CHAPTER 16

Scenarios and Sustainability Transformation

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Main Messages

Meeting an ambitious set of sustainability targets by the middle of the century is possible but current supporting policies and strategies are not adequate to achieve this. Scenario studies show that without greater efforts to implement appropriate short-term policies, to shift investments to achieve necessary long-term structural changes, and to introduce behavioural transformations, it will not be possible to meet sustainability targets. These relate to international agreements on environmental protection and human development for issues like atmosphere and climate change, land and food security, water and biodiversity.

Transforming both consumption and production is important. Scenario studies suggest that targets can be met, but only if measures are taken to influence the levels and patterns of consumption and production. Most current policies focus on changes in production processes to achieve targets, but fail to address consumption. However, changes in consumption levels and patterns have great – but as yet unrealized – potential to reduce environmental pressures.

Effective implementation of wide-ranging technical and policy measures needs to be supported by a shift in underlying motivations and value patterns. Changes need to be both short and long term, and to combine technology, investment and governance measures along with lifestyle modifications grounded in a mindset shift towards values based on sustainability and equity. They also need to reflect regional differences and priorities. Technical measures alone are unlikely to be enough, and will not have the required level of societal support if not accompanied by transformations at all leverage points.

Accomplishing such complex transformations requires a gradual but steadily accelerating transition process. Some successful policy innovations are already happening, but need to be mainstreamed to be more effective. There is also a need to stop doing the things that pull the Earth System towards unsustainability. At the same time, it is important to provide resources, build capacity and create an enabling environment in a way that is consistent with visions of a sustainable world.

Broad-based social contracts grounded in jointly developed visions of a sustainable future would help to bring key stakeholders on board. The transition requires a high degree of consensus and coordination of action between social actors – governments, the private sector and civil society.

To ensure coherence, contextually sensitive transition pathways could be developed as joint visions of the future. These can be agreed on as informal or formal social contracts that respect the requirement to assure sustainable access to the resources necessary for human well-being.

The transition process needs to be based on adaptive management. Uncertainties play a key role in the problems of the Earth System. As a result, management should be based on learning-by-doing processes, periodic reassessment based on new learning, and a great diversity of measures. This will provide better insurance against wholesale failure on critical issues – due either to inherent uncertainties or inadequate implementation – and be mutually strengthening as well.

There is a need for clear long-term environment and development targets and for stronger accountability in international agreements. Given that environmental and societal Earth System changes can be slow, long-term visions and goals – expressed as social contracts – could help focus investments and technology development, induce societal change, and engage other actors in society.

INTRODUCTION

The nature and scale of changes described in Part 1 indicate that, without additional policies, the global environment will degrade further – from a situation that already raises considerable concern. A crucial question, therefore, is how to halt and reverse such trends.

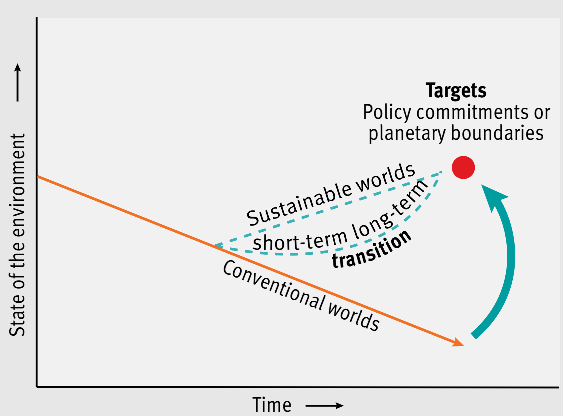
While previous *Global Environment Outlook* (GEO) reports have explored several scenarios looking at very different futures (UNEP 2002, 2007), the emphasis of *GEO-5* is on the choices and strategies that could, from 2012, lead to a sustainable future. This is advanced by looking at two very different storylines based on a review of existing scenario studies:

- a view of the world in 2050 assuming business-as-usual paths and behaviours – "conventional world" scenarios; and
- an alternative that leads to results consistent with our current understanding of sustainability and agreed-upon goals and targets on the road to 2050 – "sustainable world" scenarios.

A key difference between the two is how deeply transformation occurs, supporting the emergence of alternative development trajectories (Figure 16.1).

The ambitious goals of this systemic transformation require increasing the power of collective thinking, creativity and coordination. Cultivating profound long-term change is neither a linear nor a simple process, especially in complex dynamic systems that often exhibit non-linear behaviour or tipping points (Lenton *et al.* 2008; Folke *et al.* 2002; Levin 1998). For this reason, knowledge of the component parts of a system, their relationships, interactions and emergent behaviour can help policy makers understand, anticipate and strategize outcomes for the longer run, even when evidence of those changes may not be immediately apparent. Sustainable world scenarios represent and require many fundamental shifts in society-environment interactions. These scenario outcomes are designed to be consistent with the best available science on the Earth System and the aspirations for environment and sustainable development manifested in multilateral agreements. They combine the effects of mainstreaming promising measures that already exist with change at progressively deeper structural levels.

Figure 16.1 Conventional world and sustainable world scenarios in *GEO-5*



Source: Adapted from PBL 2012

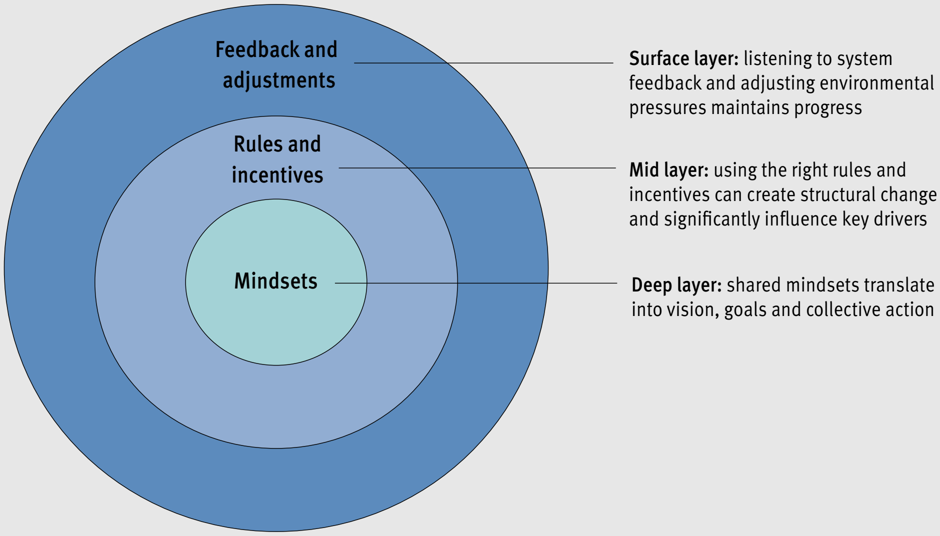
A system is a set of things – here, people and ecosystems in the Earth System – that interact with one another within a defined boundary, and that produce their own pattern of behaviour over time. Complexity theory shows that small, calculated, strategically applied actions can effect great change. In a complex system, leverage points are those where the outcome is disproportionate to the input. Identifying and acting on effective leverage points is especially difficult in cases in which casting off old paradigms is involved, but once a leverage point has been pushed in the right direction, the resultant change can be particularly lasting and profound (Meadows 1999).

> *"Magical leverage points are not easily accessible, even if we know where they are and which direction to push them on. There are no cheap tickets to mastery. You have to work at it, whether that means rigorously analyzing a system or rigorously casting off your own paradigms and throwing yourself into the humility of Not Knowing."*
> Donella H. Meadows

Figure 16.2 depicts the transformative layers where leverage points may be found. The more embedded drivers are in the system, the more enduring and profound the change needs to be: shifting mindsets is at the core of transformation because it translates into visions, goals and collective action. Changing rules and incentives is literally a game changer in the pursuit of transformation, because the right incentives can create structural change and influence key drivers. The outer layer of transformation involves creating and listening to feedback and making adjustments to environmental pressures to maintain progress towards sustainability.

Shepherding a complex dynamic system through transition is not a linear or unidirectional process, and progress or setbacks occurring in each layer continuously influence the others. Thus a policy approach that diversifies strategy across all the layers of transformation presents a diverse and resilient portfolio for using leverage to its greatest advantage. The result is an integrated policy that produces both short-term and profound long-term system shifts by cultivating and targeting ever deeper system change over time, while monitoring it as well as feeding it with successes at more superficial levels. Clearly, producing these outcomes requires an ability to accept some uncertainty, while also holding a strong focus on integrating and documenting progress towards a clearly articulated vision of success. The section on visions, goals and targets on the road to 2050 articulates a vision of a desired state of the environment, with goals and targets based on existing international agreements.

Figure 16.2 Layers of transformation



Source: Meadows 1999

The section on sustainability pathways reviews existing scenarios to provide an outlook for the drivers of environmental change and the pathways that society could follow on the road to 2050 to achieve goals and targets. Over the last few years, a large number of scenario-based assessments of global environmental problems and human development have been published, including the Intergovernmental Panel on Climate Change (IPCC) climate assessments (Nakicenovic and Swart 2000), the *Global Environment Outlook* reports (UNEP 2007, 2002), the *Millennium Ecosystem Assessment* (MA 2005a), the *International Assessment of Agricultural Science and Technology Development* (IAASTD 2009b) and the *World Water Development Reports* (UNESCO 2009, 2006). Most of these used an explorative approach with widely diverging scenarios that assess what might happen in the future. Van Vuuren *et al.* (2011a) discuss many of the assessments and highlight emerging commonalities. Generally, the scenarios explore a wide range of possible outcomes but, importantly and by design, almost none involves meeting sustainability targets – or sets them out as an objective. In contrast, some visioning exercises carried out by various organizations, such as the World Business Council on Sustainable Development (WBCSD 2010), the International Geosphere Biosphere Programme (Jäger and Cornell 2011) and UNEP's *Green Economy Report* (UNEP 2011c), have tried to do so.

The section on advancing sustainability explores strategic elements that have the potential to advance the transition onto pathways consistent with visions of a sustainable world. Changing the current unsustainable course demands a scale of effort without precedent in human history (Steffen *et al.* 2005). Meeting this challenge will require a diverse portfolio of strategies and measures, partly as a form of insurance against failure, but also to reflect the different and dynamically changing condition of individual countries and ecosystems around the world (Innes *et al.* 2005; Speth 2005). Taking into account recent scientific advances in understanding the functioning and governance of closely coupled human systems and ecosystems, this section provides guidance for developing response measures and strategies at the sub-global level. A strategic element identifies visioning and the ability to build social and political consensus around visions of sustainable-future outcomes as essential but underrated aspects of sustainable development governance (Costanza 2000; Meadows 1996). Society-wide relearning and the phase-out of unsustainable policies and practices are discussed, coupled with the redirection of resources towards high-leverage intervention points, including those that better align peoples' mindsets with sustainability and redefine the common meaning of progress as something broader and more meaningful than gross domestic product (GDP). Finally, the need for approaching the transition as an adaptive learning process to build resilience (Loorbach 2007; Holling 2001; Lee 1993) is identified. While providing guidance at the sub-global level, these strategic elements also serve as a starting point for the discussion of responses within international institutions.

VISIONS, GOALS AND TARGETS ON THE ROAD TO 2050

This section introduces a sustainable world vision for 2050 with specific goals and targets derived mainly from existing international agreements. Visioning activates awareness, emotion and imagination with the intention of bringing new systems into being, while the 40-year perspective allows enough space for societies to identify policy options and initiate the structural transformations required.

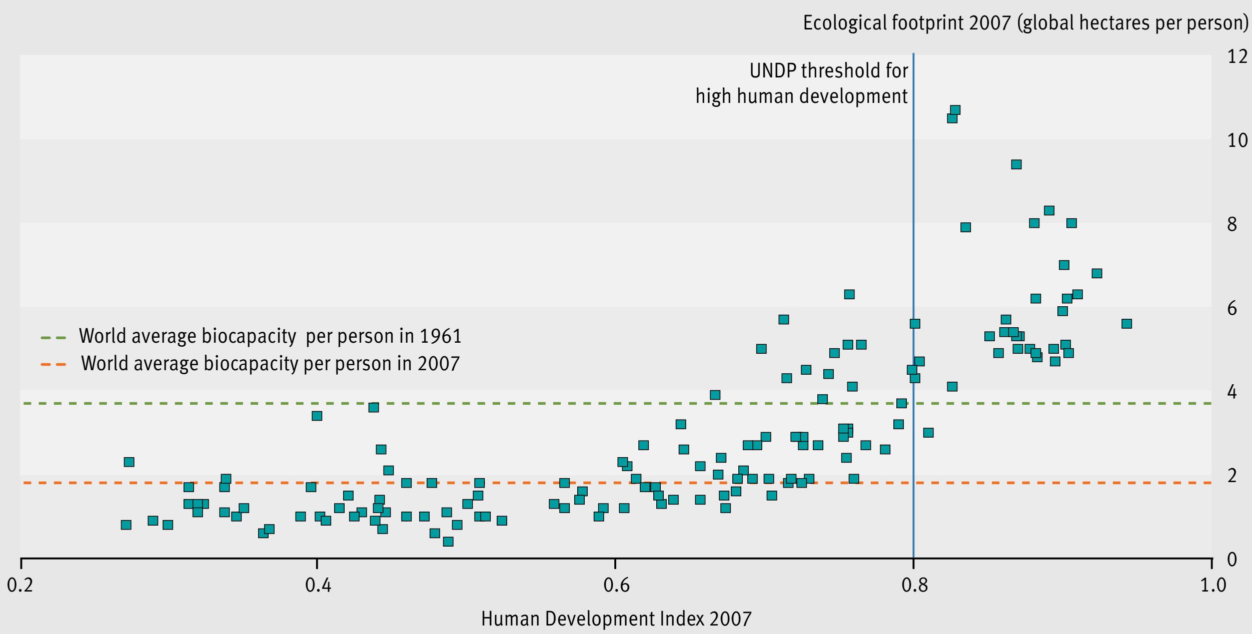
The challenge of meeting both human needs and human aspirations within the planet's carrying capacity makes the overall ambition complex (UNEP 2011c, 2007; WBCSD 2010; MA 2005b; WCED 1987). A number of countries have attained high levels of human development, but this has often been at the expense of the global natural resource base and environmental quality, and has resulted in high levels of greenhouse gas emissions (Figure 16.3). Given the analysis in Part 1, it is clear that this development path is not sustainable in the long run. Many other countries, meanwhile, are faced with prioritizing the basic human needs of their citizens – such as energy, food and water – over protecting the global commons. In general, these countries currently exert a lower per-person pressure on the global environment, but the overall pressure can still be significant where the population is large, or where there are local environmental problems. Furthermore, when future dynamics are taken into account, the situation may get even worse.

Farmers thresh their rice harvest in Punakha, Bhutan, the first country to include the concept of happiness in its national measurements of development. *© Gill Fickling/UN Photo*

A vision of a sustainable world could be based on the simultaneous achievement of broad overarching goals that take into account the fulfilment of basic human needs, mainly related to reliable and affordable energy, food, drinking water and sanitation, and the achievement of environmental sustainability at the global, national, regional and local levels. Such a vision was the basis of the 1992 Rio Declaration and was advanced further in the Millennium Development Goals (MDGs) (UN 2000).

A sustainable world cannot be realized until it is widely and actively envisioned. Of the available tools to address the challenges ahead, visioning is critical to crafting profound and enduring change. Vision statements have a specific form: they describe the future, yet they are phrased in the present tense as if the desired change had already occurred. Box 16.1 presents a possible vision for

Figure 16.3 Twin challenge



This figure plots countries on the basis of two indicators: the Human Development Index (HDI) and the ecological footprint per person. In order to achieve sustainability, countries must move towards the bottom right corner and as such decouple human development from natural resource use and environmental impacts (UNEP 2011c). The figure shows that worldwide, no country held that position in 2007.

Note: A global hectare is a hypothetical area equivalent to 1 hectare of globally averaged productivity.

Source: Global Footprint Network 2010; UNDP 2009

Box 16.1 A possible vision of the world on a path towards sustainability in 2050

The year is 2050. What appeared to be so improbable at the start of the second decade of the century is turning out to be possible, after all. Changes have been great, and there have been deep losses. Although people expect and are prepared for far greater changes than any yet experienced, a sense of possibility abounds as there have been so many successes.

Climate change is still a problem, but emissions have nearly halved compared to four decades ago. Basic drinking water and sanitation needs of even the poorest have been met. Learning and mimicking nature's resilience has helped restore ecological function in areas once considered irretrievably lost. The most devastating projections for ocean acidification, groundwater salinity, desertification and land degradation have not materialized – with real implications for the food system worldwide. An eco-efficient, highly diversified agricultural system ensures that food shortages are infrequent, local, and mostly due to extreme weather events. Civil instability and conflict over resources, food and water is now rare. More humans enjoy a higher quality of life for longer than ever before, without denying future generations the same possibility.

Most of the world's citizens are actively and personally engaged with humanity's goal of living within planetary limits. Peak oil and peaks in the supply of some other natural resources have come and gone, but thanks to radical changes in lifestyle and resource productivity, have not led to the disruption of absolute scarcity. Leadership is everywhere; as a result, diverse, innovative, bottom-up initiatives abound and are spread through social networks, faster than ever before.

Governance systems, more than ever, are creating synergistic impacts. There has been a tangible shift in the willingness to look for truly sustainable alternatives, a consensus to aim for prosperity rather than continued economic growth at all costs, a commitment to redirect investments to green entrepreneurship and innovation. Knowledge of nature, species and ecosystems is used as a measure and model for humanity's greatest challenges. Indigenous and traditional knowledge, women's access to education, governance and decision making, and a successful balance in North-South and developed-developing perspectives are the forums for pursuing these goals: each shows clearly that human systems esteem diversity as a form of wisdom.

How did this happen? Perhaps things had to get worse before they got better. Perhaps each problem that the financial, social, and ecological debt crises presented had a positive outcome. Ironically, the lynchpin in this transition was an element that had previously been all but overlooked in international governance. A generation of young people emerged, by nature more comfortable with visioning, social networking and truth-telling than its elders. The resulting intergenerational contract, building on momentum already present in society supported a generation of problem-solvers who had never learned values and behaviours that undermined planetary life-support systems, and who could envision solutions and success previously unforeseen.

Achieving these outcomes was the result of a major global effort that began at the 2012 World Summit in Rio.

2050, in line with the internationally agreed goals summarized in Table 16.1. Its transition pathways and key strategic elements are described in the subsequent sections of this chapter.

Obviously, other important global sustainable development targets exist, and the vision and goals outlined here (Box 16.1; Table 16.1) cannot provide a complete picture of a sustainable world. A vision develops through evolution and must have contributions from many people before it is mature and compelling. Thus, the vision captured here is only a start: it represents an invitation to individuals to envision the world they really want in 2050. Catalysing human imagination is integral to realizing a sustainable, desirable future.

The analysis that follows reflects the thematic structure of Part 1: first the global drivers of environmental change, followed by the environmental themes of atmosphere, land, water and biodiversity. As there has been little scenario building on the theme of Chapter 6 – chemicals and waste – it is not included in this analysis, although for the sake of completeness it appears in Table 16.1. Since meeting basic human needs is crucial to a sustainable development strategy, related human well-being objectives are addressed, where appropriate, under each theme. In the selection process, care was taken to ensure that targets properly address the desired state of the global environment and basic human needs.

