introduced a number of visions and laws over many years, such as the Fundamental Law for Establishing a Sound Material-Cycle Society (Government of Japan, 2000), that represents a conceptual turn from a throwaway society in order to become a society with greater resource recycling (Wuppertal Institute, 2007). It has reduced its resource use by 14 per cent from 2000-05.

This new trend of a cyclical economy goes far beyond old waste legislation. As is the case for all serious attempts towards a green economy and decoupling of economic wellbeing from resource consumption, the cyclical economy concept, if successful, is likely to transform the philosophy of manufacturing and consumption worldwide.

This could build on the existing progress on decoupling growth from waste production that has been achieved with strategies including elements of behavioural change. Box 7.1 describes some of this progress.

Box 7.1: Decoupling economic growth from waste production

Progress has been made in the last two decades in OECD countries to relatively decouple economic growth from waste production. In OECD counties in the mid-1990s, approximately 64 per cent of municipal waste was sent to landfills, 18 per cent for both incineration, and recycling (OECD, 2001b). In 2005, only 49 per cent of municipal waste being disposed of in landfills, 30 per cent being recycled and 21 per cent being incinerated or otherwise treated (OECD, 2008d). In 1980, America recycled only 9.6 per cent of its municipal rubbish; today the rate stands at 35 per cent. A similar trend can be seen in Europe, where some countries, such as Austria and Germany, now recycle 60 per cent or more of their municipal waste. Britain's recycling rate more than tripled from 11 per cent in 2001 to 39 per cent in 2010 (EEA, 2013). Overall, municipal waste generation is still increasing in OECD countries, but at a slower pace since 2000, hence it has been relatively decoupled from GDP. (See Figure 7.10)

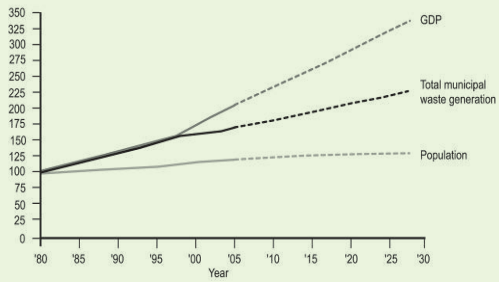

Figure 7.10 Decoupling of OECD GDP from OECD country municipal waste generation, 1980-2030

(Source: TNEP (Smith et al., 2010a) based on data from the OECD, 2008d)

There are several exciting innovations in policy, product design and process design that can help reduce or even eliminate the amount waste being generated cost effectively[57]. These innovations usually involve some combination of 1) directly reducing the amount of waste generated in producing and delivering a product or in operating an industrial process; 2)

57 For instance, a cost-benefit analysis for the United Kingdom suggested that restricting metals, glass, plastics, organics, paper from both landfill and other residual waste treatment (such as incineration) would provide a net benefit to society over the period 2009 to 2024 of £8.2 Billion (WRAP, 2010).

designing products such that their reuse and recycling is cost effective and easy; 3) designing service processes so that product take-back is cost-effective and easy; 4) increasing markets for products with recycled content, and 5) phasing in bans on categories of waste to landfill. These five features enable a much greater decoupling of waste from economic growth by reducing the costs of material inputs and enabling a market of secondary materials that are, in many cases, cheaper than the equivalent primary materials.

One of the ways in which some countries have promoted the reduction of waste is through extended producer responsibility policies[58]. These policies create new economic arrangements and incentives by requiring producers to take back and recycle a certain percentage of their products. We have described these in our report on the opportunities and limits of metal recycling (UNEP, 2013a).

58 Including the EU, India and China (UNEP, 2013a, p.90).

8 Considerations for Future Policy

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Decision-makers wanting to take steps to promote decoupling can draw on lessons from past efforts to bring about policy change and the spread of technological innovations. There are different hurdles to overcome in different contexts, and the task is not easy. The nature of the issues differs in developing countries and higher-income countries, with the different resources involved and with the variety of specific economic and political contexts. This makes it impossible to identify generally applicable policy measures that have created the conditions for higher rates of decoupling.

However, past experience with policy reform can provide guidance that may increase the chances of success. This chapter describes some broadly applicable lessons from past experience, relating them to the nature of the barriers to decoupling.

Although these considerations have been phrased for policymakers in government, many may also have some relevance to attempts at change within other large organisations which have institutional cultures and constraints.

At the core of these considerations, is the observation that the continued existence of barriers and biases against decoupling is frequently due to resistance to policy change.[59] Success in creating the conditions for decoupling would need to unlock that resistance. In this task, the chances of success appear higher where policymakers look at the institutional framework in which the political decision is made. In practice for changes to policy, this means being aware of the set of actors who are able to influence the decision, their interests, relative power and the norms and assumptions which are shaping the decision. Those seeking change:

59 As mentioned in Chapter 4.

"... need to become adept at institutional analysis, identifying those elements supportive, or hostile to, the reform in question, and work to strengthen the more supportive elements and weaken the more hostile ones." (Ekins and Salmons, 2010, p. 132).

This is one of the factors that has driven the use of packages of policy instruments. Using packages of policies can produce a set of changes which together appeal sufficiently to influential interest groups to facilitate the adoption and implementation of the policies.