At this point, it is also important to note that internationally agreed goals and targets are, by definition, a result of political compromise. They take into account scientifically established thresholds to a varying degree, but they may not be fully in agreement with them, particularly as scientific understanding of where such thresholds may lie is also evolving. Therefore, in some cases, selected targets only include a qualitative description of the objective, without further specification, either because of lack of data or because there is still divergence over quantifiable targets. For the climate change problem, for instance, what level of global mean temperature increase is seen as dangerous – and therefore must be avoided according to the qualitative objective agreed in the United Nations Framework Convention on Climate Change (UNFCCC) – is highly debated. Yet, the risks associated with temperature rise are clear, and some

Table 16.1 Goals and targets on the road to 2050

Themes	Goals	Targets
Atmosphere		
United Nations Framework Convention on Climate Change (UNFCCC 1992) Article 2 **Cancun Agreements (UNFCCC 2010) Article 1 Paragraph 4**	Prevent dangerous anthropogenic interference with the climate system	Stabilizing greenhouse gas emissions at a level that would hold the increase in global average temperature below 2°C above pre-industrial levels
Convention on Long-range Transboundary Air Pollution (CLRTAP 1979) Article 2 **World Health Organization guidelines (WHO 2006)**	Reduce and prevent air pollution	Limiting the concentration of pollutants (such as $PM_{2.5}$, PM_{10}, SO_2, NO_2, O_3, CO, Pb) in line with WHO guidelines
Johannesburg Plan of Implementation (JPOI) (WSSD 2002) Paragraph 9a **Energy for a Sustainable Future (AGECC 2010)**	Improve access to reliable, affordable, economically viable and environmentally sound energy supplies	Achieve universal access to modern energy supplies by 2030
Land		
FAO World Food Summit Plan of Action (FAO 1996) Paragraph 33g **FAO World Food Summit Plan of Action (FAO 1996) Paragraph 33g** **Agenda 21 (UNCED 1992b) Chapter 11.12a**	Conservation and sustainable use of land Sustain forest cover	Reduce salinization, combat desertification, reduce cropland expansion and prevent soil pollution and degradation Reduce the deforestation rate and expand forest areas
UN Millennium Declaration (UN 2000) MDG 1 Target 1c	Eradicate hunger	Halve, between 1990 and 2015, the proportion of people who suffer from hunger, and eradicate hunger by 2050
Water		
Johannesburg Plan of Implementation (JPOI) (WSSD 2002) Paragraph 25d **UN Millennium Declaration (UN 2000) Paragraph 23**	Sustain water resources, protect water quality and aquatic ecosystems	Intensify water pollution prevention to reduce health hazards and protect ecosystems Stop the unsustainable exploitation of water resources by developing water management strategies at the regional, national and local levels, which promote both equitable access and adequate supplies
UN Millennium Declaration (UN 2000) MDG 7 Target 7c	Universal provisioning of safe drinking water and improved sanitation	Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation and ensure full access by 2050
Biodiversity		
Convention on Biological Diversity (CBD) Aichi Biodiversity Targets (CBD 2010) Target 5 **CBD Aichi Biodiversity Targets (CBD 2010a) Target 12**	Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity and promote its sustainable use and fair and equitable benefit sharing	By 2020, at least halve and where feasible bring close to zero the rate of loss of all natural habitats, including forests, and significantly reduce degradation and fragmentation By 2020, prevent the extinction of known threatened species, and improve and sustain their conservation status, particularly of those most in decline
United Nations Convention on the Law of the Sea (UNCLOS 1982) Article 192 **Jakarta Mandate (1995)** **FAO Code of Conduct for Responsible Fisheries (FAO 1995) Paragraph 6.2**	Protect and preserve the marine environment	Promote conservation and sustainable use of the coastal and marine ecosystems as well as their natural resources Promote the maintenance of the quality, diversity and availability of fishery resources in sufficient quantities for present and future generations
Chemicals and waste		
Johannesburg Plan of Implementation (JPOI) (WSSD 2002) Paragraph 23 **Stockholm Convention on Persistent Organic Pollutants (2009)** **Rotterdam Convention on Certain Hazardous Chemicals in International Trade (Rotterdam Convention 1998) Article 1**	Reduce chemical pollution to protect human health and the environment Monitor and control the trade in certain hazardous chemicals	By 2020, use and produce chemicals in ways that lead to the minimization of significant adverse effects on human health and the environment Protect human health and the environment from persistent organic pollutants Promote shared responsibility in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm and to contribute to their environmentally sound use
Johannesburg Plan of Implementation (JPOI) (WSSD 2002) Paragraph 22	Minimize the amount of waste and promote reuse and recycling	Prevent and minimize waste and maximize reuse, recycling and use of environmentally friendly alternative materials

are becoming more acute, so preventative and precautionary action is necessary as a form of sustainability insurance (UNFCCC 2010). Strengthening the long-term globally agreed target on the basis of the best available scientific knowledge, rather than of political consensus, is still an issue under consideration at UNFCCC meetings. Overall, the targets are based on the latest multilateral agreements associated with the goals that inspire and guide humanity towards a specific destination.

PATHWAYS TO ACHIEVE LONG-TERM SUSTAINABILITY GOALS

This section examines the existing literature on quantitative scenarios to outline how sustainability targets might be met. The chapter looks at the scenarios used in earlier assessments and published in the scientific literature and summarizes the findings for the conventional world projections, scenarios that describe the consequences of continuing current policies, and compares them to sustainable world projections, those that aim to reach the long-term targets envisioned above. The purpose of this comparison is to assess the gap between these different pathways and to discuss how it might be closed. The two scenario categories have some general characteristics. Conventional world scenarios typically extrapolate historical trends, assuming no new policy direction, also described in the literature as business-as-usual. They also usually assume a continuing increase in the use of material goods and services, driven by the same market dynamics dominant in the world today. These scenarios thus tend to ignore the risks associated with environmental degradation and resource scarcity. Sustainable world scenarios, in contrast, explore the changes required if sustainable development goals are to be met. Clearly, this category includes a wide range of scenarios based on the use of advanced technologies, increased efficiency and/or lifestyle changes. In some cases new calculations have been performed to respond to gaps in the literature.

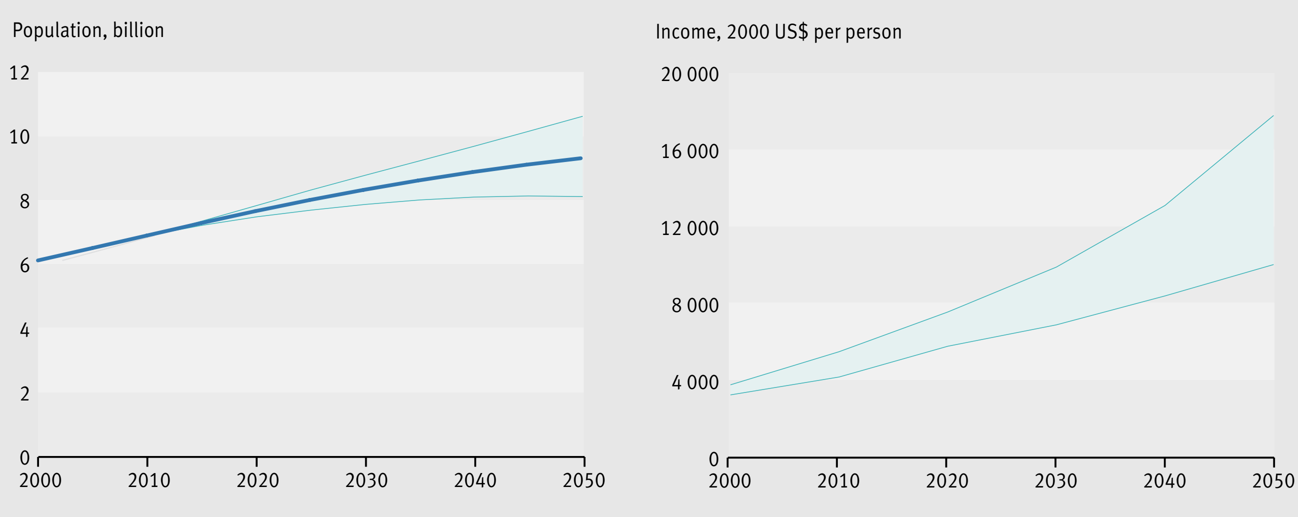
Drivers

Population and income

The global population is projected to grow to 8–10.5 billion people by 2050 (Figure 16.4), and even to as many as 15 billion by 2100 (UNDESA 2011; Lutz *et al.* 2008). By far the largest share of population growth is expected in countries that are currently low-income, mainly in sub-Saharan Africa, Northern Africa and West Asia, and South Asia. Generally, low population scenarios are more likely to lead to lower environmental pressure than high ones, although high population scenarios that result in low emissions can also be found in the literature (van Vuuren *et al.* 2012). Still, the importance of population growth in the context of sustainability targets has been recognized at the highest UN level (ICPD 1994). Investing in women's education is one of the most effective methods of reducing population growth, as women with higher levels of education have fewer children. Scenario analysis by Lutz and Samir (2011) shows a global population ranging from 8.9 to 10.0 billion people in 2050 as a result of a high or low education scenario alone.

Nearly all scenarios project a further increase in GDP as an indicator of economic development, although there is variation between scenarios, with global average per-person growth rates ranging between 1.2 and 2.2 per cent annually (Figure 16.4). The relationship between income and environmental change is ambiguous. On the one hand, high income tends to coincide with high consumption levels, leading to further environmental degradation. On the other, an increase in income can also coincide with lower population levels, an increasing appreciation of a clean environment and rapid technological change. These

Figure 16.4 Population and income projections in the scenario literature, 2000–2050



Note: The shaded areas indicate the 10–90th percentile literature range.

Source: (GDP) van Vuuren *et al.* 2012; (population) UNDESA 2009

A young girl receiving training in trade in the Kapisa Province of Afghanistan, where the vast majority of primary and secondary students are boys. *© Eskinder Debebe/UN Photo*

trends may lead to a decrease in environmental pressure as incomes rise, as observed, for instance, for local air pollution, the so-called environmental Kuznets curve (Chapter 1) (van Ruijven *et al.* 2008; Riahi *et al.* 2007; Smith 2005; Stern 2003). This effect has, however, not been observed for many global environmental problems, including carbon dioxide (CO_2) emissions, and there have been reports of displacement effects – with production shifting to low-income countries – underlying some Kuznets observations (Luzzati and Orsini 2009). It is important to note that it is not the level or rate of economic growth that determines environmental impacts, but its structure. For example, a focus on services rather than material goods could reduce the pressure on natural resources. Consistent with this scientific debate, no straightforward relationship between income projections and achievement of sustainability targets can be found in global scenarios (van Vuuren *et al.* 2012). Some scholars emphasize the positive feedbacks between economic growth and achieving sustainability goals, the green growth paradigm for example (WCED 1987), while others highlight trade-offs and the correlation between consumption rates and the flow of material goods, as in the steady-state economy paradigm (Czech and Daly 2004; Daly 1974, 1971). The difference depends on factors such as technological development, macro-economic feedbacks and avoided environmental damage (UNEP 2011b).

Consumption

Global average consumption levels have risen significantly during recent decades, outpacing simultaneous improvements in efficiency. Increases in both the number and size of cars have been much greater than improvements in fuel efficiency, leading to a rapid increase in overall transport fuel consumption (Girod *et al.* 2012). In fact, efficiency improvement itself may induce higher consumption levels by decreasing the cost of consumption – the rebound effect. Changing consumption patterns could form an important part of a sustainable development strategy as it often leads to multiple benefits and brings environmental concerns closer to consumers. Historically, however, campaigns aimed at changing consumption patterns have not always been successful. The effectiveness of changes in consumption can be illustrated by scenario studies on dietary change, discussed below in the section on land.

There is increasing recognition of the importance of the environment for human development and quality of life (World Bank 2008; UNEP 2007; MA 2005b). Currently, an estimated 24 per cent of the global disease burden and 23 per cent of all deaths can be attributed to environmental factors (Prüss-Üstün and Corvalán 2006). For child mortality, in particular, low levels of food intake, unsafe drinking water, a lack of basic sanitation and the use of solid fuels for cooking and heating are important drivers (Black *et al.* 2010). Analysis shows that, despite some progress, in conventional world scenarios, full access to sufficient food, water, and energy will not be reached for many countries in South Asia and sub-Saharan Africa by 2030, or even 2050 (World Bank/IMF 2011; Hilderink *et al.* 2009).

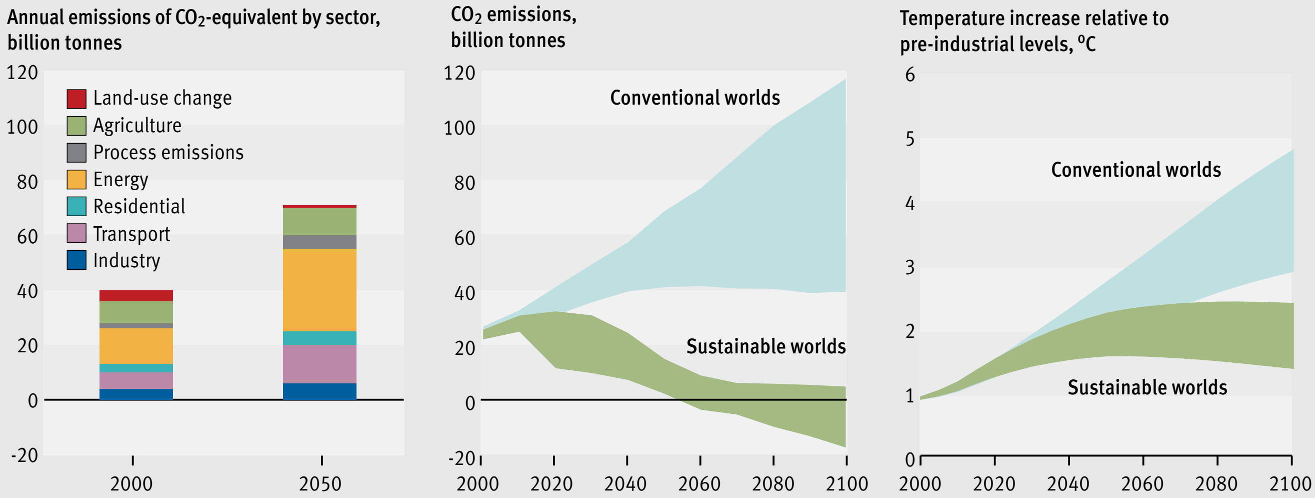
Atmosphere

Conventional world scenarios

Almost all scenarios that assume no major policy changes expect energy consumption to continue to grow worldwide. On average, they project energy consumption to increase by a factor of three over the 21st century, with a range of 2.5–5.5 (van Vuuren *et al.* 2012; Clarke *et al.* 2010; Fisher *et al.* 2007). Moreover, such conventional world scenarios project fossil fuels to retain a large market share as their price, especially for coal, is expected to be lower than that of alternative fuels. Despite the domination of fossil fuels, however, most scenarios project a significant increase in non-fossil energy production, including biomass, solar, wind and other renewables, as well as nuclear.

The projections also indicate that by 2030 nearly 3 billion people, mostly in rural areas in sub-Saharan Africa and Asia, will still rely on traditional biomass for cooking and heating, while about 1 billion people will have no access to electricity (GEA 2011; IEA *et al.* 2010). Conventional world scenarios also

Figure 16.5 Emissions and temperature scenarios



Note: Emission and temperature scenarios cover a longer time period than other scenarios in this chapter because of inertia in the climate system. The shaded areas indicate the 10-90th percentile literature range.

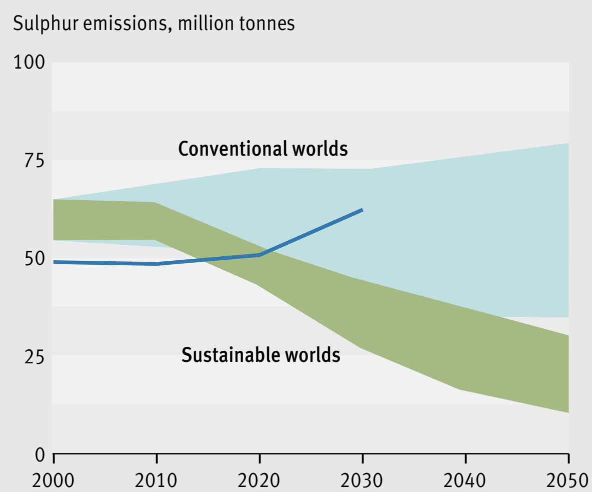
Source: van Vuuren *et al*. 2008a, 2008b; Fisher *et al*. 2007

consistently project high numbers of people suffering from the health consequences of traditional fuel use, with around 1.5 million annual premature deaths resulting from indoor air pollution in 2030 (IEA *et al.* 2010). The use of traditional fuels in inefficient stoves can also have serious implications for deforestation and local and regional air pollution (FAO 2006a; IEA 2006; Arnold *et al.* 2003). It should be noted that fuelwood use could actually increase in response to rising prices for modern fuels (Easterling *et al.* 2007).

Increasing fossil fuel use implies increasing emissions of greenhouse gases. On average, conventional world scenarios project greenhouse gas emissions to more or less double in the next 50 years (van Vuuren *et al.* 2012; PBL 2009; Fisher *et al.* 2007). Scientific knowledge leaves little doubt that a consequence of the increase will be a steady rise in global mean temperature (Figure 16.5) (van Vuuren *et al.* 2008a, 2008b; IPCC 2007), of 3–5ºC relative to pre-industrial levels by the end of the century. There is considerable uncertainty regarding both climate change and its impacts. The IPCC's Fourth Assessment Report indicates that a warming of 4ºC is likely to have negative effects on agricultural yields in most parts of the world (Easterling *et al.* 2007), with sensitive systems – coral reefs, some mountain ecosystems, polar sea ice and many of the world's glaciers – likely to be lost and sea levels possibly rising by more than 1 metre by the end of the century. Moreover, there is a risk of passing critical thresholds for the functioning of the Amazon rainforest (IPCC 2007), as well as an increase in the frequency of storms, droughts and other extreme weather events.

Historically, people have tended to invest more in the control of air pollution as they become more affluent. Typically, emissions increase in the early stages of development, but may diminish as incomes rise. In conventional world scenarios, emissions are usually shown to decrease slowly in the first decades of the 21st century in high-income countries, but to increase in low-income ones (van Ruijven *et al.* 2008). Globally, this results in a pattern

Figure 16.6 Scenarios for sulphur emissions



Conventional world scenarios include those without climate policy; sustainable world scenarios include those with stringent climate policy. The blue line represents the scenario under current legislation.

Note: The shaded area indicates the 10-90th percentile literature range.

Source: Van Vuuren *et al.* 2008a; Cofala *et al.* 2007 of stable or slowly rising emissions beyond 2050 (Figure 16.6), though some decrease would be expected over the longer term. During most of the century, therefore, these scenarios suggest that targets for health standards are unlikely to be met in many parts of the world.

Sustainable world scenarios

Several scenario studies assess the 2050 sustainability target of providing universal access to modern energy (Table 16.1) (GEA 2011; Pachuari *et al.* 2011; van Ruijven *et al.* 2012; IEA 2010). Improving access to electricity requires accelerating the pace of electrification in the least developed countries either by grid expansion or by the development of decentralized mini-grids or off-grid systems (AGECC 2010). For cooking, to increase energy efficiency and decrease health impacts, the main strategy is to promote the use of advanced-combustion biomass stoves or to make a full transition to cleaner fuels (Venkataraman *et al.* 2010). Scenario analysis shows that such strategies could avoid more than 1 million premature deaths per year up to 2030 (GEA 2011). Estimates of the annual investments to implement such strategies range from US$10 billion to 140 billion per year (GEA 2011; Bazilian *et al.* 2010; IEA *et al.* 2010). Scenario analysis also suggests that the climate impact of ensuring access to modern energy to all is small: the increase in CO_2 emissions|from fossil fuels could be around 1 per cent of global emissions in 2030 compared to a conventional world scenario, but this would be compensated for by reduced fuelwood demand and thereby reduced deforestation (GEA 2011; IEA *et al.* 2010).

Based on current estimates of the uncertainty in climate sensitivity, targets for greenhouse gas concentrations of 450 parts per million (ppm) and 400 ppm CO_2-equivalent would ensure a median chance of 50 per cent and 70 per cent, respectively, of staying below the UNFCCC's agreed limit of a 2°C temperature increase (Table 16.1) (Meinshausen *et al.* 2006). Sustainable world scenarios show that to reach such targets, global greenhouse gas emissions would need to peak in just one to two decades, then fall to around 50 per cent of current levels by 2050, and by the end of century would need to reach zero or even result in a net absorption – which could, for instance, be done by afforestation or by the combination of bio-energy and carbon capture and storage (van Vuuren and Riahi 2011; UNEP 2010a). There are four basic ways to reduce emissions:

- changing the structure of economic growth;
- increasing energy efficiency through technology or lifestyle changes;

Masdar City, under construction near Abu Dhabi, United Arab Emirates, will rely entirely on solar and other renewable energy sources, with the ambition of becoming the first zero-carbon, zero-waste city in the world. *© www.masdar.ae*

- changing energy supply including using zero-carbon energy options; and
- implementing end-of-pipe measures such as carbon capture and storage.

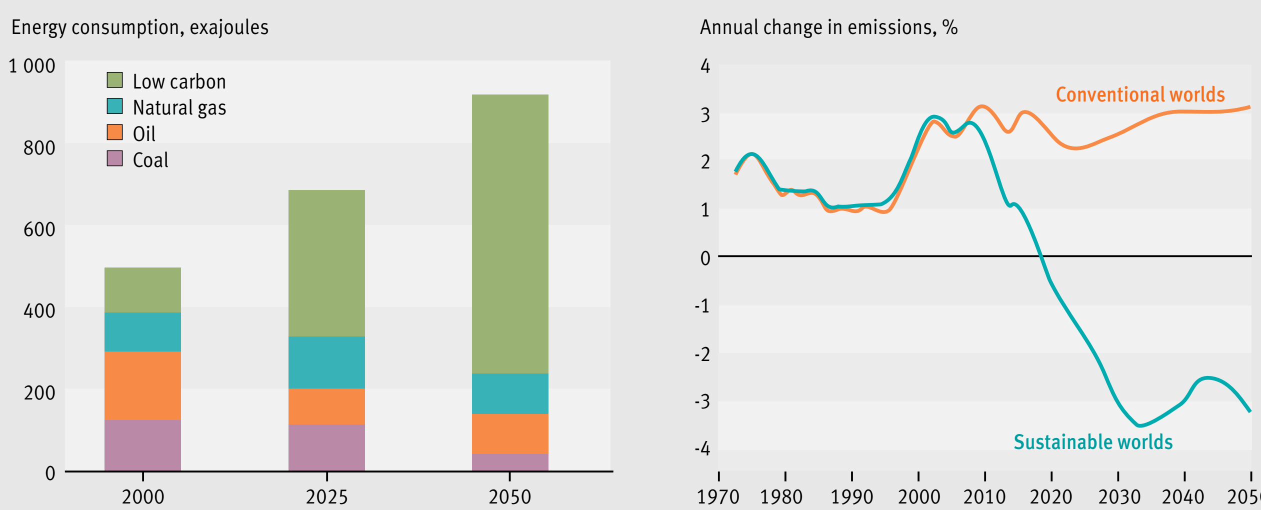
Reaching the sustainable world emission reduction targets (Table 16.1) requires a broad portfolio of measures. Figure 16.7 provides an indication of the size of the transition involved. Very many scenarios show that a low-carbon economy can be achieved with currently identifiable technologies, and they share a number of common features (Clarke *et al.* 2010; ECF 2010; Fisher *et al.* 2007; van Vuuren *et al.* 2007).

- Energy efficiency improvement is a robust option under all scenarios.
- Energy generation provides very significant emission reduction potential by introducing combinations of renewable energy, nuclear power and/or carbon capture and storage, although each of these has limitations and drawbacks. Indeed, the centralized energy sector could even achieve net negative emissions if it were based on bio-energy use with carbon capture and storage.
- Reducing non-CO_2 greenhouse gas emissions such as methane, nitrous oxide, and black carbon and ozone precursors could contribute significantly to mitigating climate change at relatively low cost, for example by reducing methane emissions from energy production and some of the methane emissions from livestock and rice cultivation.
- Lifestyle changes are not often explicitly accounted for in scenarios, but may achieve considerable reductions such as in transport or food consumption.
- The use of bio-energy is very common in low-emission scenarios (van Vuuren *et al.* 2010). Bio-energy production may, however, have serious consequences for biodiversity, food production and greenhouse gas emissions (Dornburg *et al.* 2010; Searchinger *et al.* 2008; Bringezu *et al.* 2009; Fargione *et al.* 2008), so needs to be carefully monitored and the available potential used as efficiently as possible. Moreover, it would be important to focus the use of bio-energy on sectors where it would provide the greatest benefit.
- Access to modern energy sources can be improved by grid, mini-grid or off-grid expansion, fuel subsidies and grants, or micro-loans for stoves.

Although air quality could be significantly improved in low-income countries through the rapid introduction of state-of-the-art technologies, it should be noted that air pollutant emissions are also strongly influenced by structural changes in the energy sector. In addition to the importance of pollutants such as methane and black carbon for climate change, the fact that they also negatively affect health and crop growth (via ground-level ozone) might be a much more important trigger for their reduction than climate change alone. The sustainable world scenarios show that stringent climate policies and existing air pollution control measures could significantly reduce emissions. The adoption of such strategies could be successful in achieving World Health Organization (WHO) air pollution targets, and their combined benefit would be delivered at much lower costs than the sum of separate strategies to meet climate and air pollution goals (UNEP 2011a; GEA 2011; Bollen 2008).

There are several possible consequences to the movement towards a low-carbon society. Some of these are co-benefits, for instance for greenhouse gases and air pollution, or emission reductions and improved energy security. There are some trade-

Figure 16.7 An example of primary energy use and annual change in CO_2 emissions in sustainable world scenarios



The category Low carbon refers to renewable energy, nuclear power and fossil fuels in combination with carbon capture and storage and efficiency, and illustrates the level of transition required. Different models and studies suggest different combinations.

Source: PBL 2009

offs as well. For instance, the reduction in aerosol emissions that results from measures to reduce greenhouse gas emissions will initially partly offset the climate benefits from current aerosol cooling effects. An important trade-off concerns bio-energy, but other technologies also have side effects. Hydropower infrastructure can have several impacts, such as loss of agricultural land, replacement of settlements, biodiversity loss and ongoing greenhouse gas emission episodes from water bodies (Fearnside 2011; St. Louis *et al.* 2000). Wind turbines regularly face opposition from local communities and carbon capture and storage (once it can be applied on a large scale) may entail risks of CO_2 release. Climate policy will also interact with forestry management, which could lead to both positive and negative impacts on biodiversity.

Land

Conventional world scenarios

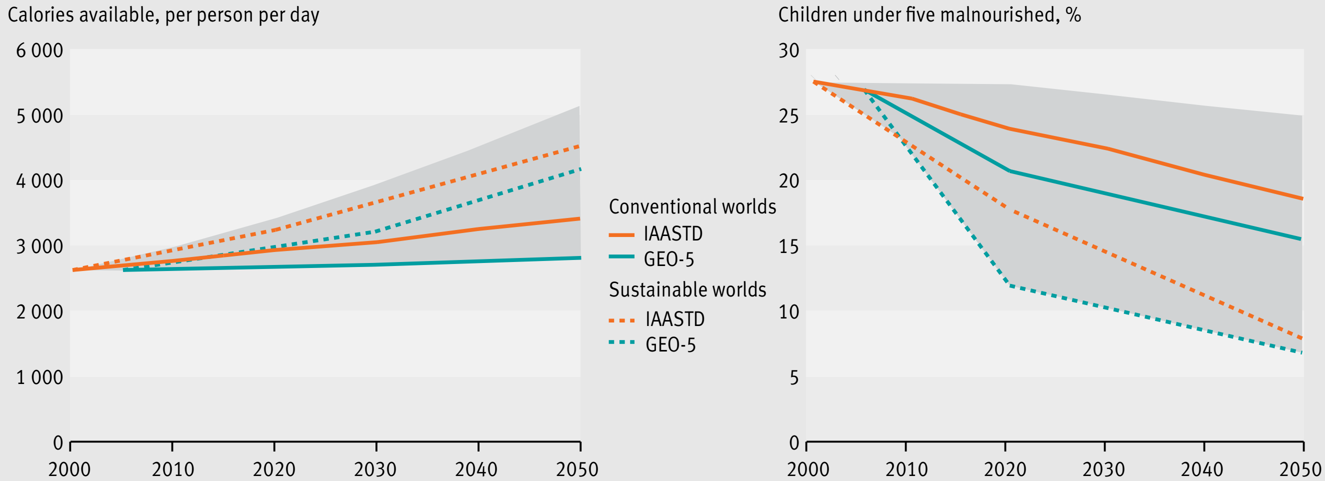
A wide range of models, from economic to biophysical, has been used to explore future trends in land use (Smith *et al.* 2010). All the studies project a strong increase in the demand for food up to 2050, driven by a rising population and dietary change spurred by economic growth. Between 2000 and 2050, global cereal demand is projected to increase by 70–75 per cent while meat consumption is expected to double (Thornton 2010; IAASTD 2009a; FAO 2006b). Meeting these needs, while avoiding a large expansion of agricultural land and protecting biodiversity, will be a major challenge. Ensuring food security will also be an issue as world food markets are likely to be influenced by increasing resource scarcity. A key mitigating factor will be continued investments in yield growth and intensification on existing cultivated land (FAO 2011; UNEP 2011b; Rosegrant *et al.* 2009).

Food security exists when all people, at all times, have physical, social and economic access to enough safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996). Looking at per-person food availability in the conventional world scenarios, by 2050 average calorie availability per person per day will be around 3 000–3 500 calories, but projected food availability in sub-Saharan Africa is much lower, in the range of 2 100–3 350 calories. Environmental degradation, lack of investment and competition for land are expected to push world food prices upwards, causing additional stress to the poor, especially in urban areas (OECD/FAO 2011; IAASTD 2009a). In other words, the conventional world scenarios suggest that it is very unlikely that malnutrition will be fully eradicated by 2050 without major policy shifts (IAASTD 2009a; UNEP 2007; FAO 2006b; MA 2005a). The prevalence of child malnutrition for 2050 in developing countries is projected to range between 13 per cent and 25 per cent (Figure 16.8; Box 16.2). The highest levels of undernourishment are projected in countries that currently suffer from hunger, have high population growth rates and poor prospects for rapid economic growth, and possess limited agricultural resources (FAO 2006b).

Population growth and dietary change have contributed to a rising demand for agricultural products. In the past four decades,

Tea plantation in Limuru, Kenya. The overall productivity of Kenya's tea plantations is considered among the highest in the world. © *Jason Jabbour*

Figure 16.8 Food consumption and child undernourishment under different scenarios



Note: Scenarios selected from GEO-4, the IAASTD study and the Millennium Ecosystem Assessment are those that most reflect the sustainable and conventional worlds on the basis of storyline or quantitative elaboration. The shaded area shows the range in the literature. *GEO-5* results as discussed in box 16.2.

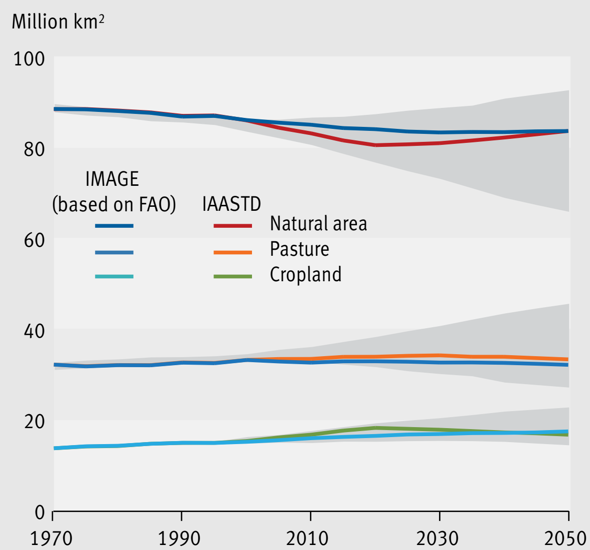
Source: Hughes *et al.* 2011; IAASTD 2009a; UNEP 2007; FAO 2006b; MA 2005a

around 78 per cent of the global increase in agricultural supply has been achieved through increases in yield and greater efficiency in the supply chain; a further 7 per cent has come from increased cropping intensity; while a mere 15 per cent has come from expansion of the arable area (Smith *et al.* 2010; Bruinsma 2003). At the regional level, however, large differences can be seen. In sub-Saharan Africa, for instance, only 34 per cent of the rise in output was derived from yield increases, and the remaining 66 per cent came from area expansion (Mery *et al.* 2010; Smith *et al.* 2010). These factors are expected to continue to be important in the future, although trends will differ over time and across regions.

Yield growth has slowed over the last several decades (FAOSTAT 2012). Moreover, environmental pressures, including the effects of climate change and ground-level ozone, could also have a negative impact on yields in the future. IPCC estimates of the potential global impact of climate change on crops, although uncertain, suggest that if no adaptation occurs climate change could have a substantial negative impact on yields, of 10–35 per cent at all latitudes for crops like maize and wheat. Adaptation measures could, in aggregate, ward off negative impacts in temperate regions, but could not avoid an average yield reduction of around 10 per cent in tropical zones (Easterling *et al.* 2007).

When focusing on crop production, scenarios show some variation in terms of expected land use (Figure 16.9) (Smith *et al.* 2010). The 2050 projections for cropland increase range from as low as 6 per cent, through an average increase of around 10–20 per cent (van Vuuren *et al.* 2008b) to more than 30 per cent as suggested by the IPCC's A2 scenario, which is based on high population growth. Regional results can be very different: while a considerable expansion of arable land is expected in Africa, Asia and Latin America, this is compensated for by a decrease in harvested area in Europe, North America and the Former Soviet Union (van Vuuren *et al.* 2008b; UNEP 2007). As land degradation (CBD 2010b) is typically not accounted for in scenario analysis, the real impacts could be worse.

Figure 16.9 Trends in land use, 1970–2050



Note: Shaded area indicates 10–90th percentile literature range

Source: Rose *et al.* 2012; Hurtt et al. 2011; Smith *et al.* 2010; IAASTD 2009a; OECD 2008a; UNEP 2007; FAO 2006; MA 2005a

For animal products, existing scenarios indicate that most of the increases in global livestock production will occur in developing countries (Bouwman *et al.* 2005). In grazing systems, strong growth is expected for confined livestock production systems, while most studies show an increase of 10 per cent or less in pasture areas.

Sustainable world scenarios

Given the strong connection between agricultural production and the ecosystem services that provide food, forage, fibre, energy and biodiversity, achieving sustainable development as it affects agriculture and land resources requires an integrated approach (Smith *et al.* 2010). Such an integrated approach would take into

Box 16.2 Integrated simulation of the 2050 targets for climate, food and land

Can very high investments in agriculture and water productivity help to achieve the sustainability objectives discussed earlier in this chapter? Here, this question is explored using the International Food Policy Research Institute (IFPRI) IMPACT model (International Model for Policy Analysis of Agricultural Commodities and Trade) (Nelson *et al.* 2010; Rosegrant *et al.* 2008). Previous analyses have shown the importance of economic development in reducing hunger and malnutrition (Nelson *et al.* 2010).

Compared to a conventional world scenario, economic growth in developing countries is assumed to be higher and population growth to be lower overall (Nelson *et al.* 2010). Additional investments in agricultural research and development will lead to rapid increases in agricultural production: as a result, by 2030, grain yields are 15 per cent greater than in the corresponding conventional world scenario and by 2050, they are 35 per cent greater. Furthermore, livestock numbers are up by 30 per cent. It is also assumed that the UNFCCC's agreed limit of a 2°C temperature rise relative to pre-industrial levels has been achieved, and that there is full access to safe drinking water by 2050, and that all girls have access to secondary schooling by 2030. Finally, the water efficiency improvements suggested by the sustainable water withdrawal scenarios are also included (with the exception of a constant irrigated area) (Box 16.3).

The changes outlined above result in average cereal prices being respectively 21 per cent and 39 per cent lower by 2030 and 2050 compared to the conventional world scenario. Under the conventional world scenario, the global harvested crop area is expected to grow at 0.23 per cent per year or 169 million hectares for 2005–2050, with contractions in some OECD countries and Asia more than offset by increases in sub-Saharan Africa and Latin America. In the sustainable world scenario, on the other hand, crop area contracts by 116 million hectares by 2030 and by 201 million hectares by 2050. The lower food prices suggested by the sustainable world scenario are expected to boost affordability and thus access to food, increasing daily calorie availability in the developing world by 496 kilocalories by 2030 and 1 336 kilocalories by 2050. As a result, about 50 million children would be malnourished, a fall of 66 million or 57 per cent. The model calculations, however, also show that eradicating hunger in 2050 is a complex, multifaceted challenge: importantly, significant steps can be made through changes in investment and policies. Key factors that can make a difference for childhood malnutrition include increasing the availability of food, access to safe drinking water and increased female secondary school enrolment. Moreover, mitigation of and adaptation to climate change will make a positive difference for agricultural production.

Table 16.2 Selected indicators for the conventional and sustainable world scenarios

	2005	2030 conventional worlds	2050 conventional worlds	2030 sustainable worlds	2050 sustainable worlds
Area-weighted grain prices, US$ per tonne	150	202	253	160	154
Total crop harvested area, thousand hectares	1 520 811	1 684 798	1 689 758	1 569 207	1 489 230
Developing country calorie availability, per person per day	2 637	2 717	2 823	3 213	4 159
Malnourished children worldwide, million	153	136	115	78	50
Proportion of children malnourished in India, %	46	41	39	30.7	27.4

Source: New calculations IMPACT model; Nelson *et al.* 2010; Rosegrant *et al.* 2008 account the relationship between competing demands for limited land resources and the environmental impact on agricultural production (UNEP 2010b).

One key to ensuring future access to food is investment in agricultural research to improve productivity (Rosegrant *et al.* 2009). Another is to reduce food wastage and loss – currently around 10–40 per cent of agricultural production is wasted (Parfitt *et al.* 2010). Through lifestyle changes, technological development and investment in infrastructure, it is possible to significantly remedy this wastage (Jäger and Cornell 2011; Parfitt *et al.* 2010). Alterations in people's diets could also help reduce the need for additional production. Scenario studies have looked into the consequences of reducing consumption of livestock products through substitution of vegetable alternatives. Different results have been published on the land consequences of such dietary changes. Some studies suggest considerable reductions in land-use (Ten Brink *et al.* 2010; Stehfest *et al.* 2009), while others highlight the risk of a rebound effect, with reduced meat consumption in developed countries leading to increased meat and cereal consumption in the rest of the world (Rosegrant *et al.* 1999). There is also some discussion of the health implication of low-meat diets: although studies claim benefits in high-income countries from reducing overconsumption of meat, low-meat diets need to be well designed.

Very few projections can be found that actually result in food security for all by 2050. According to the Food and Agriculture Organization of the United Nations (FAO 2009), however, it could be accomplished if global food supplies expand by about 70 per cent above current levels. The conditions under which this could be achieved include political stability, good governance, food security strategies, integration of world markets and strong economic growth, all on the basis of an increase in agricultural production in Africa, Asia and Latin America. This implies ensuring that agricultural trade liberalization – integration of world markets – does not lead to negative impacts on vulnerable communities (Jäger and Cornell 2011). The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD 2009a) includes a scenario with increased investments in agricultural technology combined with increased investment in water infrastructure and female secondary education. This scenario shows a significant increase in food availability but still leaves 8 per cent of children malnourished, mostly in sub-Saharan Africa. Clearly, access to food needs to be viewed in the context of poverty reduction both to promote rural development and to provide direct and immediate access to food for the most needy (Broca 2002).

Figure 16.9 shows that some scenarios lead to little expansion and even contraction of the agricultural area. One contributing factor is reduced rates of population growth leading to smaller increases in the demand for food. If historical yield growth rates can be maintained, the global agricultural area could be stabilized or even reduced. Indeed, the analyses by IAASTD (2009a) and Thornton (2010) show that it is possible to increase yields significantly on the basis of better use of agricultural knowledge, science and technology – although this will be far from easy. Policies that lead to higher agricultural yields need to be combined with policies that reduce or avoid soil degradation and other negative environmental trends such as the loss of crop resilience to pests (Killham 2010; Petermann *et al.* 2008; Kaiser *et al.* 2007; Paulitz *et al.* 2002). Finally, it is also necessary to effectively and fairly define property rights and develop local institutions that foster longer-term investment in the use of water, soil and biological resources in agriculture and forestry (FAO 2011; Von Braun and Meinzen-Dick 2009; Hazell and Wood 2008). The crop yields in the sustainable world scenarios also benefit from reduced climate change impacts. The IPCC assessment indicates that the combination of agricultural adaptation and an increase in temperature of less than 2°C above pre-industrial levels may even result, in aggregate, in positive impacts on globally averaged yields (Easterling *et al.* 2007).

Policy options that could improve sustainable agricultural production include:

- supporting investments in increasing crop yields in developing countries to limit the expansion of agricultural land and to close the yield gap between developed and developing countries;
- promoting adaptation to climate change by encouraging crops and crop varieties that are more resilient under changing climatic conditions;
- investing in infrastructure, food processing and storage techniques to reduce food waste;
- better utilizing urban-rural landscapes for food systems and natural resource use;
- reducing consumption of livestock products; and
- strengthening land-use policies and planning by promoting integrated land and resource management.

While it is technically possible to achieve zero expansion of agricultural area and still produce sufficient or more food, implementing this presents a large number of challenges. Key among these are the continuing degradation of land and water, climate change and the rising demand for biofuels (FAO 2009). For example, the current trend of increasing emissions and water pollution from nitrogen fertilizers is expected to increase by 2050, despite potential for greater efficiency in fertilizer use (Power 2010; Bruinsma 2003). Furthermore, the predicted growth in animal production in developing countries will lead to more methane and nitrous oxide emissions from manure, although the projected improvement in husbandry will somewhat reduce emissions per animal (Smeets *et al.* 2009; Bouwman *et al.* 2006). While climate change mitigation is designed to reduce negative climate impacts, in specific regions such as the Russian Federation, such policy will result in forestalling potentially positive yield changes. Furthermore, improvements will also depend on potential trade-offs between allocations of agricultural land for crops or for biofuels, which could further threaten food production and security.

Water

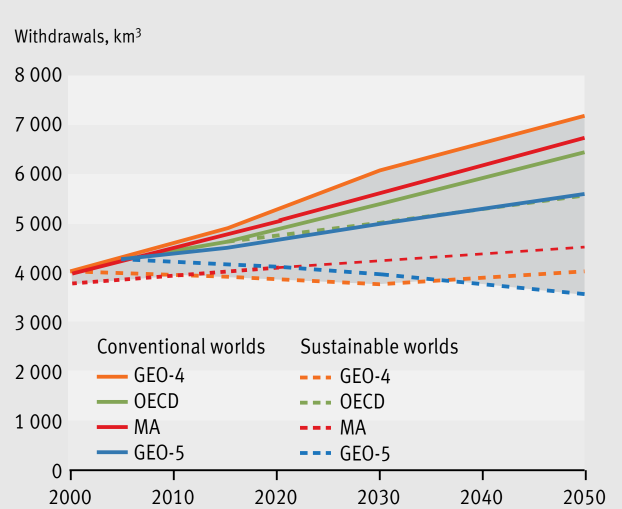
Conventional world scenarios

Chapter 4 shows that many regions are seriously affected by an imbalance between the availability and withdrawal of water, water stress and water pollution from different sources. River systems are considered the most endangered ecosystems on the planet and their loss of biodiversity has been faster over the past 30 years than in any other terrestrial or marine ecosystem (Jenkins and Lowe 2003). The Johannesburg Plan of Implementation (WSSD 2002) Paragraph 26c calls not only for an efficient and well-balanced use of freshwater resources but also for the safeguarding of drinking water quality. Important drivers of water scarcity include population growth, increasing water consumption, pollution and climate change. Increasing water use, river and reservoir regulation, or non-treated return flows lead to alterations in flow regimes that contribute to intensified and complex conflicts between ecosystem requirements and the management of rivers for human water supply and energy generation. Climate change can affect freshwater problems in many ways through changes in precipitation, discharge rates, extreme events, reduced dilution capacity of rivers and salinization due to sea level rise (Schneider *et al.* 2011; Bates *et al.* 2008).

Several scenario assessments exist, showing large variations in projected water withdrawals – the total volume of water extracted from surface or groundwater sources for various uses – based on different assumptions on such factors as population, consumption patterns and technology availability (Figure 16.10). Most of the estimates of water withdrawals indicate a large global net increase, but with significant regional differences. The most important factor for this increase is the growth of household water use, followed by industrial and agricultural use (Alcamo *et al.* 2007). As a result of increasing withdrawals, effluent returns are also likely to increase, many of which remain untreated in low-income regions. For the *GEO-4* "markets first" scenario, for instance, the volume of untreated wastewater was reported to steadily increase despite improvement in treatment. In the *GEO-4* "sustainability first" scenario, in contrast, the volume of untreated wastewater fell as a result of an overall decrease in wastewater due to greater efficiency (UNEP 2007). The *GEO-5* calculations are discussed in more detail in Box 16.3.