8.1 Leadership

Bringing about innovation where there is significant inertia against it will take leadership. Obviously, intentional resource productivity increase is not automatically popular. Extractive industries, shipping, trading, refining of minerals, and companies providing energy will be on the losing side, and consumers may fear the loss of convenience. The historical fact that "absolute decoupling" has remained the rare exception seems to indicate that the intentional increase of resource productivity tends to find more opponents than supporters. In other words, strong and determined leadership will be needed to make an intentional increase of resource productivity happen.

Economic history is built on examples of economies and firms that have been rewarded by responding first to new conditions or technologies, and of firms and countries that have declined by failing to respond sufficiently fast. The quality of leadership in responding to change seems likely to have been one of the factors separating performance.

Many changes can contribute to decoupling, which presents opportunities for leadership to many people. This includes individuals working within organisations and institutions across most parts of government, the economy and civil society (including consumers). Inside government, it includes decision-makers with influence on industrial, market regulation, development, innovation, fiscal, environment, employment and taxation policy.

8.2 Working with the institutional framework for decision making

Based on past experience for policy change[60], success appears to be more likely where policymakers seeking change:

- Take account of the potential losers from policy change. Consider what will bring them, or enough of them, to favour change. Potentially use transitional financial support to help them innovate, compensation (perhaps from the "recycling" of revenues from a tax or charge) or align implementation of change with existing investment cycles, to reduce capital destruction.
- Help those affected by change to focus their innovation towards a consensus future goal, by changing their expectations of the future. By creating shared visions and credible strategies, future investment patterns can be changed, often without great expense, as firms shift their business models and investments in advance to profit from new conditions. This allows potential winners to see opportunities, and support change.
- Create, or rely on, a source of sufficiently trusted independent advice – on the science or on the impacts of change. The nature of the source is very important, as evidence is likely to be contested or rejected where it is unfavourable. Sources seen (rightly or wrongly) to be self-interested will be

60 This section draws on Chapter 5 in Ekins and Salmons, 2010.

much less effective. Objective scientific evidence is very useful. Transparency and consensus building around information formation may help. Knowledge, and so perceptions about the future state of the world, can in any case be slow to change. The role of trusted, reliable and clear information about changes occurring in the world and their implications can be crucial for changing expectations of future conditions and so perceptions about which investments will bring greatest future economic advantage.

- Present concrete examples of policies or practices used in different countries, or in different realms of policy. Many of the reforms to increase decoupling will require new structures, behaviours or business models that may seem initially unfamiliar and odd. Demonstrating that different arrangements work elsewhere can be convincing. For example, the idea of electronic equipment manufacturers (like mobile phones) retaining ownership of valuable materials in that equipment while it is used by the consumer may seem peculiar – yet business models in the chemical sector where chemical supplier retains ownership of chemicals used in industry are frequent and long-standing.
- Create an institutional structure for the specific policy decision that is:
    - Participatory – making decisions for change appears more likely to be more successful when powerful interest groups – particularly those who might block decisions at a later stage – are included from the beginning in the decision-making. This facilitates information flows, and can help form a common vision for the future that reconciles opposing views.
    - Sufficiently broad to contain enough people who can form a pro-reform coalition within the decision-making structures. Improving resource productivity in the economy will naturally bring net economic gain, although it may create winners and losers. Finding participatory structures that allow losers to see how they could capture some of the productivity gain may help create coalitions for change. For example, bringing together the economic actors all along a value chain61 may identify ways to vertically integrate businesses, or change relationships between actors in the value chain. While these facilitative changes may require complementary policy (for example to regulatory structures), these complementary policies could form part of a policy mix.
    - Working around existing institutional blocks within political and economic actors. Within any large organisation, in government departments, private corporations or representative industry organisations, division of responsibility and consensus decision-making can mean that parts of that organisation are interested in blocking change and are able to impose this on an otherwise willing organisation. (Decision-making is said to be made to be decided by the "lowest common denominator"). Finding ways to allow the more innovative mainstream of an organisation to decide may facilitate change.
- Use a simultaneous mix of policy instruments, as mentioned in section

61 The 'value chain' refers to the chain of producers and manufacturers that pass a resource from when it is first mined or harvested up until it is (after being joined with many others) consumed by the final consumer.

6.4.2. This can help the actors in a value chain of economic activity (for example, from raw material extraction to final product consumption and recycling) to change profitably together. This may be necessary to overcome a "lock-in" between demand and supply, which can commonly happen when a seller offers what is being demanded, the purchaser buys what is being offered and there is little scope for either to innovate.

- Work to increase the cumulative effect of several smaller steps, as it is rarely the case that political or economic conditions exists that allow a policymaker to bring about a very large, radical change in resource productivity in one step.
- Be aware of options for reform and use political opportunities when they arise. Good economic times are often more favourable for introducing change, with less fear of negative consequences and greater availability of finance for innovative investments. Yet, crises can also facilitate reform, in different ways:
  - An unsustainable economic situation in New Zealand in the early 1980s, which included the state running excessive budget deficits (of 9 per cent of GDP), provided the rationale and impetus for a thorough reform of state support for the agricultural sector. The Effective Rate of Assistance to agriculture fell from 123 per cent in 1983 to around zero in the 1990s.[62]
  - Crises may also provide opportunities for productivity-reforming economic activity, when they lead to economic slack which can be stimulated to enter into new investments with low opportunity costs. By 2011, as a result of uncertainty on future returns on investments in difficult economic times, publically traded companies in Europe were holding excess cash of €750 billion (McKinsey Global Institute, 2012). Policy change can help provide certainty that frees up this unused investment potential, possibly directing it into less conventional areas. Unemployed labour can be re-employed with appropriate training, in growth sectors of the future, in ways that can also reduce the burden of social support costs for the state.

8.3 Changing the institutional framework to facilitate future policy reform

One aspect of successful reform is to take steps that create the conditions for further, future policy reform. Making changes to decision-making processes, either internal to an organisation or external, can indirectly facilitate future change.

In government, this could mean making a change to the decision-making structures (like the mandate of ministers or committees), which allows decisions promoting the long-term management of resources to be taken more easily. The frequent fragmentation of responsibility for resource productivity between different parts of government often leads to deadlock and stagnation. Changing the "mindsets" of decision-makers, and the organisations they operate in, is an important starting point for further decoupling (McKinsey Global Institute, 2011).

It could also mean implementing a policy that increases the future economic and political weight of innovators or favourably changes the perception of potential opponents to change (for example by changing company reporting to include

62 The Effective Rate of Assistance is estimated by comparing the value added of an assisted sector with the same value added of an unassisted sector (at a world or reference price.) It includes direct and indirect assistance.

information on resources that helps companies take resource factors into account in their business decisions).

Changes to institutional decision-making structures have long been appreciated to have important beneficial outcomes, and this is particularly the case for overcoming the bias of decision-making towards the short term. As examples:

- The UK is seen as a strong, liberal economy. In part this is because, in 1998, authority over monetary policy was passed from the government to the central Bank of England in 1998. This transferred the power to set interest rates – a power of huge importance to the economy. The aim was to provide greater economic stability by distancing those decisions from short-term political influence.
- The UK has also attempted to create structures which facilitate decision making for the long-term in relation to reduction of greenhouse gasses by: a) legislating for binding national 2050 greenhouse gas targets; b) legally committing to a series of five-year carbon budgets (constraints) as steps to the 2050 goal, and c) creating an independent, evidence-based organisation to provide transparent recommendations to government on what those carbon budgets should be (and other related questions)[63]. It also reorganised government departments to provide more favourable decision-making structures.
- The use of multi-year strategic programmes to steer investment is a long tradition in China, and some other countries, and these provide structures that (as in China's twelfth Five-Year Plan) can be used to create drivers for decisions on resource productivity.
- Within business, Unilever opted not to give full financial results every quarter from 2011, changing incentive structures for the company away from constant very short-term gain in the direction of longer-term planning[64].

One factor influencing internal decisions is external agreement. There have been many examples where international agreements have acted as stimulation for domestic action. In part this is because concerted action between countries, which reduces fears of unfavourable distortions in international markets. But it is also because an international commitment can act as a persuasive tool against opponents of change, not least by indicating that change is viewed as internationally important. As trade in resources is global, with value chains for manufacture of products crossing many countries, it seems likely that international institutions to improve resource efficiency will be needed, whether formed within the private sector, public sector, or both.

8.4 Putting decoupling into practice – linking resource price rises to resource productivity gains

8.4.1 Options for pricing mechanisms

Economic instruments to push technologies and markets towards higher resource productivity typically run into one characteristic difficulty: if price signals are strong, industries may just give up or emigrate, and consumers tend to contest the government imposing painful price signals. But if price signals are weak, there is a high likelihood of effects remaining insignificant.

One potential way out is a price signal that steadily increases at the pace of decoupling successes. For example, if the average efficiency of the car fleet rises by 1 per cent

63 By means of the Climate Change Act 2008.

64 See e.g.: *http://www.unilever.com/mediacentre/pressreleases/2010/UnilevermovestoQuarterlyTradingStatementsinApril2011.aspx*

in one year, a 1 per cent price increase of petrol at the pump would seem fair and tolerable. However, the firm announcement of the continuation of this scheme will induce car manufacturers and traders – as well as consumers – to speed up efforts to reduce petrol consumption per kilometre or to avoid unnecessary trips. Hence a small signal can have a strong impact if continued over a long period of time.

A policy of this kind can combine several of the considerations to unlock inertia described above, and may come close to the type of combined policy which is needed.

There are several forms in which policies to create pricing mechanisms would promote resource-productivity increases. These often include several of the considerations to unlock inertia described above, and illustrate the type of combined policy which is needed.

- One proposal is to use taxation or subsidy reduction to move the price of a chosen resource upwards in line with documented increases of energy or resource productivity inside a nation's economy[65].

65 For example, see the suggestion in Weizsäcker et al., 2009.

- Another is to apply a tax on virgin resources, which is applied at point of extraction of import, and is pre-announced by increase each year (by a small amount of 2-5 per cent). This could be coupled with resource taxes applied to products containing resources from countries without similar resource taxes[66].

In the sections below we look at different qualities of these proposals.

8.4.2 Broadening the Economic Discourse

In a simplistic economic debate that was allowed to focus only on the price level of a resource, the proposed changes would win little support. They would lose out to arguments that competitiveness or incomes would be harmed. However, that debate, focussing on just one element of a complex dynamic economic system with underlying assumptions that the economy is static, would not give an accurate picture of the nature of the proposals' impacts.