Increases in water withdrawals are projected to lead to an increase in water stress (Arnell *et al.* 2011; Alcamo *et al.* 2007, 2003; Cosgrove and Rijsberman 2000; Vörösmarty *et al.* 2000). More than 2 billion people currently live in severely water-stressed areas, primarily in Asia (Figure 16.12). Model simulations show that under the conventional world scenarios, the number of people living in water-stressed areas, as well as the extent of these areas, is expected to rise substantially due to population growth, increased use of water and climate change. The ratio of future to current numbers is given in Figure 16.12, which also demonstrates the uncertainty in the scenarios as a result of different assumptions about climate and other global change. Increases are highest in Africa, where the number of people living in severe water-stressed areas is expected to grow fourfold (median). In South America and Asia significant changes may also occur. In many river basins under severe water stress, there will be competition between domestic, industrial and agricultural users. It should be noted that changes in the use and natural condition of water somewhere in a river catchment area will affect the availability and quality of water downstream.

Figure 16.10 Water withdrawals under different scenarios, 2000–2050



Note: The shaded area shows the range in the literature.

Source: Bakkes *et al.* 2008; OECD 2008a; UNEP 2007; Alcamo *et al.* 2005b; MA 2005a

A woman on her way to the water distribution site in Tora, Northern Darfur. The closest water source is more than an hour's walk from the village. *© Olivier Chassot/UN Photo*

Currently nearly 1 billion people lack access to clean drinking water and 2.6 billion lack access to improved sanitation services (WHO/UNICEF 2010). In 2004, unsafe water and inadequate sanitation were responsible for around 1.6 million deaths and 6.3 per cent of worldwide disability adjusted life-years (DALYs), mainly due to diarrhoea (WHO/UNICEF 2010). Scenario analysis suggests that by 2015, 627 million people will still live without access to clean drinking water and 2.7 billion people will live without access to improved sanitation. Different studies project long-term developments in drinking water and sanitation, either by assuming a continuation of the 1990–2000 improvement rates (Prüss-Üstün *et al.* 2004) or by using cross-sectional relationships with socio-economic indicators (OECD 2012; Hughes *et al.* 2011). These studies project that the proportion of the world's population without access to safe drinking water will diminish from 23 per cent in 2000 to 3–5 per cent in 2050. For sanitation, the proportion will diminish from 51 per cent in 2000 to 15–18 per cent in 2050. This would lead to a significant reduction in the numbers of children suffering from related ill health (OECD 2012; Hughes *et al.* 2011).

Sustainable world scenarios

The goal for water is to reduce global water stress. Several scenarios have explored the scope for achieving this, such as the "technogarden" scenario from the *Millennium Ecosystem Assessment* (Alcamo *et al.* 2005b), and three alternative

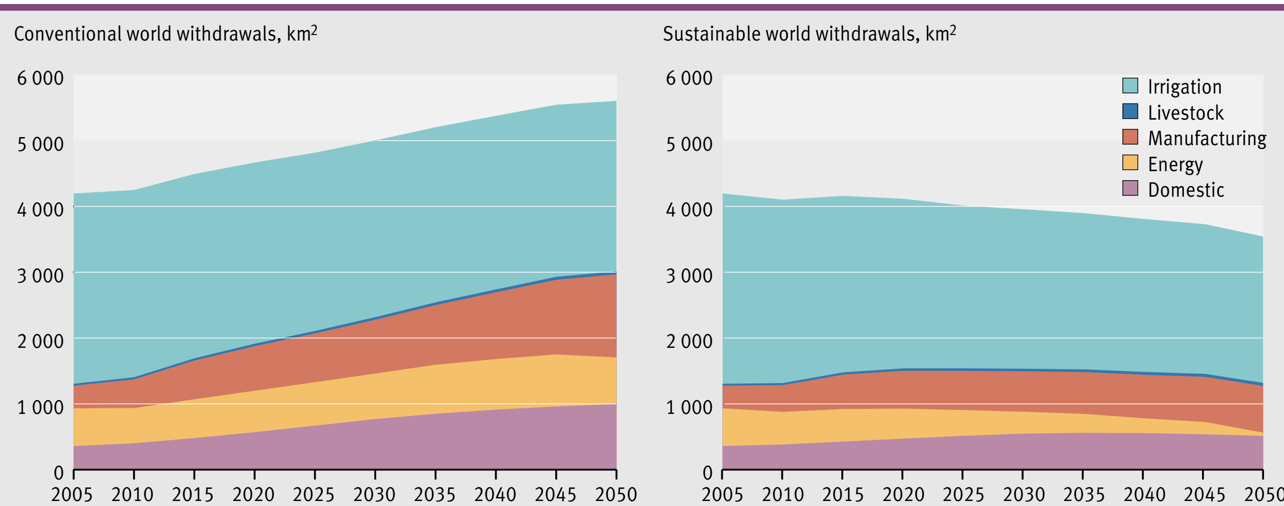
Box 16.3 The sustainable world scenario for water withdrawals

Simulations were carried out to calculate future water availability, water withdrawals (Figures 16.10 and 16.11) and water stress (Figure 16.12) under conventional and sustainable world scenario conditions, assuming the same socio-economic development. In these calculations, for the sustainable world scenario the following assumptions were made:

- stringent efficiency measures are taken in industry and residential water use;
- the irrigation area remains constant;
- climate policies lead to a reduced demand for thermal cooling in power generation as fossil-fuel-powered plants are partly replaced by renewable energy sources; and
- the climate patterns were assumed to be consistent with limiting global temperature rise to 2°C above pre-industrial levels.

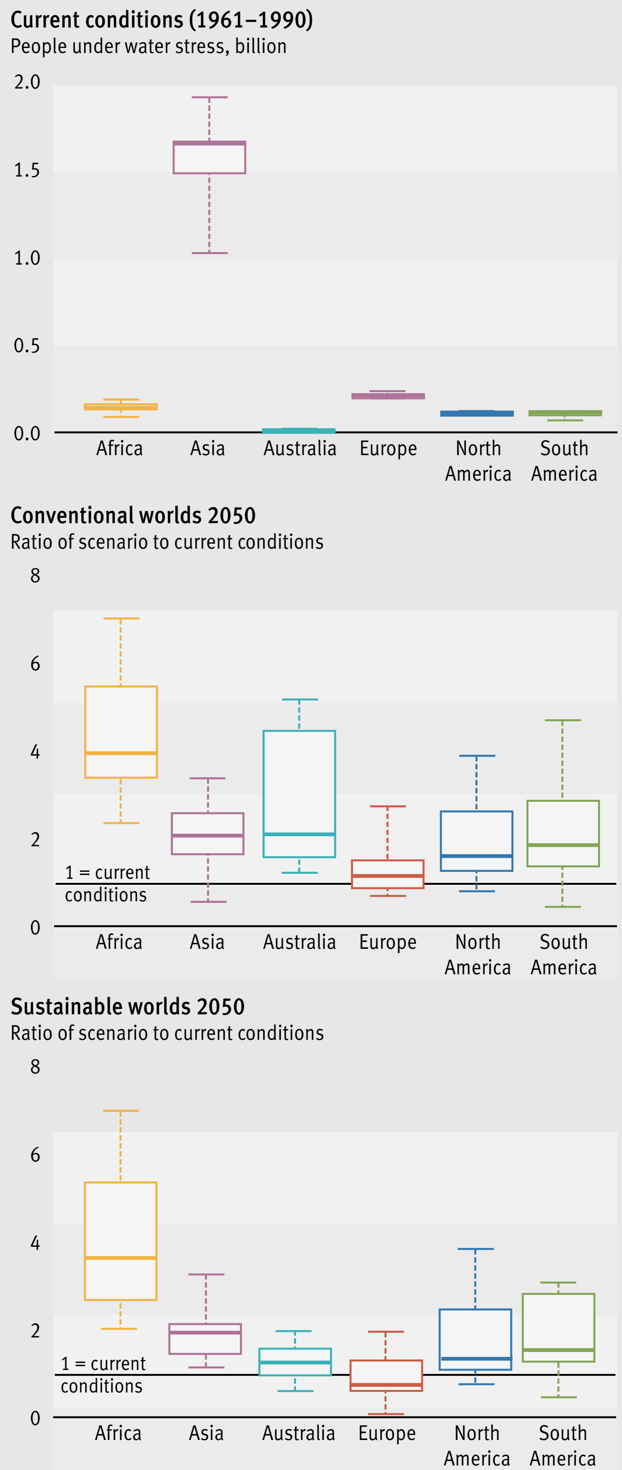
As a result, global water withdrawals after 2015 are projected to decrease substantially compared to the conventional world scenario (Figure 16.11). Nevertheless, regions affected by severe water stress still exist and the number of people living in river basins suffering from water stress could reach 3.9 billion in 2050 (Figure 16.12). An important lesson is that improvements in efficiency of water use are necessary to reduce water withdrawals, but are insufficient to avoid water scarcity. The core issue is the amount of water used for irrigation and the high concentration of water demand in urban areas. In other words, if water scarcity is to be reduced further, fundamental changes in agricultural practices are needed – improving irrigation efficiency, shifting irrigated areas from water-scarce to water-rich basins, moving from irrigated crops to rain-fed crops, or relying on imports from other regions.

Figure 16.11 Water withdrawals under conventional world and sustainable world scenarios, 2005–2050



Source: New calculations for *GEO-5*; WaterGap model from Alcamo *et al.* 2003 and Flörke and Alcamo 2004

Figure 16.12 Water stress under current conditions and for 2050 under conventional and sustainable world scenarios



Note: By using a Box-Whisker plot the five-number-summary can be depicted, i.e. the minimum, lower quartile, median, upper quartile, and the maximum are presented in the same graph. The uncertainty ranges expressed in the plot represent different model runs categorized as "baseline" and "challenge" scenarios by two global hydrological/water models taking into account different conditions.

Source: Arnell *et al.* 2011; Alcamo *et al.* 2007, 2005b; UNEP 2007

transition scenarios developed by the WBCSD (WBCSD 2006). The main measure, increased efficiency, is discussed in Box 16.3. In general, the sustainable world scenarios lead to lower numbers of people living with severe water stress, mostly as a result of a reduction in water withdrawals due to behavioural and technological change. However, even under sustainable world scenario assumptions, some regions experience a doubling (median) in the number of people living with water stress compared with current conditions (Figure 16.12). Nevertheless, due to regional population growth and spatial variation of climate change impacts, an increase in water stress is apparent compared to current conditions. This implies that competition between water-related sectors would still be important.

The OECD's *Environmental Outlook to 2050* (OECD 2012) assesses the costs and benefits of halving the number of people without access to safe drinking water by 2030 compared to 2005 levels, and of full access by 2050. The study indicates that, to reach such goals, significant infrastructure investments and operation and maintenance resources would be needed. The average required was estimated at US$1.8 billion globally between 2010 and 2030, and US$7.6 billion between 2031 and 2050. The improved access to drinking water and sanitation would also lead to other major benefits: Hutton and Haller (2004) estimate that every dollar spent on drinking water and sanitation creates economic returns of US$12–34, depending on the region and the technology. Three-quarters of these benefits stem from decreased collection time, particularly for women and especially when water is piped to premises, while the other benefits are mostly linked to a reduction in water-borne disease and death, such as from diarrhoea. The OECD (2012) projects total avoided deaths of around 90 000 per year in 2050. Possible policy levers to improve access to safe drinking water and reduce water stress include:

- investing in research, development and training to increase irrigation efficiency;
- controlling the extent of irrigated areas;
- using waste water and desalinated water to conserve freshwater resources;
- reusing water in manufacturing industries;
- investing in devices and processes for reusing grey water (wastewater from domestic activities);
- investing in education to raise awareness of the need to save water and the link between unsafe drinking water and disease;
- investing in infrastructure for accessing safe water and for collecting and purifying waste water;
- reducing the use of cooling water in the generation of electricity; and
- developing adaptation and mitigation policies to reduce climate change impacts.

As agriculture is the largest user of water worldwide, water stress and food security are strongly interrelated. Lack of sufficient water, possibly caused by alternative water use, can limit food production; at the same time, water consumption for agricultural production could limit residential and industrial water supply.

These relationships further emphasize the need for integrated resource planning at the level of water basins.

Terrestrial biodiversity

Conventional world scenarios

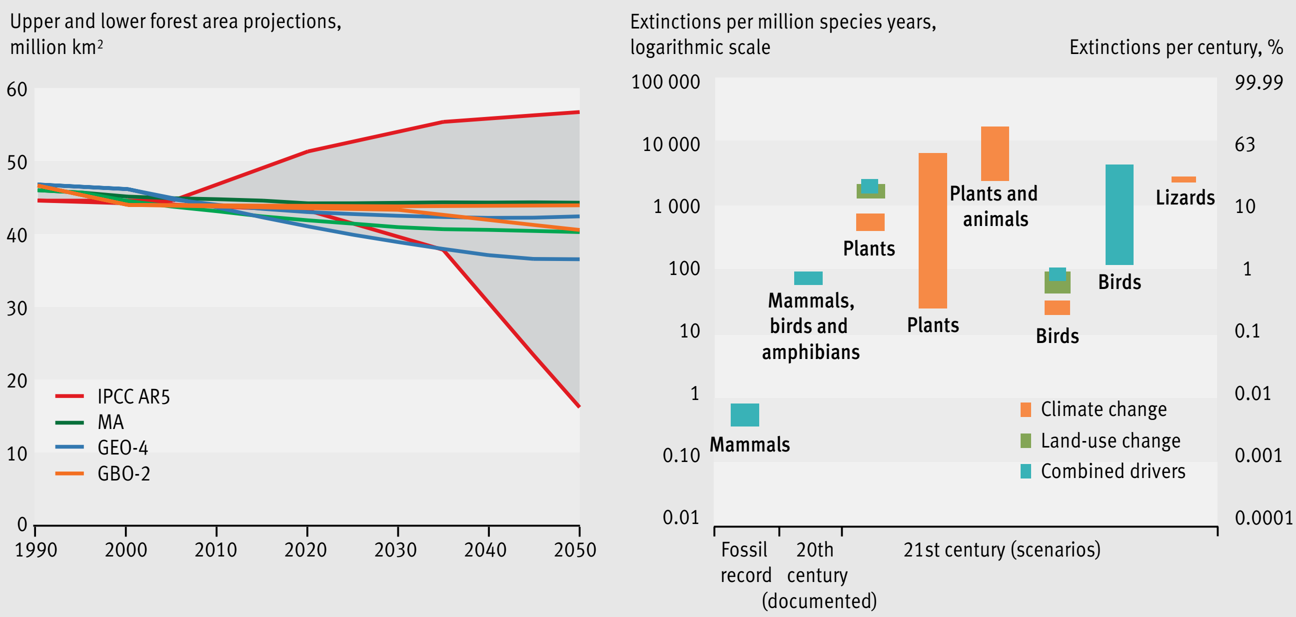
Different scenario studies and assessments have considered biodiversity loss (CBD 2010b, 2006; UNEP 2007; van Vuuren *et al.* 2006; MA 2005a; Sala *et al.* 2000), including information on extinction rates, changes in forest cover and changes in species abundance and distribution (Leadley *et al.* 2010). An important element of future biodiversity loss is land-use change (Figure 16.13), with particularly important trends including the loss of mangroves, wetlands and tropical forests (CBD 2010b). Scenarios indicate a further decline of tropical forests, while the area of temperate forests is likely to expand. Another factor affecting biodiversity is natural asset exploitation: an increasing population with rising affluence in the conventional world scenarios implies, for example, greater demand for forest and tree products. Currently, most timber products are extracted from natural forests, while plantations provide some 35 per cent of harvested wood (Sohngen *et al.* 2001). The increased timber demand is expected to lead to a further expansion of managed forest in tropical zones, at the expense of unmanaged forests (Gibson *et al.* 2011).

Projections of extinction rates vary widely between studies. Those based on species/area relationships lead to relatively high extinction rates, whereas species distribution models that allow for migration generate much lower rates. However, all estimates of future extinction rates are considerably higher than is considered sustainable. Conservative estimates of future rates of extinction expect them to be similar to the currently high rates (Pereira *et al.* 2010).

Sustainable world scenarios

It has been shown that the expansion of agricultural land could be avoided by increasing crop yields combined with policies to reduce food waste, control biofuel use, conserve resources and shift diets (Figure 16.14) (Ten Brink *et al.* 2010; Stehfest *et al.* 2009; Wise *et al.* 2009). Analysis has also shown that the 2020 target to prevent the extinction of known threatened species could be achieved by a well chosen network of protected areas in combination with reduced habitat loss (Butchart *et al.* 2012; Ricketts *et al.* 2005). In a recent study, a combination of policy options – including the expansion of protected areas into a well-chosen network covering 29 per cent of the world's surface, an increase in agricultural productivity and reduced post-harvest losses, dietary change, improved forest management, and climate mitigation – suggested a significant restoration of natural areas and reduced biodiversity loss (Ten Brink *et al.* 2010). A great impact on land-use change could also be achieved through financial mechanisms: Wise *et al.* (2009) demonstrated that a policy that provided equal monetary incentives to reduce greenhouse gas emissions to all emission sources, including land use, could lead to the preservation of both managed and

Figure 16.13 Changes in the extent of forest up to 2050 in different global scenarios, and estimated rates of species loss

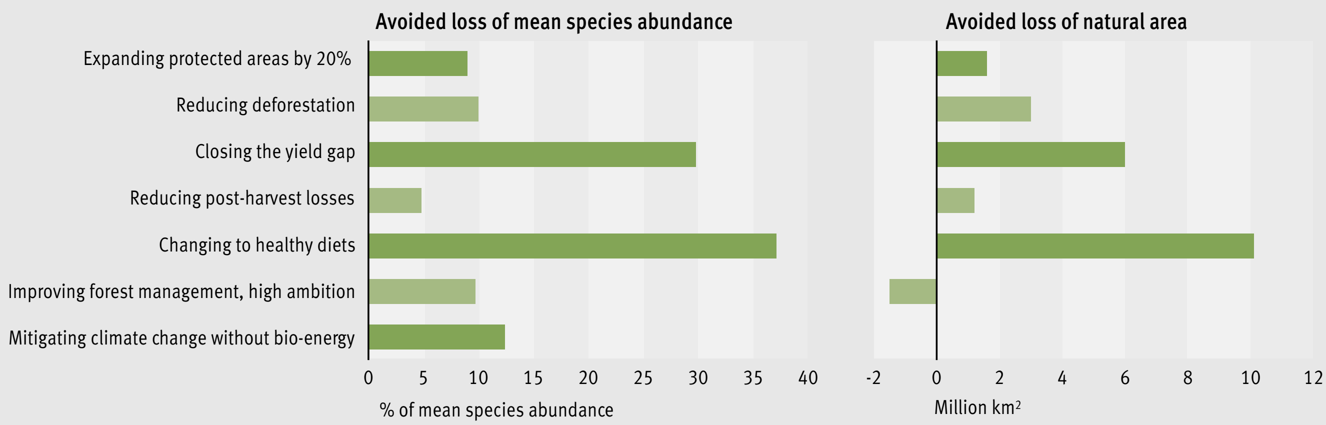


The graph offers a comparison of extinction rates in the distant and recent past, with projections of species committed to extinction during the 21st century according to different global scenarios. The extinction rate caused by each driver and the total extinction rates are differentiated when possible.

Note: For 20th-century extinctions, mammals fall into the upper bound, and birds and amphibians into the lower bound.

Source: CBD 2010b; Pereira *et al.* 2010a

Figure 16.14 Options for reducing biodiversity loss by 2050



Note: Mean species abundance is the average relative to the original state.

Source: Ten Brink *et al.* 2010

unmanaged forest. Other measures that could also be considered include agroforestry and the certification of sustainable wood products (Angelsen 2010).

A critical threat to biodiversity is rising demand for agricultural land leading to conversion of natural habitats, whereas a substantial increase in yields reduces the demand for land and is considered necessary to reduce habitat loss. This may, however, cause a decline in the biodiversity and ecosystem services of farmlands (Robinson and Sutherland 2002; Tilman *et al.* 2002) but an increase in biodiversity across the landscape (Phalan *et al.* 2011). An expansion of protected areas may increase competition for land, decreasing the potential for agricultural production, which could in turn lead to higher food prices.

Aquatic biodiversity

Conventional world scenarios

Conventional world projections of changes in the biodiversity of aquatic ecosystems are scarce; however, pressures are expected to remain high as a result of increasing water scarcity, climate change, pollution and exploitation (CBD 2010b; Rands *et al.* 2010). For freshwater systems, organic pollution and dam construction are important threats. For marine systems, destructive and intensive fisheries and ocean acidification are among the main factors that could reduce biodiversity (Halpern *et al.* 2008; Pinnegar *et al.* 2006; Pauly *et al.* 2003). Ocean acidification may transform coral reefs into systems dominated by other species, and will cause major disruptions in marine food webs, especially in the Southern Ocean (McNeil and Matear 2008).

About 32 per cent of wild marine fish populations are classified as collapsed, depleted or recovering (FAO 2010), and while there has been some rebuilding in areas with strong fisheries management (Worm *et al.* 2009), the majority of the world's fisheries are operating with severe overcapacity (Anticamara *et al.* 2011) resulting in significant economic losses (Arnason *et al.* 2009; Srinivasan *et al.* 2012). Global assessments for exploited marine invertebrates indicate similar trends (Purcell *et al.* 2011). Overexploitation has already depleted fishery yields, reduced

Certain marine fish populations have been depleted to such an extent that they may not be able to recover. *© J Tamelander/IUCN* the abundance of large fish and caused local extinctions. Analysis indicates that global wild fish catches will decrease in the future unless fishing effort and catch rates are reduced to sustainable levels (Figure 16.15). Projections also show that if current trends persist, the populations of medium and larger fish in the world's oceans will continue to decrease while small fish may increase in abundance due to release from predation (Ten Brink *et al.* 2010; Pauly *et al.* 2003).