66 For example, proposals along these lines were considered in discussions in the European Resource Efficiency Platform *http://ec.europa.eu/environment/resource_efficiency/re_platform/about/meetings/index_en.htm*

Where the announcement of price increases led to efficiency gains, the costs of resource used (which influence competitiveness and livelihood) would, on average, not increase. In these circumstances, on average, one would pay the same amount of money for the same quality of energy services as the year before – paying a higher price for each unit of energy, but consuming fewer units of energy, as each unit of energy delivers more output thanks to the productivity gain.

By explicitly linking price rises to efficiency gains, the structure of the first policy proposal helps broaden the political discourse around the effects of the proposal. It moves the debate to net costs, innovation and investment rather than just price and fears of losses. By providing a different framing for the issue, the proposal could remove most fears of losses to individuals, to families and to commercial businesses.

The presentation of the second proposal could also make clear that productivity increases were the expected result, and that net costs of resources used in the economy might not increase, while use of the additional tax revenues could improve the economy. Making comparisons with past experiences could also facilitate a change in the political discourse. The competitiveness of industry, particularly in mature countries, now hinges less on resource prices than on innovative services and goods. Japan during the late 1970s and 1980s had industrial energy prices roughly twice as high as in the USA. But it flourished, building up a first-class high-tech industry that created much higher added value per unit of energy than industries in competing countries. Similarly, any country going ahead now with the proposals would likely be earning the first mover advantages in a world of resource constraints. And on average, one could expect continued growth with a very small rebound effect on resource consumption.

Political discussion could also include a partial analogy with the success of labour productivity increases over 160 years since the industrial revolution. Labour productivity in developed countries is now easily 20 times higher, facilitates a previously unimaginable standard of living – and yet is correlated with ever increasing labour costs (See Annex B).

8.4.3 Reducing bias against new investment by reducing uncertainty

The proposals would not entirely remove uncertainty about returns on investments in resource productivity within a country, as variations in resource prices and uncertainty about future energy or resource productivity increases would remain. However, uncertainty would be reduced, in particular long-term uncertainty about the direction of prices.

Worries about remaining unpredictability of future prices could be tackled by the introduction of a legally binding price trajectory, which is relatively simple, although details would vary. The state can define corridors for prices moving slowly upwards. For instance, for energy this could be differentiated corridors for vehicle fuels, electric power and heating purposes. Market prices would be allowed to fluctuate inside the corridors. Uncertainty of extreme disruptions in price can therefore be removed: if prices touch the lower band, taxes will bring them back. And if they touch the upper band, the state could reduce the levy. Such corridors of pricing have been debated in relation to carbon prices, with the introduction of price floor (a minimum price for carbon) receiving much attention. This idea of defining corridors could apply whether prices are announced to move broadly in line with efficiency gains or by a pre-determined percentage increase in tax each year: both could be adjusted.

The policies would serve as a strong and predictable incentive to investors, states, individual companies or research laboratories to systematically invest in ever-more resource productivity. They could afford to think big in terms of investing in radical improvements of energy and resource productivity as for the first time in history, the community of resource efficiency investors would have no fear of losses due to prices of the relevant commodities collapsing. This would drive innovation and adoption of the type of technologies outlined in Chapter 3 that would lead to greater resource productivity (and so greater growth). It seems plausible that the mutual reinforcement between prices and efficiency increases will lead to a long term and ultimately dramatic increase of resource productivity (rather like in the case of labour productivity discussed in Annex B).

If a manifest crisis of oil availability or climate risks plagues the world, decisions can be made to move prices upwards somewhat faster, so as to stimulate a speedier transition to resource efficiency, just as larger increases in past wage prices went hand in hand with greater increases in labour productivity. Coordination of this policy with other enabling policies would also bring greater gains.

8.4.4 Creating sufficient winners in favour of change

The proposals have aspects that give them the potential to create sufficient winners to form a coalition that supports their introduction.

Firstly, by providing a source of government revenue, each mechanism creates choices for the government to reduce taxation on other people or firms in the economy, increase spending or to reduce fiscal deficits: this may either win political support from people outside government who benefit, or from the finance ministry, whose support may be crucial to the policy's success in becoming law. The idea of gradually increasing resource prices via taxes tackles the concern that governments frequently have with taxes which aim to change behaviour (like environmental taxes), namely that they erode as their steering effect becomes successful. Linking the magnitude of the tax to productivity increases, or increasing it yearly, means that the total potential revenue does not decline, even as the number of units of resource consumed decreases.

Secondly, by increasing resource tax the proposal increases the relative competitive advantage of firms which have above average resource productivity gains: these firms reduce costs relative to their competitors. This not only provides greater incentives for competition based on increased resource productivity, but provides reasons for the more innovative and productive firms to take political positions in favour of change.

8.4.5 Taking account of potential losers in a policy mix

By itself, the proposal would result in some losers who have no access to the innovative solutions, or whom are less productive. There may be branches of industry that had already exhausted their efficiency potential and now have to fear their competitors abroad working under conditions of lower resource prices. There may be poor families who simply cannot afford to buy new equipment. Producers of resources face declining revenues in countries mining natural resources. All these concerns are real. But all of them could be answered by measures taking account of the concerns, if desired, by applying a mix of policy instruments as part of a coherent policy package.

Here the model for operation comes from Sweden. In the early 1990s Sweden, like much of Europe, was plagued by acid rain leading to dying forests and acidic lakes no longer supporting animal life. Nitrous oxides were seen as one of the main causes. The government announced a tax on NOx, which is the sum of two types of nitrous oxides. Large power plants were made liable to pay the tax. Small plants had no obligation because of prohibitive cost – but that would have been unfair to the big operators.

So the government decided to apply the tax together with a mechanism that returned the tax revenues to the operators of power plants, but not in relation to how many kilograms of NOx they produced but based on the kilowatt hours of power they produced. Thus the industry as a whole did not lose any money but each operator had a strong incentive to reduce the nitrous oxides. This model can be, and has in practice, been adjusted to energy and resource taxes for industry. For example, the refund of revenue raised could be made based on workers employed.

Countries have also found ways to protect vulnerable low-income people (who have limited capacity to improve their resource use) from policy-induced price rises. In many countries of the world, a move from generally low and subsidised energy and water prices to realistic market prices (encouraging private capital to invest in more supplies) has been accompanied by policies that allow for a preferential low price level for poor families.

South Africa has set a good example with its integrated water plan. The plan involves realistic water prices encouraging private and public investments in water conservation and water supply to support the country's ambitious growth plans of 6 per cent economic growth per year. But at the same time, every person in South Africa must have access to potable water, as the responsible Department of Water Affairs and Forestry clearly says (Republic of South Africa, 2009). A "lifeline" amount of water must be really affordable for the poor. This principle, which is also in place for small amounts of energy in many countries, could be made part and parcel of the proposal for increasing resource prices in line with resource productivity gains.

Countries applying a virgin resource tax might find that their net tax revenues increased, even if the export of their virgin resources slowed as they captured more of the economic value of their resource exports. These countries would have the option on spending tax increases to support particular economic sectors in their economies, including those affected by the rising tax. Where import taxes were applied on products on the basis of their resource content, the revenues raised could be recycled to countries from where the products came, for instance to fund programmes to improve resource productivity, or to reduce the environmental and social impacts of resource extraction.

8.4.6 Creating new institutional arrangements

The design of a policy mechanism that raised prices of energy or resources would require new, presumably legally binding, institutional arrangements. Those would be context-specific to autonomous countries, but would be likely to involve binding pre-commitment of government to the mechanism, with independent and credible mechanisms for assessment, monitoring and tax level calculation.

For the proposal linking price levels to documented efficiency gains, these new institutions would include standard metrics by which efficiency gains would be assessed. For a proposal calculating resource taxes on the basis of content of resources in products, international mechanisms would need to be created to remove arbitrary decisions on tax levels. Standards and metrics would need to be set for estimation of the content, so that each product had a "product passport" detailing its components' characteristics. This potentially complex exercise – which would otherwise have to deal with components from multiple sources – would need simplification through agreement. It could tie to institutions linking assessment and enforcement mechanisms with revenue sharing. Part of this arrangement could be that resources from countries with comparable resource taxation did not receive any additional taxation when imported, creating an incentive for domestic imposition of resource taxation. These tax arrangements might evolve over time, just as agreements over income tax revenue have evolved between countries.

9 Conclusions

This report has sought to build on our first Decoupling report by providing information on actions which can lead to greater decoupling. It highlights how:

- Trends in global consumption and exhaustion of natural resources and environmental systems imply that the decoupling of economic growth from resource use will become ever more important for stable, successful economies. These trends are already sufficiently significant to influence the factors that make economies competitive. This presents an opportunity for some countries, but many trends in resources unsustainably erode the natural resource base on which many economies depend. The scale of change is very large: one estimate suggests a need for more than US$ 3 trillion per year in investments to respond to the trends.
- Many technologies and techniques that deliver significant resource productivity increases are already commercially available and used in developing and developed economies. They allow economic output to be achieved with fewer resource inputs, reducing waste and savings costs that can further expand the economy or reduce its exposure to resource risks.
- A well-functioning economy might be expected to naturally adjust to changes in resource availability by directing investments into areas of economic activity that bring patterns of resource use in line with society's goals (for example, into innovation in resource productivity). In practice, we see that many economies do not naturally adjust in this way, but suffer from blocks to transition.
- These blocks to adjustment appear to lie in biases and barriers to change within the political and economic

spheres, and interactions between the economy, politics and other aspects of society's activity, which "lock-in" existing patterns of resource use. These obstacles to decoupling can be categorised as arising from:

- the legacy of past policy decisions (including those made before information on resource trends was available); and
- technological, behavioural, organisational and institutional biases against innovation in resource productivity.

- Facilitating decoupling will involve removing these obstacles, to create the conditions in which investments in resource productivity become widespread.
- Developing countries may have a relative advantage in decoupling, because they are not so strongly locked-in by resource-intensive consumption and productions patterns, infrastructure and institutions.
- There has been a wealth of experience across the world in policy to intentionally facilitate the decoupling of resource use, or impacts of resource use, from economic growth, with some notable successes. They indicate that absolute decoupling of economic growth from resource use is possible.
- The continued existence of barriers to decoupling is frequently due to resistance to policy change.[67] Creating the conditions for decoupling would need to unlock that resistance. The chances of success appear higher where the policymaker looks at the institutional framework in which the political decision is made. In practice for changes to policy, this means being aware of the set of actors who are able to influence the decision, their interests, relative power and the norms and assumptions which are shaping the decision.
- Leadership will be needed to break out of resistance to policy changes. Leaders within the public and private sectors can draw on past experiences with policy for guidance on how to take forward decoupling.
- There are forms of policy available to promote decoupling that combine several of the considerations described above. The report mentions two, which are illustrative of the type of combined policy which is needed. One proposal uses taxation or subsidy reduction to move resource prices upwards in line with documented increases of energy or resource productivity. Another looks to shift revenue-raising onto resource prices through resource taxation at source or in relation to product imports, with recycling of revenues back to the economy.