Sustainable world scenarios

Reducing fishing effort, even to the level of maximum sustainable yields for all fish populations, could make an important difference for a sustainable world. It would require a stringent reduction, but only temporarily while larger- and medium-sized fish populations recover (Ten Brink *et al.* 2010; Pauly *et al.* 2003). After this period, fishing could return to a level that can be sustained in the long run.

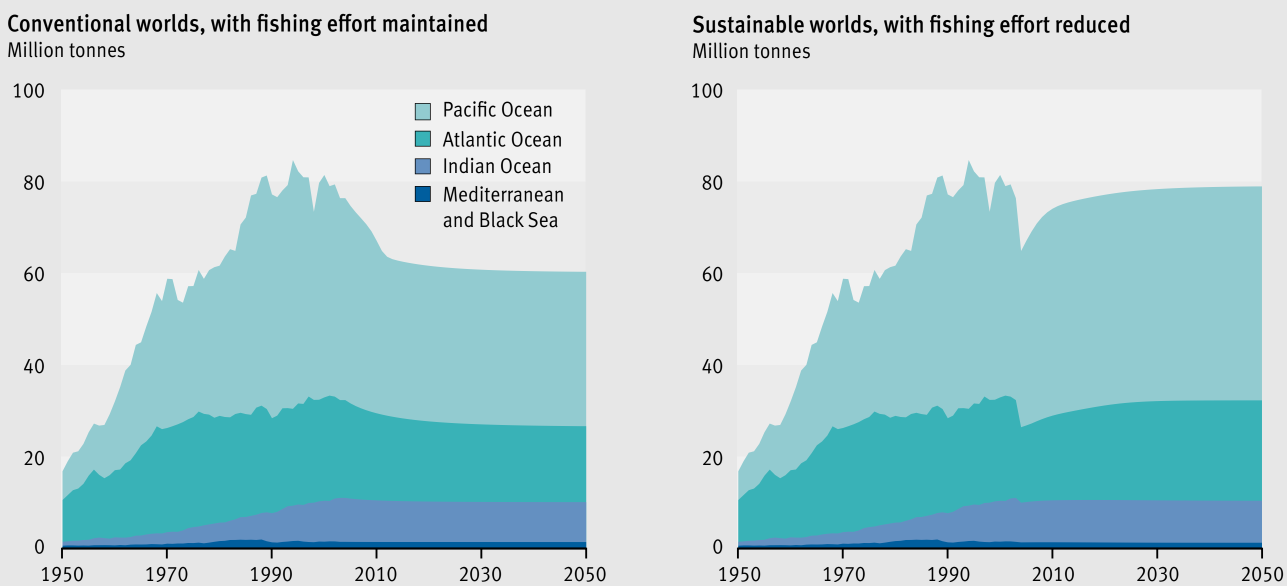
Increasing the protected area of land and sea would reduce the availability of suitable land and fishing grounds for food production. Increasing protection will only therefore be effective if it is done in combination with more efficient production methods on the land under cultivation and the establishment of sustainable fisheries. It should also be noted that reduced fishing effort initially leads to reduced fish landings. This implies that while populations rebuild, demand for wild-caught fish needs to be replaced by demand for aquaculture – which itself has specific environmental impacts – or crop and animal products. As fish populations rebuild, the supply of fish would, however, grow to a long-term sustainable level that is comparable to the peak 1980s catch levels (Ten Brink *et al.* 2010; Pauly *et al.* 2003).

Synthesis: gaps and sustainability pathways

The review of conventional world and sustainable world scenarios in relation to the strategic goals discussed earlier in the chapter illustrates that continuing on the current trajectory would lead to major environmental damage and a serious loss of ecosystem services by 2050. It would also leave many people without sustainable access to food, water and energy. In contrast, the sustainable world scenarios show how societies could meet some of the 2050 targets or, at least, join a trajectory that would make meeting such targets more feasible. The changes suggested in the sustainable world scenarios include all kinds of measures related to greater technological implementation, changes in consumption patterns and improved management. In general, major shifts from current trends are required for each specific issue. It should be noted that, due to inertia in the human-environment system, several targets still imply significant environmental change, such as the target to limit temperature increase to 2°C above pre-industrial levels. Sustainable world scenarios, as well as requiring mitigating measures, call for measures to cope with or adapt to these adverse effects.

Table 16.3 presents an overview of the key measures suggested in the thematic sections of *GEO-5*, including changes in consumption and production levels and patterns. On the production side, changes include improving efficiency and using fewer inputs; input switching and producing with low- or non-polluting inputs; end-of-pipe measures; and integrated production systems. On the consumption side, changes consist of alterations in lifestyle, such as dietary shifts and greater use of public transport. A focus on education, including awareness raising, investment in infrastructure and the creation or

Figure 16.15 Marine catches with and without a reduction in fishing effort, by region, 1950–2050



Source: Ten Brink *et al.* 2010

strengthening of markets, and adaptation to unmitigated change are other measures included in the sustainable world scenarios. Measures can also be related to the layers of transformation in Figure 16.2: while many measures address the outer layer, others deal with the mid or even deep layers, such as changes in behaviour, mainly the result of education and awareness raising.

Table 16.3 Overview of the gap between the conventional and sustainable world scenarios and important measures to close the gap

Theme	Gap between the conventional and sustainable world scenarios	Examples of important measures to close the gap
Atmosphere and energy	By 2050 greenhouse gas emissions have increased by 70% compared to now, while the vision requires a 50% reduction By 2030 1 billion people live without access to electricity and nearly 3 billion rely on traditional biomass for cooking and heating Air pollution levels are still above WHO guidelines in most developing countries	Reduce carbon intensity by 4–5% per year compared to a baseline increase of 2% per year, partly by increasing the contribution of non-carbon energy options to more than 50% and by significantly increasing energy efficiency Increase investment in electrification Create a smart subsidy and micro-financing system to provide modern fuels for cooking and heating to the poorest Promote less energy-intensive lifestyles and material consumption Increase investment in research and development Use technology to reduce air pollution
Land and food	By 2050 13–25% of all children are undernourished By 2050 cropland has increased by 10–20% compared to 2010 By 2050 pasture area has increased by 10% compared to 2010	Increase crop yields and overall agricultural productivity by, for example, closing the yield gap in developing countries Encourage planting crops and crop varieties that are better suited under changing climatic conditions Reduce food waste Improve use of urban-rural landscapes for food systems and natural resources Strengthen land-use policies and planning Make appropriate social, technological and economic investments in infrastructure and regulate agriculture, including increasing efficiency of irrigation, nutrient recycling and pest management Reduce consumption of livestock products
Water	In 2050 6.5 billion people live in areas under water stress By 2030 5–8% of the population live without safe drinking water By 2030 17–28% of the population live without improved sanitation	Invest in research, development and training to increase irrigation efficiency Control the extent of irrigated areas Use wastewater and desalinated water to save freshwater resources Invest in education to raise commitment and awareness for water saving Invest in infrastructure for safe drinking water and wastewater treatment Reduce cooling water needs with new technologies Increase reuse of water in manufacturing industries; invest in devices and processes for reusing grey water Mitigation policies to prevent climate change impacts Adaptation measures for climate change such as rainwater harvesting, flood control for rivers and water transfer
Terrestrial and aquatic biodiversity	By 2050 forest area has further decreased compared to 2010 Extinction rates are clearly above fossil record rates Global fish are exploited above sustainable levels	Conserve key terrestrial and aquatic biodiversity Reduce the pressure on land, mainly through the options under the land theme Reduce global fishing effort Improve forest management

Box 16.4 Integrated global analysis of sustainability scenarios

The scenario assessments address gaps and sustainability pathways by theme, as well as the potential trade-offs and co-benefits with the other themes. It is, however, important to further analyse the links between themes in an integrated manner. Here, the global Threshold 21 (T21) model (Bassi *et al.* 2010) is used to address how to achieve the goals set out in Table 16.1 by focusing on the investments needed and the trade-offs and synergies of the interventions across various sectors. Two alternative sustainable world scenarios to 2050 are compared to a conventional world scenario. Scenario A focuses entirely on additional investments in transforming technology and production to achieve the goals. Scenario B focuses on how adding lifestyle change reduces those investments.

Scenario A shows that investments of about 2 per cent of GDP between 2011 and 2050 will make the necessary shift to sustainable development. The interventions include efforts to reduce energy demand in buildings, industry and transport (38 per cent of investments); shifting to more renewable energy sources (31 per cent); increasing food production through ecological agricultural practices (10 per cent); rebuilding fishery stocks (8 per cent); and sustainable management of forests (3 per cent) and water (10 per cent). Thus, achieving the climate goal emerges as requiring the highest investment. The measures in the energy and agriculture sector reduce greenhouse gas emissions to a level that limits atmospheric concentrations below 450 ppm. In T21, managing natural resources more sustainably also helps restore key natural resources or greatly mitigate their depletion (Table 16.4). Scenario B shows that lifestyle changes that reduce demand for energy, including for transport, heating and cooling, water and biomass, will reduce the need for investments in production and technology to about 1.2 per cent of GDP. It should be noted that the costs of the lifestyle changes are not accounted for and will at least involve the costs of transmission of information.

In both scenarios, the synergies from the additional investments focused on environmental sustainability and on reducing the stress that natural resource depletion puts on economic productivity. Overall, the macro-economic results of the T21 model show that investing to reach the sustainability goals creates more jobs than a conventional world scenario and leads to higher GDP growth. The shift to greener investment will lead to slightly lower growth rates in initial years, as is usual for transition investments, but A and B scenarios' GDP will pass business-as-usual projections well before 2030 (UNEP 2011c). This is a significant, but uncertain, result as some other models show negative GDP impacts, depending on the assumed cost of fossil fuels and renewable alternatives, the impacts of environmental change and responses to increases in investments (Bassi and Eaton 2011; Clarke *et al.* 2010; Fisher *et al.* 2007). Taking account of the cross-sectoral impacts of an integrated approach, such as synergies between agriculture and forestry, enables further understanding of the complexity underlying mutual socio-economic and environmental dependence and the need for coordinated programmes and investments to achieve the *GEO-5* goals.

Table 16.4 Threshold 21 scenario results for key indicators

	2011	2050		
	Conventional worlds	Conventional worlds	Sustainable worlds A	Sustainable worlds B
Economic sector				
Real GDP, US$ billion per year	69 363	155 192	190 428	181 762
GDP, US$ per person per year	9 996	17 472	21 166	20 217
Additional investment, US$ billion per year	0	0	3 712	2 133
Social sector				
Total population, billion	7.0	8.9	9.0	9.0
Calories per person per day	2 787	2 981	3 348	3 234
Population below US$2 per day, %	19.5	11.1	8.9	9.4
Human Development Index	0.60	0.67	0.71	0.70
Total employment, million people	3 186	4 624	4 689	4 612
Environmental sector				
Forest area, billion hectares	3.9	3.7	4.5	4.5
Waste generation, million tonnes per year	11 242	13 855	14 497	14 338
Ratio of footprint to biocapacity	1.5	2.1	1.1	1.2
Primary energy demand, million tonnes of oil-equivalent per year	12 956	19 733	13 421	12 470
Renewable energy share of primary demand, %	13	13	27	26
Fossil fuel greenhouse gas emissions, billion tonnes per year	32.1	52.0	18.9	20.6

There are important synergies between the different goals. For example, reduced climate change would improve water availability and crop yields as well as relieve pressure on biodiversity. Decreased consumption of food, water and fossil fuels would reduce the mitigation requirements to achieve the biodiversity, water stress and climate change objectives, while increased agricultural yields would lessen the pressure on biodiversity. In some cases, however, options for a specific theme may induce important trade-offs with other themes. Policies that combat environmental degradation may have impacts on human development, and vice versa: creating bio-reserves, for example, may increase land and food prices, while desalinating water would significantly increase the demand for energy. Ignoring such cross-sectoral links might jeopardize the success of the sustainability transition effort and lead to significant delays in reaching the targets. Strategies must therefore go beyond theme-oriented conventional thinking and take a broader systemic view that reflects these links. Central to this is how the measures introduced for the different themes would work together. Box 16.4 describes an example of an analysis in which integrated scenarios are explored. This shows that it is indeed possible to identify pathways that would meet multiple sustainable development targets.

ADVANCING SUSTAINABILITY

Given the massive gap between conventional and sustainable worlds in 2050, it is clear that inertia is a principal obstacle – in the form of dominant unsustainable processes, structures and habits. Moving off the current path will require a transformation without precedent in human history (Steffen *et al.* 2005; Takács-Sánta 2004). Guiding changes of such magnitude and complexity will require time and patience to facilitate a sometimes steady, sometimes fitful, transition process. During this process, structures and underlying mental models need to be evaluated – some phased out and others energetically phased in. These underlying models should be consistent with the desired trajectory for targets relating to atmosphere and climate, land, water and biodiversity, resource efficiency and waste management. The changes must effectively transform society's material metabolism, especially those elements and dynamics currently locking countries into trajectories that are not the ones they would prefer. The changes needed to realize sustainable world trajectories have to be diverse and should combine demographic, technological, governance and investment measures, along with lifestyle changes resulting from shifting mindsets towards dematerialized values. They also need to provide sufficient leverage to break the inertia of unsustainable trends.

Diversity is key to understanding the structure and function of complex adaptive systems and enhancing their resilience to stress (Innes *et al.* 2005). A diversity of potential responses is required because effective interventions must be sensitive to socio-cultural and environment-development contexts. Diversity also helps strengthen resilience and provides a form of insurance if some of the responses fail, as many have over the last few decades with regard to biodiversity, climate and other key environmental issues (Speth 2005).

Ecuador, one of the UN-REDD programme's partner countries, is prioritizing social and environmental co-benefits in its REDD+ readiness preparations.

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Grounding responses in local processes and experience not only builds diversity, it can also tap into knowledge that has evolved in direct connection with a particular environment. This section focuses on the sub-global level, where countries, communities or other entities, when addressing environmental problems from the perspective of a particular place, self-organize their response mechanisms. The self-organizing potential of communities, businesses, civil society and other actors can be strengthened by building networks, by matching the scale of governance to the scale of the ecosystem in question, and by promoting innovation and action (Berkes *et al.* 2003).

Paying attention to how response measures interact with, support or constrain each other is difficult but increasingly important. The significance of this in the case of ecosystem services has been recognized and may involve the reduction of one to enhance another, for example sacrificing the potential value of mining to optimize a forest's carbon sequestration or biodiversity value – or vice versa (Rodríguez *et al.* 2006). At the same time, a diversity of measures offers increased opportunities for finding synergies and supporting measures that produce multiple benefits (UNEP 2011b), such as the carbon sequestration and biodiversity co-benefits of forest conservation.

While responses at the sub-global level are likely to be diverse and grounded in local conditions, it is important to identify some common strategic elements for advancing sustainability. This section discusses four strategic elements:

- compelling visions and social contracts;
- reversing the unsustainable;
- leverage points; and
- adaptive management and governance.

Such strategic elements inform and guide the development and implementation of specific policy measures under the widest range of geographic and thematic conditions, across all scales from the local to the national and regional. In some cases they also apply at the global level, with implications for the international priority responses discussed in Chapter 17.

Social consensus around compelling visions of sustainability

Initiating and managing the transition towards internationally agreed goals and targets requires setting well-defined directions through a clearly articulated vision. Governments and other organizations at all levels should develop the capacity to engage society in expressing cohesive visions of an environmentally sustainable future around which new social consensus – in the form of deliberately agreed social contracts, sectoral and thematic strategies and policies – can be developed and implemented.

Based on the experience of public- and private-sector organizations, developing visions of an environmentally sustainable future is an effective mechanism for achieving progress in a desired direction (Costanza 2000). The generation of shared visions is not only an essential element, but also an underrated element of environmental strategic policy development and management (Meadows 1996). Current public institutions often have limited capacity to construct legitimate and credible visions relying on stakeholders' inputs (Walker *et al.* 2006). This has also been recognized by the Global Survey on Sustainable Lifestyles, which concluded that the missing links between global environmental challenges and individual action are pragmatic, holistic and compelling visions of what sustainable societies could look like (UNEP 2011c).

In the absence of a clear, coherent vision that reflects the links between social, economic and environmental issues, policies may lead to disadvantageous trade-offs, often sacrificing environmental or social goals in the face of more quantifiable economic objectives. The result is often addressing one sustainability problem while passing the true cost to another sector, community, region or even another generation, creating even more persistent and complex risks in the long term (Loorbach and Rotmans 2005).

Visioning is important both for exploring the broader implications of the effort needed for simultaneously meeting internationally agreed global goals and targets, and for discussing environmental futures from strategic sub-global points of view under different economic, social and ecological conditions. The power of visions to provide direction, navigate pathways, recognize solutions and explore uncertainty has been recognized and illustrated by the growing number of sub-global efforts that involve articulating a vision or outlook for the future. Some prominent examples follow.

- *Regional projection of options for resource efficiency improvements.* UNEP and regional partners prepared an outlook to explore how resource efficiency improvements can help maintain ecosystem health and contribute to the provision of essential ecosystem services in the rapidly industrializing economies of Asia and the Pacific (UNEP 2011b).
- *Scenario visioning at the state and city level.* A combination of qualitative visioning and quantitative modelling methods, involving extensive participation, has been used in Minnesota, United States. The purpose of the process was to help regional leaders make strategic decisions about sustainability, to identify related knowledge and research gaps and to introduce systems thinking into policy making and planning (Schmitt-Olabisi *et al.* 2010). An innovative 100-year vision has been developed for Panjim, the capital of the Indian state of Goa and surrounding areas, around the concept of "RUrbanism", an integration of urban and rural development in terms of resource use and the convergence of human well-being (Revi *et al.* 2006).
- *Visions focused on solutions to specific environmental problems.* A vision has been developed to tackle the acute water shortages in Kuwait (Al-Damkhi *et al.* 2009). Pathways of possible emission reduction and low-carbon futures have been developed for specific regions in Europe (Matthes *et al.* 2006) and cities in North America (Metro City of Vancouver 2011; Danish Architecture Centre 2011).

The development of visions involves creative tensions between quantitative model-based projections and qualitative normative articulation of what is desired for the future (Schmitt-Olabisi *et al.* 2010; Patel *et al.* 2007; Strauss 1987). A vision refers to a moving target, guiding the self-organizing and innovative forces of a society – forces that otherwise would remain diffuse. A vision differs from a goal; it is a tangible image of a future that is not subjected to the exact definitions involved in setting and achieving goals (Jaeger *et al.* 2000).

When developing visions, it is essential to ensure integration across policy themes to capture the intricately linked ecological, social, economic, ethical and institutional dimensions of sustainability problems, while reflecting on uncertainty – including surprise, critical thresholds and abrupt change, which are inherent in non-linear natural and social systems such as the Earth System (Swart *et al.* 2004). The visioning process should also account for human decisions as a key conditioning factor – the constitution, reproduction and reformulation of human needs, wants, vulnerabilities and values is essential for illuminating consumption, social goals, institutional innovation, social learning and the prospects for alternative futures (Robinson 2004; Swart *et al.* 2004).

Participatory, integrated visioning processes are most useful when they are iterative, support policy development and adaptation, and are embedded in institutional cultures with adequate capacity to manage the process. Embedding elements of a vision in institutions can take place through legal and administrative means. However, creating and maintaining the political will that makes such measures feasible requires more – as does recruiting society to adopt lifestyle changes included in the sustainability scenarios elaborated above.

According to the German Advisory Council on Global Change, formalizing the transition agenda to a low-carbon economy can be achieved in the form of new social contracts (WBGU 2011). The council argues that the need for such contracts is grounded in the joint responsibility of states and their global communities – business, science, civil society and even individuals – for tackling threats to the stability of the Earth System, with changes going beyond technical and bureaucratic reforms. Formulated around positive visions of the future, a new form of interaction between politics, society, the economy and science would need to be defined to bring creativity, resources, capacity, legitimacy and political will together in the interest of navigating the transition and achieving tangible progress towards outcomes consistent with such visions.

A social contract is a contract or agreement between people to form a society that determines their moral and/or political obligations. With Socrates being its earliest known proponent in antiquity, the concept is almost as old as philosophy. Social contracts can exist in different forms at different levels, and can outline different obligations for specific stakeholders. For example, a social contract for science would need to focus on the commitment of the scientific community to systematically apply its creativity to addressing the fundamental problems of the Earth System and the public's interests therein (Lubchenco 1998). But social contracts could take other forms in other sectors. Standards with a focus on the sustainability of products and processes in sectors such as forestry or agriculture have been proposed as a form of social contract, with the state providing an overall operating framework but with non-govenmental organizations, businesses and consumer associations working out and codifying the details (Giovannucci and Ponte 2005).

Social contracts would need to address both short-term and long-term issues. The Stockholm Memorandum of Nobel Prize Winners called for a dual-track approach: short-term actions, emergency solutions to address the most pressing environmental trends and their drivers within today's faulty institutional framework; and long-term changes focused on transforming the institutional framework itself, to create an environment for innovation, learning and action without the barriers of today. In the short term, they call for focus on achieving the Millennium Development Goals (MDGs), and in the long run for a new agreement between developed and developing countries to scale up the investment and capacity building necessary to reach those goals (Royal Swedish Academy of Sciences 2011).

Reversing the unsustainable

The transition towards internationally agreed sustainability goals and targets requires not only introducing innovative new measures and policies, but also the rapid phasing out of policies and practices that reinforce vested interests that prevent the transition from happening.