67 As mentioned in Chapter 4.

Annexes

Annex A: Enabling Technologies to Reduce Freshwater Demand

SECTOR	Table A1: Enabling Technologies to Reduce Demand for Water and Increase Water Recycling
Agriculture	– Drip or sprinkler irrigation, sensors and irrigation scheduling, mulching, drought and salt tolerate crops, no-tillage farming practices, rainwater harvesting and managed aquifer recharge and recovery, urban water treatment and reuse in peri-urban agriculture.
Residential buildings	– Various low-flow showerhead designs exist to reduce water consumption by between 50-75 per cent, – Low-flow aerators reduce faucet water flow by 30-50 per cent and can also reduce the energy costs of heating water by up to 50 per cent. – Water-efficient appliances such as front-loading domestic washing machines are 40-50 per cent more efficient than top loading options. – Toilets that use dual-flush systems are capable of reducing water usage significantly compared with conventional models. – Rainwater tanks for rainwater harvesting and reuse. – Drip irrigation, drought tolerant plants, mulch to reduce water loss from evaporation in gardens or small-scale urban agriculture.
Commercial buildings	– Waterless urinals use liquid-repellent coatings and a lighter-than-urine biodegradable trap liquid to prevent odours. – Hybrid dry air/water cooling systems for large buildings have been optimised to reduce typical consumption of water by as much as 75 per cent. – Rainwater tanks
Industry/ manufacturing	– **Water-efficient technologies:** Waterless conveyor belt lubricants, water-efficient spray nozzles and spray guns nozzles/guns, clean in place technologies (i.e sensors), steam traps and condensate return systems, water efficient cooling tower technologies. – **Onsite water harvesting technologies:** Rainwater tanks, stormwater harvesting systems, constructed wetlands. – **Onsite water treatment technologies (to enable onsite water recycling):** Settling ponds, dissolved air flotation (DAF), membrane filtration (micro/nano/ultra filtration), membrane bioreactors (Stephenson et al., 2006), sequential batch reactors (SBR), ion exchange (Zagorodni, 2006), disinfectants (ultraviolet light, chemicals, ozone)[68]. – **Utilise recycled water supplied by water utility:** dual reticulation piping to ensure freshwater and recycled water can both be used.
Fossil fuel power stations	– **Water-efficient cooling systems** - hybrid cooling towers, saline water-cooling towers (which use sea water directly). – Transitioning to using more renewable technologies as energy sources, such as wind and solar technologies, reduces the water intensity of delivering energy.

Source: Compiled by Smith, M and Hargroves, K (2013) building on Smith et al (2010c) and Weiszacker et al (2009).

68 See lecture 6.3 from Smith et al., 2010c: *http://www.naturaledgeproject.net/WaterTransformed/TNEP-WaterTransformed-Lecture6.3.pdf*

Annex B: Alternative Economic Narratives

Evidence from political and behavioural science suggests that for widespread decoupling to happen the mainstream political perspective, or narrative, on economic growth would first need to be adapted. Currently, political arguments often focus on the importance of preventing costs for firms or industrial groups due to changes to the policy framework. This constrains the economy within current structures.

Broadening the political discourse to look at the implications of change for the performance of the economy over time can help decision makers consider where the most beneficial set of policy mixes and investments may be for the economy as a whole. This Annex briefly gives two examples of information that can help provide alternative narratives.

B.1 Putting Costs in Context of Transition

As economies grow, new markets and new technologies make some products, processes and organisational structures less productive, or obsolescent. There are usually winners and losers from every innovation or change. The losers from change often point to any additional costs to them as "costs to the economy". This creates a narrative that decoupling involves greater costs (i.e. needs for new investment) than other development paths. This is usually a misrepresentation, when the full benefits and costs to the economy are considered.

A better picture of the net benefits of costs to the economy comes from looking at alternative development paths and comparing the investments and costs (for example from new firms and new technologies replacing old). Three points are particularly relevant:

1. Individual firms causing environmental harm or over-exploiting resources are usually not taking into account the costs of causing harm to other firms, citizens or society as a whole. From the perspective of the economy as a whole, the position is different. There, the costs of harm to environmental resources (for example pollution of water) do matter to economic success (for instance the costs to other water users). Factoring these costs in, and seeing how they can be reduced by decoupling can increase net benefits of a decoupling development path.

2. Similarly, there may be reductions on future incomes from over-exploitation of resources in the present. If these costs are considered, and factored into decision-making (or market prices) rather than ignored, it seems that costs have increased. In truth, considering these costs allows the economy to reduce costs through efficiency.

3. Costs of new investments in response to change (for example policy change) are also frequently overestimated in political discussion, partly because they do not take into account innovation. Innovation in response to a need to change tends to greatly reduce investment costs, compared to their initial estimates. Good examples of this over-estimation come from decoupling economic growth from costly pollution.