Learning what not to do is a necessary, yet often neglected, precondition to framing the improvement of sustainability and, in particular, to the integrated sustainable governance of complex social-ecological systems. Understanding the constraints and opportunities for bringing such framing into science, education and policy debate while avoiding simple ideological discussions is essential in advancing to a sustainable world (Tàbara and Pahl-Wostl 2007). However, phasing out existing policies and practices is not always easy. Policies create dependencies, and discontinuing a policy may hurt economic and other vested interests and result in adjustments. Yet discontinuing unsustainable policies and practices may also free up resources and create new niches that innovative measures, consistent with the sustainable world trajectory, can fill.

One important area for the phasing out of existing unsustainable measures is counterproductive government subsidies. These are a widespread phenomenon encouraging unsustainable activities in sectors such as agriculture, energy and transport (van Beers and van den Bergh 2009). A subsidy is a "payment by a government to an individual or firm, the intent of which, theoretically, is to decrease the divergence between social costs and benefits – to internalize externalities" (Myers and Kent 2001).
Subsidies can produce socially desirable outcomes, such as

provision of a public good that would be undersupplied by the market. When properly designed and applied, they can also provide investment to help green industry or technology start-ups become economically competitive (Bagstad *et al.* 2007). However, not all subsidies help progress towards agreed goals and targets. There are so-called "perverse" subsidies that increase the divergence between private and social costs and benefits (Myers and Kent 2001), typically by increasing the size and pollution intensity of economic activities, and often without clear, compensating social benefits but with economic benefits channelled to a small minority of entrenched interests in business-as-usual (van Beers and van den Bergh 2009, 2001). Examples include:

- agricultural subsidies that encourage the intensification of production or the expansion of farmland at the expense of natural ecosystems; without precautions, such measures often lead to significant negative impacts on biodiversity and habitats (Robin *et al.* 2003);
- fossil fuel subsidies increase greenhouse gas emissions and thus contribute to climate change; while these subsidies are often designed to keep energy costs lower for the poor, they typically end up benefiting medium- to high-income households: in 2008, for example, the Indonesian Ministry of Economic Affairs concluded that the top 40 per cent of high-income families benefited from 70 per cent of the subsidies, while the bottom 40 per cent of low-income families from only 15 per cent of them (IISD GSI 2011; IEA 2008);
- subsidies for road transport, in which subsidized road construction directly destroys habitat, and burning subsidized fossil fuels in motor vehicles is a major contributor to air pollution and climate change (Myers and Kent 2001).

Discontinuing existing unsustainable practices may be a long and uneasy process, but does lead to a shift to sustainable behaviour. An example of reversing the unsustainable can be observed in marine fisheries through the implementation of the Wellington Convention signed in 1989, which prohibits fishing with long driftnets in the South Pacific. This type of fishing is destructive because of its non-selectiveness and the high level of by-catch. Driftnet fishing was widely used, especially during the 1980s, and posed a threat to fish stocks, in particular to albacore tuna. Although the convention initially created tension among the distant-water fishing nations, it managed to balance the economic interests of fisheries with the pressure on the marine environment and led to the adoption of a global moratorium on full driftnet fishing on the high seas (Techera 2011; Hewison 1993). The International Convention for the Regulation of Whaling (ICRW), which originally aimed to prevent the oversupply of whale products but turned into a key instrument of whale conservation (Maffei 1997), can stand as another example. The governance regime for whales has contributed to more sustainable practices and a change in mindsets, allowing a transition from predominantly consumptive exploitation of a natural resource (whaling) to non-consumptive use such as whale watching and related tourism.

Sustainability not only requires being aware of complexities and uncertainties, but also developing normative patterns of knowledge creation and collective behaviour that render action possible (Mangalagiu *et al.* 2011). A transition to sustainability demands profound changes in understanding, interpretative frameworks and broader cultural values, just as it requires transformations in the practices, institutions and social structures that regulate and coordinate individual behaviour. In this context, it is essential to get to the position where people, industry and governments can easily distinguish between objective facts and opinions that are presented as facts to advance particular interests, and rely on the former to make informed decisions. This is where education becomes paramount, and involves raising awareness of the challenges and solutions as well as harnessing and communicating diverse knowledge.

A road penetrates a rainforest in the Chiriqui Highlands of Panama. The growing networks of roads through tropical rainforest are of serious environmental concern. *© Alfredo Maiquez*

Reversing or phasing out unsustainable policies and practices is essential. But it is only a first step that must be accompanied by investment in investigating solutions that incorporate traditional knowledge and novel forms of sustainability science as well as engaging with broader civil society (Bäckstrand 2003). Reversing unsustainable practices must be accompanied by providing society with knowledge and practices that are consistent with management within planetary means.

Applying leverage

Achieving internationally agreed goals and targets will require that policy makers look for advantageous places to intervene and apply leverage through the design and implementation of a diverse array of policies and instruments that:

- facilitate a mindset shift to align with sustainability principles;
- change the rules and incentives to advance sustainable practices; and
- create feedback and make adjustments to keep environmental pressures in check.

The comparison of conventional and sustainable world scenarios brings into focus the challenge at hand: an urgent need for a societal system-wide shift in the way energy is generated and used, in consumption patterns, and in natural resource management – to quickly adjust the pathway towards sustainability – in the context of an unstable global economy and present underachievement of most of the MDGs. In short, there is neither time nor money to waste. However, the crisis of sustainability may help increase awareness and understanding of the problem, its underlying causes and the relationship between them, and create momentum. Future policy efforts must be as efficient and effective as humanly possible: by specifically addressing the deeply embedded underlying drivers and targeting and coordinating progress towards long-term change.

Progress toward deep transformation will not be rapid, but evidence of change and progress at levels less deeply embedded in the system will help create the conditions that support and assist deep level change. What is emphasized here is the importance of constructing a diversified portfolio of policy intervention at levels that are fairly easy to access and influence, in conjunction with other interventions which involve deeper analysis, coordination and structural change.

Three layers of transformation were introduced in Figure 16.2 where leverage points might be found, providing practical guidance for policy makers in managing the sustainability transition. Reflecting on the presence or absence of intervention at each of these leverage points can help broaden and diversify policy emphasis, leading to a more resilient and responsive overall strategy. Several examples follow, beginning with those that are at the core of the sustainability transition.

Shift mindsets

At the core of the sustainability transition lie critical reflection and changes in the mindsets and goals that determine how issues themselves are framed. Mindsets in this respect refers both to those held by individuals and to those shared mindsets that define how social groups, cultures, nations or the human species at large approach things. Recognizing the importance of mindsets in the sustainability transition allows an opportunity to reflect and examine underlying assumptions, identify shared values and cultivate common ground. Each of these contributes to defining the shared goals and the compelling visions necessary to bring these changes about. Consider the following examples:

- *Youth education for sustainable development.* Introducing the principles of sustainability at an early and formative age in primary and secondary school supports the power of complex problem solving and can instil the belief that change is possible and preferable, and that a sustainable world is indeed achievable. The United Nations Decade of Education for Sustainable Development (UNESCO 2011) is an example of a global response meant to facilitate national and sub-national efforts in this regard. Policy interventions that help schools integrate sustainability into curriculums have the potential to change mindsets.
- *Social marketing*. While the world is replete with advertisements for products and services, there is a dearth of public messaging to promote the principles of sustainability and non-material aspects of well-being such as health, leisure or time with friends and family. Changes in the rules and ethics of advertising and marketing that match the audience-reach of product and service advertising, but that communicate critical behavioural change for a sustainable future – such as water and energy conservation or the use of green products – have the potential to change mindsets.
- *Beyond GDP.* Nobel prize-winning economists Joseph Stiglitz and Amartya Sen were commissioned by President Nicholas Sarkozy of France to examine the measurement of economic performance and social progress. The Stiglitz-Sen Commission called for a shift in emphasis from measuring economic production to measuring people's well-being and the sustainability of that well-being (Stiglitz *et al.* 2009). They stressed the importance of measuring such aspects as the state of health, education, personal activities, environmental conditions, social connections and political voice, as well as insecurity, inequalities and proximity to dangerous levels of environmental damage. An example of the type of transformation that such a change in mindset represents is Bhutan's Gross National Happiness Index and the national priority to focus on increasing happiness rather than merely focusing on perpetual GDP growth (Government of Bhutan 2011).

Change the rules and incentives

Coordinating deep and enduring system change is neither a single pathway nor a linear process. For example, the rules of a system often arise from a change in mindset, but in turn help support mindset shifts. At this level of system intervention the emphasis is on getting the signals right. Because rules and incentives can institute structural change, they represent the game changers that can catalyse and retain a strong influence on system behaviour over time.

The Rio Branco sawmill in the Brazilian Amazon, working under Forest Stewardship Council certification. Third-party forest certification systems are being used as a way to promote sustainable practices and reduce the carbon footprint of products while improving market access for community-based forest enterprises. *© Antoine Lorgnier*

Policy instruments such as laws, taxes, subsidies and market mechanisms can be directed to shift specific drivers that affect the state of the environment, and the more influential the driver, the more systemic the change can be. Some instruments that are already in place in many jurisdictions, such as pollution charges, can create direct incentives for the reduction of emissions. Other measures, however, with potentially more far-reaching impacts, may require and represent a deeper mind-shift. For example, payment for ecosystem services schemes include a suite of approaches that attempt to attach value to ecological functions that are usually left out of cost-benefit calculations and mainstream economic models, including direct public and private payments (Milder *et al.* 2010). Payment for ecosystem services has been advanced for example in Latin America and the Caribbean (Wunder 2007), and China has implemented some of the largest schemes in the world (ADB 2010).

Create feedback and make adjustments

Interventions aimed at less structurally embedded parts of a system can contribute to the sustainability transition, especially when they catalyse mass action. Interventions that strengthen feedback are designed to "deliver information to a place where it wasn't going before and therefore causing people to behave differently" (Meadows 1999). Such feedback provides the evidence base for the mitigation of environmental pressures. Examples include:

- *Household water and energy metering.* A digital household meter for electricity and water consumption can have a significant impact on individual behaviour. In Armenia, for example, studies on water consumption soon after meter installation revealed that on average water use decreased three to four times (OECD 2008b).
- *Product labelling.* Providing information such as the carbon footprint of products, or forest or marine stewardship certification, can influence consumer behaviour and lead to transformation across sectors. For example, the Marine Stewardship Council (MSC) provides certification standards and requirements for sustainable seafood. As of 2011 there were 133 MSC-certified fisheries representing almost 6 per cent of the total wild fish catch (MSC 2011).
- *Community indicator systems*. Communities that undertake multi-stakeholder processes to identify priority aspects of quality of life and indicators to track progress over time, create important feedback loops that can influence collaborative action and transformation in communities. In a 2011 study (US-GAO 2011), the US Government Accountability Office highlighted that community indicator systems are a "vehicle for encouraging civic engagement both through the system's development process and through action once the indicator system is in place"; "help address community or national challenges by facilitating collaboration of various parties inside and outside of government"; and "provide solutions to long-term challenges". One example from Nevada's Reno and Sparks communities is *Truckee Meadows Tomorrow, Quality of Life Indicators* (TMT 2011).

Adaptive governance

Recognizing that humanity is encroaching on critical planetary boundaries, new modes of adaptive governance are needed to initiate transition management and achieve internationally agreed goals and targets.

This analysis has demonstrated that the transition path towards a sustainable world scenario is feasible but requires navigating a wide range of highly complex and interrelated issues simultaneously. Contextually, society's pursuit of well-being and the requisite use of natural resources is a complex adaptive system, where different systems interact and adapt to one another, giving rise to the emergent ability of both people and ecosystems to self-organize in response to sudden shocks and more slowly changing stresses (Liu *et al.* 2007). Such a system is never at a standstill, but rather is in a constant process of incremental adaptation, reconfiguration, modification, revision and re-ordering, where long periods of stability or equilibrium are visited by short periods of radical change (Grin *et al.* 2010; Loorbach 2007).

In such unpredictable settings, it is nearly impossible to create a fail-proof blueprint or to formulate optimal policies. What is required instead is an inclusive, learn-by-doing process with careful monitoring of policy effects, and an ability to make critical choices and improvements consistent with the trajectories leading to established goals. Society has already experienced the inadequacies of inflexible blueprint-style approaches and is gaining both experience and insights into alternative strategies and policies that are more adaptive and that help build resilience. Resilience thinking puts three aspects of social-ecological systems at the centre: resilience, adaptability and transformability. Resilience refers to the capacity of a system – such as a country or an ecosystem – to adapt to change, deal with surprise, and retain its basic function and structure while remaining within critical boundaries. Adaptability – part of resilience – represents the capacity to adjust responses to changing external drivers and internal processes, and thereby channel development along the preferred trajectory in what is called a stability domain. Transformability is the capacity to cross thresholds, enter new development trajectories, abandon unsustainable actions and chart better pathways to established targets (Folke *et al.* 2010).

There are different related approaches emerging that put these concepts into practice, including adaptive management, sustainability transition management, adaptive governance and adaptive policy making. They each have common features as well as different niches and scales in which they are relevant. The adaptive management approach, pioneered in the 1980s and 1990s (Lee 1993; Holling 1978), offers practical and experience-based guidance for the type of skilful navigation that would be necessary for local and regional place-based natural resource management efforts.

Recommendations for managing the transition to sustainability, resilience thinking and intervening in complex adaptive systems all provide governance-level insights (Grin *et al.* 2010; Loorbach 2007; Berkes *et al.* 2003; Rihani 2002; Ruitenbeek and Cartier 2001; Axelrod and Cohen 2000). In relation to the design and implementation of adaptive policy instruments, there is also an array of research and experience with practical applications to draw from that embody many of the same principles as adaptive management and managing sustainability transitions (Swanson *et al.* 2010; Walker and Marchau 2003; Bankes 2002; Dewey 1927). An example of what adaptive governance and policy-making entail in relation to watershed management in India is shown in Box 16.5. The range of research and experience cited in this paragraph reveals a consistent set of critical functions for adaptive governance and managing the transition to sustainability, here largely adopting the terminology of Loorbach (2007):

- *Multi-actor deliberation and agenda building*. Many stakeholders influence societal change. Governance must, therefore, be participatory to recognize advantageous leverage points, the levers for change and the correct direction to move them; to achieve coherent coalitions for creating shared notions of goals and ambitions; and to strengthen policy design and implementation.
- *Futures analysis and long-term collective goal setting*. Integrated and forward-looking assessments are critical tools that inform ongoing processes of change by systematically reflecting upon the future and developing shared notions of future goals and targets.

Box 16.5 India's National Watershed Development Project for Rainfed Areas (NDWPRA) – adaptive governance and policy-making at the sub-national level

The objectives of India's NWDPRA project include:

- sustainable enhancement of agricultural productivity and production;
- restoration of the ecological balance in degraded and fragile rain-fed ecosystems by greening these areas through an appropriate mix of trees, shrubs and grasses;
- reduction in regional disparity between irrigated and rain-fed areas; and
- creation of sustained employment opportunities for the rural poor.

In Maharashtra, the NDWPRA project launched in 1990/91 continued through India's Ninth Five-Year Plan, when it was considerably restructured. Greater emphasis was placed on decentralization and community participation. In the Tenth Five-Year Plan (2002–2007), the state of Maharashtra continued to implement the scheme with a participatory approach, extending it to 433 micro-watersheds across 33 districts, with a targeted treatment area of 203 000 hectares. The shift towards a decentralized approach contributed to improvements in water-management and represents an example of adaptive governance.

Source: Swanson and Bhadwal 2009

- *Enabling self-organization and networking*. Creating opportunities for cooperation and replicating successes, ensuring that social capital remains intact, and guaranteeing that members of the population are free and able to interact, are all fundamental elements of building the capacity of actors and policy itself to plan for and adapt to surprises.
- *Variation, experimentation and innovation*. Diversity of responses forms a common risk-management approach, and continuous reflection and improvement helps to develop a context in which innovation for desired change can thrive.
- *Reflexivity and adaptation*. Systemic review of past, present and future sustainability conditions and policy performance through interaction and cooperation with a range of stakeholders is critical for continuous improvement and social learning.

These critical functions of sustainability transition management and adaptive governance, together with the other strategic elements described earlier – social consensus for achieving compelling visions, discarding the unsustainable, and applying leverage in policy making – provide practical guidance for advancing sustainability and achieving internationally agreed targets.

In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive. *© Ilias Kordelakos*

CONCLUSIONS

The envisioned sustainable world aims simultaneously to achieve universal human well-being and environmental sustainability at global, national, regional and local levels. The vision assumes that, by 2050, all people have access to food, safe drinking water, improved sanitation and modern sources of energy, all within the ecological limits of the planet.

Without major course correction, however, continuing on the current trajectory would lead, by 2050, to major environmental damage, a serious loss of ecosystem services, depletion of natural resources and many people left without sustainable access to food, water or energy. As a consequence, most internationally agreed goals and targets would be missed, some by a wide margin, particularly those related to climate change, biodiversity, water and food security.

The review of sustainable world scenarios suggests that measures can be put in place to help achieve these targets and reduce the risk of Earth System changes and negative impacts on future human development. Measures at the mid layer of transformation, such as rule changes, will not be enough to move to a sustainable world pathway. Structural measures and stronger policy action are needed to influence both production and consumption patterns. Such changes should be both short- and long-term, and combine technology, investment and governance measures along with lifestyle modifications grounded in a mindset shift towards sustainability and equity-based values.

A transformation of such complexity requires a gradual, but steadily strengthening, transition process. During this, there is a need to stop activities that pull the Earth System towards unsustainability. At the same time, it is important to provide resources, build capacity and create an enabling environment for all in a way that is consistent with the vision of a sustainable world.

Such a transition requires a high degree of consensus and coordination between societal actors with diverse interests and working environments. As a first step, broad-based social contracts, grounded in jointly developed visions of a sustainable future, would be needed to focus people's attention on the future. To ensure coherence among all societal actors, contextually sensitive transition pathways can be developed and agreed as joint visions of the future that respect social responsibility and ensure that the rest of society has sustainable access to the resources necessary for well-being. Given that systemic changes, both environmental and societal, are often slow, long-term goals would help focus investment and technological development, induce societal change and engage other actors in society.

The transition process would necessarily be based on adaptive management, since uncertainties play a key role in the problems of the Earth System. A diversity of measures would provide better insurance against wholesale failure on critical issues – due either to inherent uncertainties or inadequate implementation – and be mutually strengthening. Of course, strategies to achieve the targets will necessarily differ between developed and developing countries, and between regions, countries, and communities within those categories. The momentum of green economy initiatives to integrate environmental imperatives into major sectors also needs to be sustained and turned into detailed work on policy, innovation and practice. Reversing ecosystem degradation while meeting the increasing demand for resources may seem challenging, but policy measures that help achieve environmental goals and targets also have the potential to deliver benefits to human well-being.

All this requires political determination and strong governance. Questions of how to do it and what kind of global responses and institutions would be needed are discussed in Chapter 17.