Estimates of costs of different forms of pollution reduction in the USA point to estimates of investment costs being consistently at least double, and sometimes many factors greater than the final costs. (See Table below). Similar overestimations have been observed in other economies (Oosterhuis, 2006).

Table B1 Industry original estimates of the cost of particular forms of environmental protection versus the actual costs (in $US)

POLLUTANT	Initial Cost Estimate	Actual Cost Estimate	Overestimation as a Percent of Actual Cost
Asbestos *(for the manufacturing and insulation sectors)*	$150 million	$75 million	100%
Benzene	$350,000 per plant	Approx. $0 per plant	Infinite
CFCs	**Early 1980s:** Predicted financial catastrophe as no 'cheap' alternatives existed.	Total cost globally of implementing the Montreal Protocol - US$235 billion in 1997 (Bornman and van der Leun, 1998).	Less that Catastrophe
CFCs-Auto Air Conditioners	$650-$1,200 per new car	$40-$400 per new car	63%-2,900%
Coke Oven Emissions OSHA 1970's	$200 million – $1 billion	$160 million	29%-1,500%
Coke Oven Emissions EPA 1980s	$4 billion	$250-400 million	900%-1,500%
Cotton Dust	$700 million per year	$205 million per year	241%
Halons	**1989:** phase out not considered possible.	**1993:** phase out considered technologically and economically feasible.	n/a
Landfill Leachate	**Mid-1980's:** $14.8 billion	**1990:** $5.7 billion	159%
Sulphur Dioxide	**1980s:** $1,000–1,500 per ton of sulphur dioxide.	**1996:** $90 per ton of sulphur dioxide.	~750%
Surface Mining	$6-$12 per ton of coal	$0.50-41 per ton	500%-2,300%
Vinyl Chloride	$109 million per year	$20 million per year	445%

Source: Hodges, H. (1997).

B.2 Discussion of a new growth cycle

Economic growth has been observed to come in waves of prosperity, each driven by the spread of new technologies and structural economic change. Between each period of growth are periods where growth has slowed as the old economic structures exhaust their growth potential. These "Kondratiev cycles" (Freeman and Louçã, 2001) of technological innovations and growth are illustrated in Figure 4.1 shows these findings as an increasing trend in innovation with every tightening timeframes for markets to respond.

For some (Perez, 2002), the next wave of long-term prosperity will in part be driven by improved resource productivity, notably through environmental technology.

As growing economies are always in transition (by definition) discussions of policy change which influence investments are, at their heart, discussions about the optimal direction of transition. They inevitably involve making a choice on which areas of the economy would be more important for the future.

There are sufficient indications are that resource productivity could provide the driver for the next wave. The global market for eco-industries is likely to be hundreds of billions of dollars per year: Some studies evens peak of €1.7 trillion per annum (BMU 2009), and may be growing by around 5% per annum (Roland Berger Consultancy, 2010). Gaining 'first-mover advantage' in these technological and commercial fields can capture growing markets.

B.3 The Paradigm of the Industrial Revolution

The potential of increasing resource productivity can be considered in light of what can be called the biggest economic success story of history, namely, the Industrial Revolution. That can be described as the increase of labour productivity over 160 years.

Compared with the typical labour productivity of the middle of the 19th century, today's labour productivity in industrialized countries is easily twenty times higher. This success has allowed many countries and families to reach levels of wealth that were positively unimaginable 160 years ago.

This increase in productivity has one striking feature: labour productivity went hand in hand for most of the time with gross wages per hour of work. As productivity increased, workers could successfully demand higher wages. And as wages went up, employers were driven to speed up further increases of labour productivity. In effect, there was an eternal "ping-pong". The rise in wages drove greater productivity, which in turn lead to more (not less) economic growth. Figure B.1 shows the parallel lines of growth between labour productivity and wages for one country (the USA) and for one segment of time of 60 years duration.