REFERENCES

ADB (2010). *An Eco-Compensation Policy Framework for the People's Republic of China: Challenges and Opportunities*. Asian Development Bank, Manila. http://www.adb.org/documents/reports/eco-compensation-prc/eco-compensation-prc.pdf

AGECC (2010). *Energy for a Sustainable Future: Summary Report and Recommendations*. The Secretary-General's Advisory Group on Energy and Climate Change. United Nations, New York. http://www.unido.org/fileadmin/user_media/Publications/download/AGECCsummaryreport.pdf (accessed 24 September 2011)

Alcamo, J., Floerke, M. and Maerker, M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. *Hydrological Sciences Journal* 52, 247–275

Alcamo, J., van Vuuren, D.P. and Cramer, W. (2005a). Change in ecosystem services and their drivers across the scenarios. In *Ecosystems and Human Well-being: Scenarios. Volume 2* (eds. Carpenter, S.R., Pingali, P., Bennett, E.M. and Zurek, M.B.). Island Press, Washington

Alcamo, J., van Vuuren, D., Ringler, C., Cramer, W., Masui, T., Alder, J. and Schulze, K. (2005b). Changes in nature's balance sheet: model-based estimates of future worldwide ecosystem services. *Ecology and Society* 10(2)

Alcamo, J., Döll, P., Henrichs, T., Kaspar, F., Lehner, B., Rösch, T. and Siebert, S. (2003). Development and Testing of the WaterGAP 2 Global Model of Water Use and Availability. *Hydrological Sciences Journal*, 48(3), 317–337

Al-Damkhi, A.M., Al-Fares, R.A., Al-Khalifa, K.A. and Abdul-Wahab, S.A. (2009). Water issues in Kuwait: a future sustainability vision. *International Journal of Environmental Studies* 66(5), 619–636

Angelsen, A. (2010). Policies for reduced deforestation and their impact on agricultural production. *Proceedings of the National Academy of Sciences of the United States of America* 107(46), 19639–19644

Anticamara, J.A., Watson, R., Gelchu, A. and Pauly, D. (2011). Global fishing effort (1950–2010): trends, gaps, and implications. *Fisheries Research* 107, 131–136

Arnason, R., Kelleher, K. and Willman, R. (2009). *The Sunken Billions: The Economic Justification for Fisheries Reform.* World Bank, Washington, DC and Food and Agriculture Organization of the United Nations, Rome

Arnell, N.W., van Vuuren, D.P. and Isaac, M. (2011). The implications of climate policy for the impacts of climate change on global water resources. *Global Environmental Change* 21(2), 592–603

Arnold, M., Kohlin, G., Persson, R. and Shepherd, G. (2003). *Fuel Wood Revisited: What Has Changed in the Last Decade?* Center for International Forestry Research, Jakarta

Axelrod, R. and Cohen, M.D. (2000). *Harnessing Complexity: Organizational Implications of a Scientific Frontier*. Basic Books, New York

Bäckstrand, K. (2003). Civic science for sustainability: reframing the role of experts, policy-makers and citizens in environmental governance. *Global Environmental Politics* 3(4), 24–41

Bagstad, K.J., Stapleton, K. and D'Agostino, J.R. (2007). Taxes, subsidies, and insurance as drivers of United States coastal development. *Ecological Economics* 6(3), 285–298

Bakkes, J.A. and Bosch, P.R. (eds.) (2008). *Background Report to the OECD Environmental Outlook to 2030. Overviews, Details, and Methodology of Model-based Analysis*. Netherlands Environmental Assessment Agency, Bilthoven

Bankes, S.C. (2002). Tools and techniques for developing policies for complex and uncertain systems. *Proceedings of the National Academy of Sciences of the United States of America* 99(3), 7263–7266

Bassi, A.M. and Eaton, D. (2011). In defence of green economy report. *Nature* 475, 454

Bassi, A.M., Pedercini, M., Ansah, J.P. and Tan, Z. (2010). *T21-World Model Documentation, Modeling the Green Economy*. Millennium Institute, Arlington, VA

Bates, B., Kundzewicz, Z.W., Shaohong, W. and Palutikof, J. (2008). *Climate Change and Water.* IPCC Technical Paper VI. Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva

Bazilian, M., Nussbaumer, P., Haites, E., Levi, M., Howells, M. and Yumkella, K.K. (2010). Understanding the scale of investment for universal energy access. *Geopolitics of Energy* 32, 10–11

Berkes, F., Colding, J. and Folke, C. (2003). *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change.* Cambridge University Press, Cambridge

Black, R.E., Cousens, S., Johnson, H.L., Lawn, J.E., Rudan, I., Bassani, D.G., Jha, P., Campbell, H., Walker, C.F., Cibulskis, R., Eisele, T., Liu, L. and Mathers, C. (2010). Global, regional, and national causes of child mortality in 2008: a systematic analysis. *Lancet* 375, 1969–1987

Bollen, J.C. (2008). *Energy Security, Air Pollution, and Climate Change: An Integrated Cost Benefit Approach*. Netherlands Environmental Assessment Agency, Bilthoven

Bouwman, A.F., van der Hoek, K.W., Drecht, G.V. and Eickhout, B. (2006). World livestock and crop production systems, land use and environment between 1970 and 2030. In *Rural Lands, Agriculture and Climate beyond 2015: A New Perspective on Future Land Use Patterns* (eds. Brouwer, F. and McCarl, B.). pp.75–89. Springer, Dordrecht

Bouwman, A.F., van der Hoek, K.W., Eickhout, B. and Soenario, I. (2005). Exploring changes in world ruminant production systems. *Agricultural Systems* 84(2), 121–153. doi:110.1016 j.agsy 2004.1005.1006

Bringezu, S., Schütz, H., O'Brien, M., Kauppi, L., Howarth, R.W. and McNeely, J. (2009). *Towards Sustainable Production and Use of Resources: Assessing Biofuels*. International Panel for Sustainable Resource Management. United Nations Environment Programme, Division of Technology, Industry and Economics (UNEP DTIE), Paris

Broca, S.S. (2002). *Food Insecurity, Poverty and Agriculture: A Concept Paper*. Agricultural and Development Economics Division, Food and Agriculture Organization of the United Nations (FAO), Rome

Bruinsma, J. (ed.) (2003). *World Agriculture: Towards 2015/2030. An FAO Perspective*. Earthscan, London

Butchart, S.H.M., Scharlemann, J.P.W., Evans, M.I., Quader, S., Aricò, S., Arinaitwe, J., Balman, M., Bennun, L.A., Besançon, C., Boucher, T.M., Bertzky, B., Brooks, T.M., Burfield, I.J., Burgess, N.D., Chan, S., Clay, R.P., Crosby, M.J., Davidson, N.C., De Silva, N., Devenish, C., Dutson, G.C.L., Díaz Fernández, D.F., Fishpool, L.D.C., Fitzgerald, C., Foster, M., Heath, M.F., Hockings, M., Hoffmann, M., Knox, D., Larsen, F.W., Lamoreux, J.F., Loucks, C., May, I., Millett, J., Molloy, D., Morling, P., Parr, M., Ricketts, T.H., Seddon, N., Skolnik, B., Stuart, S.N., Upgren, A. and Woodley, S. (2012). Protecting important sites for biodiversity contributes to meeting global conservation targets. *PLoS ONE* 7(3)

CBD (2010a). *Aichi Biodiversity Targets*. Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity (COP 10), Nagoya. Secretariat of the Convention on Biological Diversity, Montreal

CBD (2010b). *Global Biodiversity Outlook 3*. Secretariat of the Convention on Biological Diversity, Montreal

CBD (2006). *Global Biodiversity Outlook 2.* Secretariat of the Convention on Biological Diversity, Montreal

Clarke, L., Edmonds, J., Krey, V., Richels, R., Rose, S. and Tavoni, M. (2010). International climate policy architectures: overview of the EMF 22 international scenarios. *Energy Economics* 31(2), S64–S81

CLRTAP (1979). *Convention on Long-range Transboundary Air Pollution (CLRTAP)*. United Nations Economic Commission for Europe (UNECE), Geneva

Cofala, J., Amann, M., Klimont, Z., Kupiainen, K., Höglund-Isaksson, L. (2007). Scenarios of global antropogenic emissions of air pollutants and methane until 2030. *Atmospheric Environment* 41, 8468–8499

Cosgrove, W. and Rijsberman, F. (2000). *World Water Vision: Making Water Everybody's Business.* World Water Council, Earthscan Publications, London

Costanza, R. (2000). Visions of alternative (unpredictable) futures and their use in policy analysis. *Conservation Ecology* 4(1), 5

Czech, B. and Daly, H.E. (2004). The steady state economy – what it is, entails and connotes. *Wildlife Society Bulletin* 32(2), 598–605

Daly, H.E. (1974). The economics of the steady state. *American Economic Review* 64(2), 15–21

Daly, H.E. (1971). *The Stationary-State Economy: Toward a Political Economy of Biophysical Equilibrium and Moral Growth*. Distinguished Lecture Series No. 2. University of Alabama, Alabama

Danish Architecture Centre (2011). *Lyon: An Overall Vision for Transport – Urban Mobility Master Plan*. Danish Architecture Centre, Copenhagen. http://sustainablecities.dk/en/city-projects/cases/lyon-an-overall-vision-for-transport-urban-mobility-master-plan

Dewey, J. (1927). *The Public and its Problems*. Holt and Company, New York

Dornburg, V., van Vuuren, D., van de Ven, G., Langeveld, H., Meeusen, M., Banse, M., van Oorschot, M., Ros, J., van den Born, G.J., Aiking, H., Londo, M., Mozaffarian, H., Verweij, P., Lysen, E. and Faaij, A. (2010). Bioenergy revisited: key factors in global potentials of bioenergy. *Energy and Environment Science* 3, 258–267

Easterling, W., Aggarwal, P., Batima, P., Brander, K., Erda, L., Howden, M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhube, S. and Tubiello, F. (2007). Food, fibre and forest products. In *Climate Change 2007: Impacts, Adaptation and Vulnerability* (eds. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

ECF (2010). *Roadmap 2050. A Practical Guide to a Prosperous, Low Carbon Europe.* European Climate Foundation, The Hague

FAO (2011). *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW): Managing Systems at Risk.* Food and Agriculture Organization of the United Nations, Rome and Earthscan, London

FAO (2010). *State of World Fisheries and Aquaculture 2010.* Food and Agriculture Organization of the United Nations, Rome.

FAO (2009). *High-level Expert Forum: How to Feed the World in 2050*. Food and Agriculture Organization of the United Nations, Rome

FAO (2006a). WISDOM – *East Africa: Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) Methodology. Spatial Woodfuel Production And Consumption Analysis of Selected African Countries.* Forestry Department, Food and Agriculture Organization of the United Nations, Rome

FAO (2006b). *World Agriculture: Towards 2030/2050. Prospects for Food, Nutrition, Agriculture and Major Commodity Groups*. Food and Agriculture Organization of the United Nations, Rome

FAO (1996). *Rome Declaration on World Food Security and World Food Summit Plan of Action*. Adopted at the World Food Summit, November 13–17, Rome. Food and Agriculture Organization of the United Nations, Rome

FAO (1995). *Code of Conduct for Responsible Fisheries*. Food and Agriculture Organization of the United Nations, Rome

FAOSTAT (2012). *FAO Statistical Databases*. Food and Agriculture Organization of the United Nations, Rome. http://faostat.org

Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science* 319, 1235–1238

Fearnside P.M. (2011). Methane emissions from hydroelectric dams. *Science* 28 July 2011, 50. http://www.sciencemag.org/content/331/6013/50/reply

Fisher, B., Nakicenovic, N., Alfsen, K., Corfee Morlot, J.C., de la Chesnaye, F., Hourcade, J.-C., Jiang, K., Kainuma, M., La Rovere, E., Matysek, A., Rana, A., Riahi, K., Richels, R., Rose, S., van Vuuren, D. and Warren, R. (2007).) Issues related to mitigation in the long-term context. In *Climate Change 2007. Mitigation of Climate Change* (eds. Metz, B., Davidson, O.R, Bosch, P.R., Dave, R. and Meyer, L.). pp.169–250. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York

Flörke, M. and Alcamo, J. (2004). *European Outlook on Water Use.* European Environment Agency, Copenhagen. http://scenarios.ewindows.eu.org/reports/fol949029

Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T. and Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society* 15(4), 20. http://www.ecologyandsociety.org/vol15/iss4/art20/

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S. and Walker, B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *Ambio* 31(5), 437–440

GEA (2011). *Global Energy Assessment*. Cambridge University Press, Cambridge

Gibson, L., Ming Lee, T., Pin Koh, L., Brook, B.W., Gardner, T.A., Barlow, J., Peres, C.A., Bradshaw, C.J.A., Laurance, W.F., Lovejoy, T.E. and Sodhi, N.S. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* 478, 378–381

Giovannucci, D. and Ponte, S. (2005). Standards as a new form of social contract? Sustainability initiatives in the coffee industry. *Food Policy* 30(3), 284–301

Girod, B., van Vuuren, D.P. and Deetman, S. (2012). Global travel within the 2°C climate target. *Energy Policy* 45, 152–166

Global Footprint Network (2010). *The Ecological Wealth of Nations: Earth's Biocapacity as a New Framework for International Cooperation.* http://www.footprintnetwork.org/images/uploads/Ecological_Wealth_of_Nations.pdf (accessed 24 September 2011)

Government of Bhutan (2011). *Gross National Happiness*. National Portal of Bhutan, Government of Bhutan. http://www.bhutan.gov.bt/government/gnh.php

Grin, J., Rotmans, J. and Schot, J. (2010). *Transitions to Sustainable Development. New Directions in the Study of Long Term Transformative Change*. Routledge, New York, London

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R. (2008). A global map of human impact on marine ecosystems. *Science* 319, 948

Hazell, P. and Wood, S. (2008). Drivers of change in global agriculture. *Philosophical Transactions of the Royal Society B* 363, 495–515

Hewison, G.J. (1993). The Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific. *Case Western Reserve Journal of International Law* 25, 449

Hilderink, H.B.M., Lucas, P.L. and Kok, M. (eds.) (2009). *Beyond 2015: Long-term Development and the Millennium Development Goals*. Netherlands Environmental Assessment Agency, Bilthoven

Holling, C.S. (2001). Understanding the complexity of economic, ecological and social systems. *Ecosystems* 4(5), 390–405

Holling, C.S. (1978). *Adaptive Environmental Assessment and Management*. John Wiley, New York

Hughes, B.B., Kuhn, R., Peterson, C.M., Rothman, D.S. and Solórzano, J.R. (2011). *Improving Global Health. Patterns of Potential Human Progress Vol.3.* Oxford University Press, New Delhi

Hutton, G. and Haller, L. (2004). *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level*. World Health Organization, Geneva

Hurtt, G., Chini, L., Frolking, S., Betts, R., Edmonds, J., Feddema, J., Fisher, G., Goldewijk, K.K., Hibbard, K.A., Houghton, R., Janetos, A., Jones, C.D., Kindermann, G. Kinoshita, T., Goldewijk, K.K., Riahi, K., Shevliakova, E., Smith, S., Stehfest, E., Thomson, A., Thornton, P., van Vuuren D.P., and Wang, Y.P. (2011). Harmonization of land-use scenarios for the period 1500–2100: 600 years of global gridded annual land-use transitions, wood harvest, and resulting secondary lands. *Climatic Change* 109(1), 117–161

IAASTD (2009a) *High-level Expert Forum: How to Feed the World in 2050*. International Assessment of Agricultural Science and Technology for Development: Global Report. Island Press, Washington, DC and Rome

IAASTD (2009b) *Synthesis Report: A Synthesis of the Global and Sub-Global IAASTD Reports.* International Assessment of Agricultural Science and Technology for Development: Global Report. Island Press, Washington, DC and Rome. http://www.agassessment.org/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Synthesis%20Report%20(English).pdf

ICPD (1994). *Report of the International Conference on Population and Development, Cairo, 5–13 September 1994.* UN Population Fund

IEA (2010). *World Energy Outlook 2010*. International Energy Agency, Paris

IEA (2008). *Energy Policy Review of Indonesia*. International Energy Agency, Paris. http://www.iea. org/textbase/nppdf/free/2008/Indonesia2008.pdf

IEA (2006). *Angola, Towards an Energy Strategy*. International Energy Agency, Paris

IEA/UNDP/UNIDO (2010). Energy Poverty: How To Make Modern Energy Access Universal? Special early excerpt of the *World Energy Outlook 2010* for the UN General Assembly on the Millennium Development Goals. International Energy Agency, United Nations Development Programme and United Nations Industrial Development Organization. OECD/IEA, Paris

IISD GSI (2011). *A High-Impact Initiative for Rio+20: A Pledge to Phase out Fossil-Fuel Subsidies.* Global Subsidies Initiative of the International Institute for Sustainable Development (IISD), Geneva and Winnipeg

Innes, A.D., Campion, P.D. and Griffith, F.E. (2005). Complex consultations and the "edge of chaos". *British Journal of General Practice* 55(510), 47–52

IPCC (2007). *Climate Change 2007: Synthesis Report* (eds. Pachauri, R.K. and Reisinger, A.). Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Interngovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Jaeger, C.C., Kasemir, B., Stoll-Kleemann, S., Schibli, D. and Dahinden, U. (2000). Climate change and the voice of the public. *Integrated Assessment Journal* 1, 339–349

Jäger, J. and Cornell, S.E. (eds.) (2011). *The Planet in 2050: The Lund Discourse of the Future*. Routledge

Jakarta Mandate (1995). *The Jakarta Mandate on the Conservation and Sustainable Use of Marine and Coastal Biological Diversity.* http://www.ngo.grida.no/wwfneap/Projects/Reports/jakmand.pdf

Jenkins, G. and Lowe, J. (2003). *Handling Uncertainties in the UKCIP02 Scenarios of Climate Change*. Hadley Centre Technical Note 44. Met Office, Exeter

Kaiser, M., Ellerbrock, R.H. and Gerke, H.H. (2007). Long-term effects of crop rotation and fertilization on soil organic matter composition. *European Journal of Soil Science* 58, 1460–1470

Killham, K. (2010). Integrated soil management – moving towards globally sustainable agriculture. Foresight Project on Global Food and Farming Futures. *Journal of Agricultural Science* 149, 29–36

Leadley, P., Pereira, H.M., Alkemade, R., Fernandez-Manjarres, J.F., Proenca, V., Scharlemann, J.P.W. and Walpole, M.J. (2010). *Biodiversity Scenarios: Projections of 21st Century Change in Biodiversity and Associated Ecosystem Services*. Technical Series No. 50. Secretariat of the Convention on Biological Diversity, Montreal

Lee, K. (1993). *Compass and Gyroscope: Integrating Science and Politics for the Environment*. Island Press, Washington, DC

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S. and Schellnhuber, H.J. (2008). Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences of the United States of America* 105(6), 1786–1793

Levin, S.A. (1998). Ecosystem and the biosphere as complex adaptive systems. *Ecosystems* 1(5), 431–436

Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H. and Taylor, W.W. (2007). Complexity of coupled human and natural systems. *Science* 317(5844), 1513–1516

Loorbach, D. (2007). *Transition Management: New Mode of Governance for Sustainable Development*. International Books, Utrecht

Loorbach, D. and Rotmans, J. (2005). Managing transitions for sustainable development. In *Industrial Transformation – Disciplinary Approaches Towards Transformation Research* (eds. Wieczorek, A.J. and Olshoorn, X.). pp.187–206. Kluwer Academic Publishers Dordrecht

Lubchenco, J. (1998). Entering the century of the environment: a new social contract for science. *Science* 279(5350), 491–497

Lutz, W. and Samir, K.C. (2011). Global human capital: integrating education and population. *Science* 333(6042), 587
Lutz, W., Sanderson, W. and Scherbov, S. (2008). The coming acceleration of global population ageing. *Nature* 451, 716–719

Luzzati, T. and Orsini, M. (2009). Investigating the energy-environmental Kuznets curve. *Energy* 34, 291–300

MA (2005a). *Ecosystems and Human Health: Scenarios*. Millennium Ecosystem Assessment. Island Press, Washington, DC

MA (2005b). *Ecosystems and Human Health: Synthesis*. Millennium Ecosystem Assessment. Island Press, Washington, DC

Maffei, M.C. (1997). The International Convention for the Regulation of Whaling. *International Journal of Coastal and Marine Law* 12(3), 287–305

Mangalagiu, D., Wilkinson, A. and Kupers, R. (2011). When futures lock in the present. In *Reframing the Problem of Climate Change: From Zero Sum Game to Win-win Solutions* (eds. Jaeger, C.C., Hasselmann, K., Leipold, G, Mangalagiu, D. and Tàbara, J.D.). Earthscan, London and Washington DC

Matthes, F.C., Gores, S., Graichen, V., Repenning, J. and Zimmer, W. (2006). *The Vision Scenario for the European Union*. Öko-Institut e.V., Berlin and Freiburg

McNeil, B.I. and Matear, R.J. (2008). Southern Ocean acidification: a tipping point at 450-ppm atmospheric CO_2. *Proceedings of the National Academy of Sciences of the United States of America* 105, 18860–18864

Meadows, D. (1999). *Leverage Points: Places to Intervene in a System*. The Sustainability Institute, Hartland. http://www.sustainabilityinstitute.org/pubs/Leverage_Points.pdf

Meadows, D.H. (1996). *Envisioning a Sustainable World*. Prepared for the Third Biennial Meeting of the International Society for Ecological Economics, 24-28 October 1994, San Jose, Costa Rica. http://www.infoark.org/InfoArk/Sustainability/Envisioning%20a%20Sustainable%20World%20-%20Meadows_1994-10-24.pdf

Meinshausen, M., Hare, B., Wigley, T.M.L., van Vuuren, D., den Elzen, M.G.J. and Swart, R. (2006). Multi-gas emissions pathways to meet climate targets. *Climatic Change* 75(1–2), 151–194

Mery, G., Katila, P., Galloway, G., Alfaro, R.I., Kanninen, M., Lobovikov, M. and Varjo, J. (eds.) (2010). *Forests and Society – Responding to Global Drivers of Change*. IUFRO World Series Volume 25. IUFRO – The Global Network for Forest Science Cooperation, Vienna

Metro City of Vancouver (2011). *Climate Smart*. Metro Vancouver Program Information. Metro Vancouver, Vancouver. https://climatesmartbusiness.com/metrovancouver/#overview

Milder, J.C., Scherr, S.J. and Bracer, C. (2010). Trends and future potential of payment for ecosystem services to alleviate rural poverty in developing countries. *Ecology and Society* 15(2), 4. http://www.ecologyandsociety.org/vol15/iss2/art4/

MSC (2011). *Marine Stewardship Council: Certified Sustainable Seafood*. http://www.msc.org

Myers, N. and Kent, J. (2001). *Perverse Subsidies. How Tax Dollars Can Undercut the Environment and the Economy.* Island Press, Washington, DC

Nakicenovic, N. and Swart, R. (eds.) (2000). *Emissions Scenarios*. IPCC Special Report. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T.B., Ringler, C., Msangi, S. and You, L. (2010). *Food Security, Farming, and Climate Change to 2050.* International Food Policy Research Institute (IFPRI), Washington, DC

OECD (2012). *OECD Environmental Outlook to 2050*. Organisation for Economic Co-operation and Development, Paris

OECD (2008a). *OECD Environmental Outlook to 2030*. Organisation for Economic Co-operation and Development, Paris

OECD (2008b). *Promoting the Use of Performance-Based Contracts between Water Utilities and Municipalities in EECCA. Case Study No. 2: Armenian Water and Wastewater Company*, *SAUR Management Contract.* Organisation for Economic Co-operation and Development, Paris

OECD/FAO (2011). *Agricultural Outlook 2011–2020*. Organisation for Economic Co-operation and Development, Paris and Food and Agriculture Organization of the United Nations, Rome

Parfitt, J., Barthel, M. and Macnaughton, S. (2010). Food waste within food supply chains: quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B* 365, 3065–3081

Patel, M., Kok, K. and Rothman, D.S. (2007). Participatory scenario construction in land use analysis: an insight into the experiences created by stakeholder involvement in the Northern Mediterranean. *Land Use Policy* 24(3), 546–561

Paulitz, T., Smiley, R.W. and Cook, R.J. (2002). New insights into the make-up and management of soilborne cereal pathogens under direct seeding in the Pacific Northwest. *Canadian Journal of Phytopathology* 24, 416–428

Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P. and Watson, R. (2003). The future for fisheries. *Science* 302(5649), 1359–1361

PBL (2012). *Roads from Rio+20: Pathways to achieve global sustainability goals by 2050.* Van Vuuren, DP and Kok, MTJ (eds.). Den Haag/Bilthoven, the Netherlands, PBL Netherlands Environmental Assessment Agency.

PBL (2009). *Growing within Limits*. Netherlands Environmental Assessment Agency, Bilthoven

Pereira, H.M., Leadley, P.W., Proença, V., Alkemade, R., Scharlemann, J.P.W., Fernandez-Manjarrés, J.F., Araújo, M.B., Balvanera, P., Biggs, R., Cheung, W.W.L., Chini, L., Cooper, D., Gilman, E.L., Guénette, S., Hurtt, G.C., Huntington, H.P., Mace, G.M., Oberdorff, T., Revenga, C., Rodrigues, P., Scholes, R.J., Sumaila, U.R. and Walpole, M. (2010). Scenarios for global biodiversity in the 21st century. *Science* 330(6010), 1496–1501

Petermann, J.S., Fergus, A.J.F., Turnbull, L.A. and Schmid, B. (2008). Janzen-Connell effects are widespread and strong enough to maintain diversity in grasslands. *Ecology* 89, 2399–2406

Phalan, B., Onial, M., Balmford, A. and Green, R.E. (2011). Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science* 333, 1289–1291

Pinnegar, J.K., Viner, D., Hadley, D., Dye, S., Harris, M., Berkout, F. and Simpson, M. (2006). *Alternative Future Scenarios for Marine Ecosystems: Technical Report*. Cefas, Lowestoft

Power, A.G. (2010). Ecosystem services and agriculture: tradeoffs and synergies. *Philosophical Transactions of the Royal Society B* 365, 2959–2971

Prüss-Üstün, A. and Corvalán, C. (2006). *Preventing Diseases Through Healthy Environments: Towards an Estimate of the Environmental Burden of Disease*. World Health Organization, Geneva

Prüss-Üstün, A., Kay, D., Fewtrell, L. and Bartram, J. (2004). Unsafe water, sanitation and hygiene. In *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors* (eds. Ezzati, M., Lopez, A.D., Rodgers, K.B. and Murray, C.J.L.). World Health Organization, Geneva

Purcell, S.W., Mercier, A., Conand, C., Hamel, J.-F., Toral-Granda, M.V., Lovatelli, A. and Uthicke, S. (2011). Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. *Fish and Fisheries* (forthcoming)

Rands, M.R.W., Adams, W.M., Bennun, L., Butchart, S.H.M., Clements, A., Coomes, D., Entwistle, A., Hodge, I., Kapos, V., Scharlemann, J.P.W. and Vira, B. (2010). Biodiversity conservation: challenges beyond 2010. *Science* 329, 1298–1303

Revi, A., Prakash, S., Mehrotra, R., Bhat, G.K., Gupta, K. and Gore, R. (2006). Goa 2100: the transition to a sustainable RUrban design. *Environment and Urbanization* 18(1), 51–65

Riahi, K., Grübler, A. and Nakicenovic, N. (2007). Scenarios of long-term socio-economic and environmental development under climate stabilization. *Technological Forecasting and Social Change* 74(7), 887–935

Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffman, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S.L., Secrest, W., Wallace, G.E., Berlin, K., Bielby, J., Burgess, N.D., Church, D.R., Cox, N., Knox, D., Loucks, C., Luck, G.W., Master, L.L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G.E., Shire, G., Strand, H., Wettengel, W. and Wikramanayake, E. (2005). Pinpointing and preventing imminent extinctions. *Proceedings of the National Academy of Sciences of the United States of America* 102(51), 18497–18501

Rihani, S. (2002). *Complex Systems Theory and Development Practice: Understanding Non-Linear Realities*. Zed Books, New York

Robin, S., Wolcott, R. and Quintela, C.E. (2003). *Perverse Subsidies and the Implications for Biodiversity: A Review of Recent Findings and the Status of Policy Reforms.* Proceeding of the 5th World Parks Congress: Sustainable Finance Stream, September 2003, Durban, South Africa. http://www.conservationfinance.org/guide/WPC/WPC_documents/Overview_PanB_Wolcott_v2.pdf

Robinson, J. (2004). Squaring the circle? Some thoughts on the idea of sustainable development. *Ecological Economics* 48(4), 369–384

Robinson, R.A. and Sutherland, W.J. (2002). Post-war changes in arable farming and biodiversity in Great Britain. *Journal of Applied Ecology* 39, 157–176

Rodríguez, J.P., Beard, T.D., Bennett Jr., E.M., Cumming, G.S., Cork, S., Agard, J., Dobson, A.P. and Peterson, G.D. (2006). Trade-offs across space, time, and ecosystem services. *Ecology and Society* 11(1). http://www.ecologyandsociety.org/vol11/iss1/art28/

Rose, S.K, Ahammad, H, Eickhout, B., Fisher, B., Kurosawa, A., Rao, S., Riahi, K. and van Vuuren, D.P. (2012). Land-based mitigation in climate stabilization. *Energy Economics* 34(1), 365–380

Rosegrant, M.W., Ringler, C., Sulser, T.B., Ewing, M., Palazzo, A., Zhu, T., Nelson, G.C., Koo, J., Robertson, R., Msangi, S. and Batka, M. (2009). *Agriculture and Food Security under Global Change: Prospects for 2025/2050.* Prepared for the Strategy Committee of the CGIAR. International Food Policy Research Unit (IFPRU), Washington, DC. http://alliance.cgxchange.org/documentation-for-the-development-of-the-cgiar-strategy-and-mega-programs/SRF_IMPACT10-10-09c.pdf

Rosegrant, M.W., Ringler, C., Msangi, S., Sulser, T.B., Zhu, T. and Cline, S.A. (2008). *International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model Description*. International Food Policy Research Unit (IFPRU), Washington, DC. http://www.ifpri.org/sites/default/files/publications/impactwater.pdf

Rosegrant, M.W., Leach, N. and Gerpacio, R.V. (1999). Alternative futures for world cereal and meat consumption. *Proceedings of the Nutrition Society* 58, 219–234

Rotterdam Convention (1998). *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade*. http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

Royal Swedish Academy of Sciences (2011). *The Stockholm Memorandum. Tipping the Scales towards Sustainability*. 3rd Nobel Laureate Symposium on Global Sustainability, Stockholm, 16–19 May 2011. Royal Swedish Academy of Sciences, Stockholm

Ruitenbeek, J. and Cartier, C. (2001). *The Invisible Wand: Adaptive Co-Management as an Emergent Strategy in Complex Bio-economic Systems*. Centre for International Forestry Research, Bogor

Sala, O.E., Chapin III, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., LeRoy Poff, N., Sykes, M.T., Walker, B.H., Walker, M. and Wall, D.H. (2000). Global biodiversity scenarios for the year 2100. *Science* 287(5459), 1770–1774

Schmitt-Olabisi, L.K., Kapuscinski, A.R., Johnson, K.A., Reich, P.B., Stenquist, B. and Draeger, K.J. (2010). Using scenario visioning and participatory system dynamics modeling to investigate the future: lessons from Minnesota 2050. *Sustainability* 2(8), 2686–2706

Schneider, C., Flörke, M., Geerling, G., Duel, H., Grygoruk, M. and Okruszko, T. (2011). The future of European floodplain wetlands under a changing climate. *Journal of Water and Climate Change* 2(2–3), 106–122

Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. and Yu, T.-H. (2008). Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science* 319, 1238–1240

Smeets, E.W.M., Bouwman, A.F., Stehfest, E., van Vuuren, D.P. and Posthuma, A. (2009). The contribution of N_2O emissions to the greenhouse gas balance of first-generation biofuels. *Global Change Biology* 15, 1–23. doi: 10.1111/j.1365-2486.2008.01704.x

Smith, S.J. (2005). Income and pollutant emissions in the ObjECTS MiniCAM model. *Journal of Environment and Development* 14(1), 175–196

Smith, P., Gregory, P.J., van Vuuren, D., Obersteiner, M., Havlík, P., Rounsevell, M., Woods, J., Stehfest, E. and Bellarby, J. (2010). Competition for land. *Philosophical Transactions of the Royal Society B* 365(1554), 2941–2957

Sohngen, B., Mendelsohn, R. and Sedjo, R. (2001). A global model of climate change impacts on timber markets. *Journal of Agricultural and Resource Economics* 26(2), 326–343

Speth, J.G. (2005). *Red Sky at Morning: America and the Crisis of the Global Environment*. Yale University Press, New Haven, CT

Srinivasan, U.T., Watson, R. and Sumaila, U.R. (2012). Global fisheries losses at the exclusive economic zone level, 1950 to present. *Marine Policy* 36, 544–549

Steffen, W., Sanderson, R.A., Tyson, P.D., Jäger, J., Matson, P.A., Moore III, B., Oldfield, F., Richardson, K., Schellnhuber, H.-J., Turner, B.L. and Watson, R.J. (2005). *Global Change and the Earth System*. Springer, Berlin

Stehfest, E., Bouwman, L., van Vuuren, D.P., den Elzen, M.G.J., Eickhout, B. and Kabat, P. (2009). Climate benefits of changing diet. *Climatic Change* 95(1–2), 83–102

Stern, D.I. (2003). *The Environmental Kuznets Curve*. International Society for Ecological Economics/ Internet Encyclopedia of Ecological Economics. http://www.ecoeco.org/pdf/stern.pdf

Stiglitz, J.E., Sen, A. and Fitoussi, J.-P. (2009). *Report by the Commission on the Measurement of Economic Performance and Social Progress*. Technical Report September 2009. http://www.stiglitz-sen-fitoussi.fr

St. Louis, V.L., Kelly, C.A., Duchemin, E., Rudd. J.W.M. and Rosenberg, D.M. (2000). Reservoir surfaces as sources of greenhouse gases to the atmosphere: a global estimate. *BioScience* 50, 766–775

Stockholm Convention (2009). *Stockholm Convention on Persistent Organic Pollutants (POPs) – as Amended in 2009*. http://chm.pops.int/Convention/Media/Publications/tabid/506/language/en-US/Default.aspx (accessed 20 November 2011)

Strauss, A.L. (1987). *Qualitative Analysis for Social Scientists*. Cambridge University Press, Cambridge

Swanson, D.A. and Bhadwal, S. (eds). (2009). *Creating Adaptive Policies: A Guide for Policy-making in an Uncertain World*. Sage Publications, New Delhi/IDRC, Ottawa

Swanson, D.A., Barg, S., Tyler, S., Venema, H.D., Tomar, S., Bhadwal, S., Nair, S., Roy, D. and Drexhage, J. (2010). Seven tools for creating adaptive policies. *Technological Forecasting and Social Change* 77, 924–939

Swart, R.J., Raskin, P. and Robinson, J. (2004). The problem of the future: sustainability science and scenario analysis. *Global Environmental Change* 14(2004), 137–146

Tabara J.D. and Pahl-Wostl, C. (2007). Sustainability learning in natural resource use and management. *Ecology and Society* 12(2), 3

Takács-Sánta, A. (2004). The major transitions in the history of human transformation of the biosphere. *Human Ecology Review* 11(1), 51–66

Techera, E.J. (2011). Convention for the Prohibition of Fishing with Long Drift Nets in the South Pacific. In *Encyclopaedia of Sustainability. Vol. 3: The Law and Politics of Sustainability* (eds. Bossellman, K., Fogel, D. and Ruhl, J.B.). Berkshire Publishing, Great Barrington

Ten Brink, B., van der Esch, S., Kram, T., van Oorschot, M., Alkemade, J.R.M., Ahrens, R., Bakkenes, M., Bakkes, J.A., van den Berg, M., Christensen, V., Janse, J., Jeuken, M., Lucas, P., Manders, T., van Meijl, H., Stehfest, E., Tabeau, A., van Vuuren, D. and Wilting, H. (2010). *Rethinking Global Biodiversity Strategies: Exploring Structural Changes in Production and Consumption to Reduce Biodiversity Loss*. Netherlands Environmental Assessment Agency (PBL), Bilthoven

Thornton, P.K. (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B* 365, 2853–2867

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature* 418, 671–677

TMT (2011*). Truckee Meadows Tomorrow: Engaging the Community, Measuring Our Progress*. http://www.truckeemeadowstomorrow.org/

UN (2000). *United Nations Millennium Declaration*. Resolution adopted by the General Assembly. United Nations, New York

UNCED (1992). *Agenda 21*. United Nations Convention on Environment and Development http://www.un.org/esa/sustdev/documents/agenda21/english/Agenda21.pdf

UNCLOS (1982). *The United Nations Convention on the Law of the Sea*. Montego Bay

UNDESA (2011). *World Population Prospects: The 2010 Revision*. Population Division, United Nations Department of Economic and Social Affairs. http://esa.un.org/unpd/wpp/index.htm

UNDESA (2009). *World Population Prospects: The 2008 Revision*, Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat.

UNDP (2009). *Human Development Report 2009. Overcoming Barriers: Human Mobility and Development.* United Nations Development Programme, New York

UNEP (2011a). *Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers.* http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_SDM.pdf

UNEP (2011b). *Resource Efficiency: Economics and Outlook for Asia and the Pacific. Key Messages and Highlights.* United Nations Environment Programme, Nairobi. http://www.unep.org/roap/Portals/96/REEO_AP_Key.pdf

UNEP (2011c). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. United Nations Environment Programme, Nairobi. http://www.unep.org/greeneconomy/GreenEconomyReport/tabid/29846/Default.aspx (accessed 17 November 2011)

UNEP (2010a). *Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 1.5 or 2 Degrees C? Emissions Gap Report*. United Nations Environmental Programme, Nairobi

UNEP (2010b). *Global Environment Outlook: Latin America and the Caribbean – GEO LAC 3*. United Nations Environment Programme, Regional Office for Latin America and the Caribbean, Panama City

UNEP (2007). *Global Environment Outlook 4*. United Nations Environment Programme, Nairobi

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

UNESCO (2011). *UN Decade of Education for Sustainable Development (2005–2014*). United Nations Educational, Scientific and Cultural Organization, Paris. http://www.unesco.ca/en/interdisciplinary/ESD/default.aspx

UNESCO (2009). *Water in a Changing World. The United Nations World Water Development Report 3.* United Nations Educational, Scientific and Cultural Organization, Paris. http://webworld.unesco.org/water/wwap/wwdr/wwdr3/pdf/WWDR3_Water_in_a_Changing_World.pdf

UNESCO (2006). *Water – A Shared Responsibility*. *The United Nations World Water Development Report 2*. United Nations Educational, Scientific and Cultural Organization, Paris. http://www.unesco.org/water/wwap/wwdr/wwdr2/pdf/wwdr2_front_matter.pdf

UNFCCC (2010). *Report of the Conference of the Parties on Its Sixteenth Session*. United Nations Framework Convention on Climate Change, Cancun. http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2

UNFCCC (1992). *United Nations Framework Convention on Climate Change.* FCCC/INFORMAL/84 GE.05-62220 (E) 200705. http://unfccc.int/resource/docs/convkp/conveng.pdf

UNCED (1992a). *Rio Declaration on Environment and Development*. United Nations Convention on Environment and Development, Rio de Janeiro

US-GAO (2011). *Key Indicator Systems: Experiences of Other National and Subnational Systems Offer Insights for the United States*. United States Government Accountability Office. http://www.gao.gov/new.items/d11396.pdf

Van Beers, C. and van den Bergh, J.C.J.M. (2009). Environmental harm of hidden subsidies: global warming and acidification. *Ambio* 38(6), 339–341

Van Beers, C. and van den Bergh, J.C.J.M. (2001). Perseverance of perverse subsidies and their impact on trade and environment. *Ecological Economics* 36(3), 475–486

Van Ruijven, B.J., Schers, J. and van Vuuren, D.P. (2012). Model-based scenarios for rural electrification in developing countries. *Energy* 38, 386–397

Van Ruijven, B., Urban, F., Benders, R.M.J., Moll, H.C., van der Sluijs, J.P., de Vries, B. and van Vuuren, D.P. (2008). Modeling energy and development: an evaluation of models and concepts. *World Development* 36(12), 2801–2821

Van Vuuren, D.P., Riahi, K., Moss, R., Edmonds, J., Thomson, A., Nakicenovic, N., Kram, T., Berkhout, F., Swart, R., Janetos, A., Rose, S.K. and Arnell, N. (2012). A proposal for a new scenario framework to support research and assessment in different climate research communities. *Global Environmental Change* 22, 21–35

Van Vuuren, D.P. and Riahi, K. (2011). The relationship between short-term emissions and long-term concentration targets – a letter. *Climatic Change* 104(3–4), 793–801

Van Vuuren, D.P., Kok, M., Girod, B., Lucas, P., de Vries, H.J.M. and (2011a). Scenarios in global environmental assessments: key characteristics and lessons for future use. *Global Environmental Change* (submitted)

Van Vuuren, D.P., Bellevrat, E., Kitous, A. and Isaac, M. (2010). Bio-energy use and low stabilization scenarios. *The Energy Journal* 31 (Special Issue 1), 193–222

Van Vuuren, D.P., Meinshausen, M., Plattner, G.K., Joos, F., Strassmann, K.M., Smith, S.J., Wigley, T.M.L., Raper, S.C.B., Riahi, K., de la Chesnaye, F., den Elzen, M.G.J., Fujino, J., Jiang, K., Nakicenovic, N., Paltsev, S. and Reilly, J.M. (2008a). Temperature increase of 21st century mitigation scenarios. *Proceedings of the National Academy of Sciences of the United States of America* 105(40), 15258–15262

Van Vuuren, D.P., Ochola, W.O., Riha, S., Giampietro, M., Ginzo, H., Henrichs, T., Hussain, S., Kok, K., Makhura, M., Mirza, M., Palanisami, K.P., Ranganathan, C.R., Ray, S., Ringler, C., Rola, A., Westhoek, H., Zurek, M., Avato, P., Best, G., Birner, R., Cassman, K., de Fraiture, C., Easterling, B., Idowu, J., Pongali, P., Rose, S., Thornton, P.K. and Wood, S. (2008b). Outlook on agricultural change and its drivers. In *Agriculture at a Crossroads* (eds. McIntyre, B.D., Herren, H.R., Wakhungu, J. and Watson, R.T.). pp.255–305. Island Press, Washington, DC

Van Vuuren, D.P., den Elzen, M.G.J., Lucas, P.L., Eickhout, B., Strengers, B.J., van Ruijven, B., Wonink, S. and van Houdt, R. (2007). Stabilizing greenhouse gas concentrations at low levels: An assessment of reduction strategies and costs. *Climatic Change* 81, 119–159

Van Vuuren, D.P., Sala, O.E. and Pereira, H.M. (2006). The future of vascular plant diversity under four global scenarios. *Ecology and Society* 11(2), 25

Venkataraman, C., Sagar, A.D., Habib, G., Lam, N. and Smith, K. (2010). The Indian National Initiative for Advanced Biomass Cookstoves: the benefits of clean combustion. *Energy for Sustainable Development* 14, 63–72

Von Braun, J. and Meinzen-Dick, R. (2009). *Land Grabbing by Foreign Investors in Developing Countries – Risks and Opportunities.* IFPRI Policy Brief No. 13. International Food Policy Research Institute, Washington, DC

Vörösmarty, C.J., Green, P., Salisbury, J. and Lammers, R. (2000). Global water resources: vulnerability from climate change and population growth. *Science* 289, 284–288

Walker, W.E. and Marchau, V.A.W.J. (2003). Dealing with uncertainty in policy analysis and policy-making. *Integrated Assessment Journal* 4(1), 1–4

Walker, B.H., Gunderson, L.H., Kinzig, A.P., Folke, C., Carpenter, S.R. and Schultz, L. (2006). A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society* 11(1), 13. http://www.ecologyandsociety.org/vol11/iss1/art13/

WBCSD (2010). *Vision 2050*. World Business Council for Sustainable Development, Geneva

WBCSD (2006). *Business in the World of Water: WBCSD Water Scenarios to 2025*. World Business Council for Sustainable Development, Geneva

WBGU (2011). *World in Transition. A Social Contract for Sustainability*. Summary for Decision-Makers. German Advisory Council on Global Change (WBGU). WBGU Secretariat, Berlin

WCED (1987). *Our Common Future: Report of the World Commission on Environment and Development*. World Commission on Environment and Development. Oxford University Press, New York

WHO (2006). WHO *Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005*. World Health Organization, Geneva

WHO/UNICEF (2010). *Progress on Sanitation and Drinking Water: 2010 Update*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. World Health Organization, Geneva and United Nations Children's Fund, New York

Wise, M., Calvin, K., Thomson, A., Clarke, L., Bond-Lamberty, B., Sands, R., Smith, S.J., Janetos, A. and Edmonds, J. (2009). Implications of limiting CO_2 concentrations for land use and energy. *Science* 324(5931), 1183–1186

World Bank (2008). *Global Monitoring Report – MDGs and the Environment: Agenda for Inclusive and Sustainable Development.* World Bank, Washington, DC

World Bank/IMF (2011). *Global Monitoring Report 2011: Improving the Odds of Achieving the MDGs*. World Bank, Washington, DC

WSSD (2002). *Johannesburg Plan of Implementation*. World Summit on Sustainable Development. http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POIToc.htm

Worm, B., Hilborn, R., Baum, J., Branch, T., Collie, J., Costello, C., Fogarty, M., Fulton, E., Hutchings, J., Jennings, S., Jensen, O., Lotze, H., Mace, P., McClanahan, T., Minto, C., Palumbi, S., Parma, A., Ricard, D., Rosenberg, A., Watson, R. and Zeller, D. (2009). Rebuilding global fisheries. *Science* 325, 578

Wunder, S. (2007). The efficiency of payments for environmental services in tropical conservation. *Conservation Biology* 21(1), 48–58