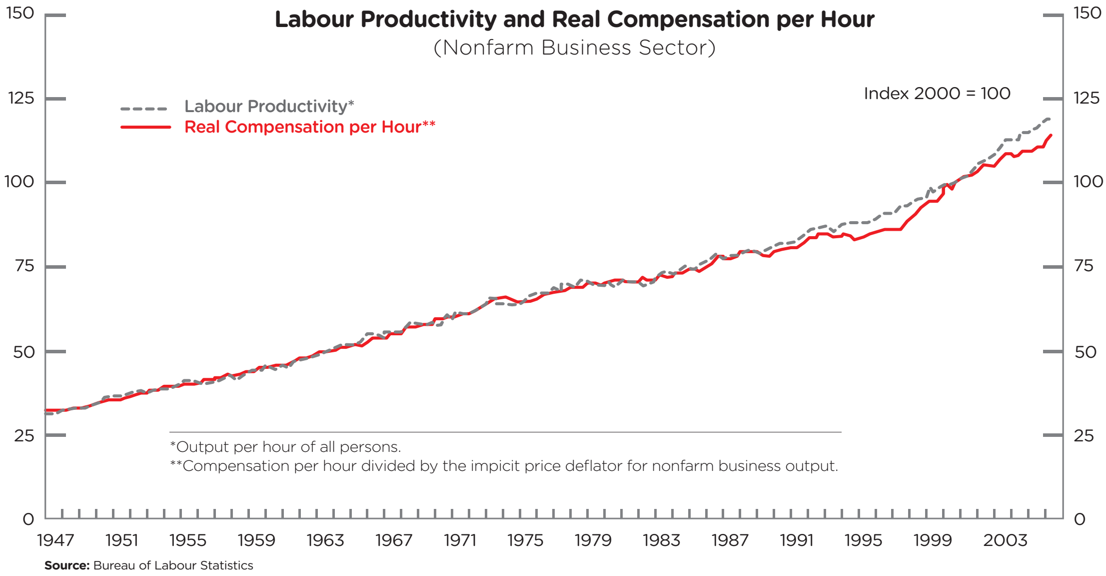

Figure B.1 The parallel increase of labour productivity and of gross hourly wages in the United States from 1947 – 2007.
Source: US Bureau of Labor

The tandem increase of labour productivity and wages can be observed in all OECD countries. Developing countries, beginning with China are well underway emulating the success story.

The mutual causality between factor prices (as economists would call wages in this context) and productivity and growth gives a very different perspective on how growth is stimulated over time, as growth comes mainly from increases in productivity. Applied to another production factor – natural resources – this success story suggests another side to price rises of resources: that they induce productivity and growth in a dynamic, flexible economy.

Annex C: Balance of trade in water embodied in products (virtual water)

Table C1: Top-ten of net virtual water exporters (Gm3/yr) and top-ten of net virtual water importers. (Period 1997-2001)

Countries with net exports	Export	Import	Net Exports	Rank	Countries with net imports	Import	Export	Net Imports
Australia	73	9	64	1	Japan	98	7	92
Canada	95	35	60	2	Italy	89	38	51
USA	229	176	53	3	United Kingdom	64	18	47
Argentina	51	6	45	4	Germany	106	70	35
Brazil	68	23	45	5	South Korea	39	7	32
Ivory Coast	35	2	33	6	Mexico	50	21	29
Thailand	43	15	28	7	Hong Kong	28	1	27
India	43	17	25	8	Iran	19	5	15
Ghana	20	2	18	9	Spain	45	31	14
Ukraine	21	4	17	10	Saudi Arabia	14	1	13

Annex D: Lessons from History on the dangers of lock-in and lack of foresight

Archaeological evidence reveals such courses of decline and eventual collapse in a diverse array of ancient civilisations: Sumerians from Mesopotamia, Maya in the Yucatán, the Anasazi in the American Southwest, the Garamantian Empire of the Sahara, the Greenland Norse, the statue builders of Easter Island, the Nazca civilization in Peru, Great Zimbabwe in Africa, and Angkor Wat in Cambodia.

These past civilisations succumbed to environmental degradation and resource depletion in different forms. These led to food shortages and diminishing returns on investments in energy and resource extraction. Weakened by this, ancient civilisations became more vulnerable to foreign invasions, internal conflict or simply declined. Table D1 summarises some of these falls.

Table D1: Patterns of Decline – Why Civilisations Collapsed

Angkor Wat, Khmer Empire, Cambodia (800 to 1500 AD)	Deforestation to extend their farmland up to the slope of Kulen mountain, 80 kilometres to the north, led to flooding and huge amounts of sediment and sand were washed down to fill up their extensive canal water system – ruining the city's water supply.[69]
Sumeria (Mesopotamia)	Agricultural irrigation systems where underground drainage was weak, raised the water table. As the water climbed to the surface, it evaporated, leaving behind salt. Salinisation of agricultural lands resulted in collapse (Jacobsen and Adams, 1958).
Garamantian Empire (Sahara) 500 BC – 300 AD	The Garamantian empire was made possible in the Sahara by a 3,000-mile network of underground irrigation canals to exploit ancient groundwater. Overexploitation of groundwater resulted in its collapse.
Mayan civilization, Central America	Loss of soil fertility and drought from deforestation and climate change led to a crisis from lack of sufficient food and rising levels of internal and external violence (Diamond, 2005).

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"Decoupling 2: technologies, opportunities and policy options". The report was produced by the Decoupling Working Group of the International Resource Panel. It explores technological possibilities and opportunities for both developing and developed countries to accelerate decoupling and reap the environmental and economic benefits of increased resource productivity. It also examines several policy options that have proved to be successful in helping different countries to improve resource productivity in various sectors of their economy, avoiding negative impacts on the environment.

It does not seem possible for a global economy based on the current unsustainable patterns of resource use to continue into the future. The economic consequences of these patterns are already apparent in three areas: increases in resource prices, increased price volatility and disruption of environmental systems. The environment impacts of resource use are also leading to potentially irreversible changes to the world's ecosystems, often with direct effects on people and the economy – for example through damage to health, water shortages, loss of fish stocks or increased storm damage.

But there are alternatives to these scary patterns. Many decoupling technologies and techniques that deliver resource productivity increases as high as 5 to 10-fold are already available, allowing countries to pursue their development strategies while significantly reducing their resource footprint and negative impacts on the environment.

This report shows that much of the policy design "know-how" needed to achieve decoupling is present in terms of legislation, incentive systems, and institutional reform. Many countries have tried these out with tangible results, encouraging others to study and where appropriate replicate and scale up such practices and successes.

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