# Chapter 5

## Towards a sustainable future

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The essays in this book draw attention to the urgency of the sustainability challenge, which in the past decade has been brought to the forefront by the growing understanding of the nature and impacts of anthropogenic changes in atmospheric chemistry. They highlight some of the ways in which we can harness technology, human ingenuity and innovation to address critical sustainability issues particularly in managing the energy demands of the twenty-first century.

In this essay we present a broad perspective on sustainability to look at the wider set of direct and indirect pressures that humans are placing on the planet's renewable natural resources and biodiversity, drawing on data presented in the *2008 Living Planet Report* (WWF *et al.,* 2008). The Living Planet Report presents a stark picture of how humanity is living beyond our means as our consumption of natural resources exceeds their regenerative capacity and of the resulting decline in the Earth's biodiversity. If current trends are allowed to continue, by the mid 2030s we would need two planets to meet the demands we place on the planet's natural capital.

So what will the world look like in 2050? We believe that if we continue our current consumption patterns and development pathways, humankind may be facing ecological collapse on an unprecedented scale due to degradation of natural capital and loss in ecosystem services. Jared Diamond has explained how 'ecocide' – the loss in vital ecosystem services – has led to the collapse of past civilisations that were unable to adapt to environmental changes, whether man-made or natural (Diamond, 2006). In the modern world, examples of how we are eroding the planet's natural capital through overuse and misuse of natural resources are all around us. With widespread starvation, reduced life expectancy, environmental insecurity, and loss of social capital the consequences of ecological collapse at a global scale would eclipse our current concerns about rising food prices, water shortages and increased environmental risk.

Humanity has the capability to reverse the current trajectory of ecological decline, however, and to shape a future where humans live in harmony with nature. Such a 'Great Transformation' (see Potsdam Memorandum, this volume) will require bold action at a global scale to reduce our footprint and maintain or increase the resilience of natural systems. In this essay we will point out some of the major steps the global community should take in order to avoid a global environmental collapse.

## Challenges to sustainability

The *2008 Living Planet Report,* produced by the World Wide Fund for Nature (WWF) with its partners the Global Footprint Network and the Zoological Society of London (WWF *et al.,* 2008), provides a vivid picture of the path we are on. It offers three insights that define the challenge of sustainability. The first and most fundamental is the sheer volume of humanity's consumption – we are devouring the world's natural capital to the point where we are endangering our future prosperity. The second insight is interdependence – almost every country now depends upon the resources of others; better management of the planet's natural resources has thus become a shared responsibility. Finally, the *Report* charts the challenge of decoupling development and footprint – the relationships among human well-being, income, population, and sustainability.

### *The ecological credit crunch*

The *2008 Living Planet Report* offers two measures of sustainability. The *Ecological Footprint* measures our demand on the biosphere in terms of the area of biologically productive land and sea required to provide the resources we use and to absorb our waste. A country's footprint is calculated on an annual basis as the sum of the cropland, grazing land, forest and fishing grounds required to produce the food, fibre and timber it consumes, to sequester the carbon dioxide it emits from energy use, and to provide space for its infrastructure.

The Ecological Footprint can be compared to *biocapacity,* a measure of the capacity of ecosystems, including agro-ecosystems, to produce useful biological materials and to absorb waste products in a given year. In 2005, the global Ecological Footprint was 17.5 billion global hectares (gha), or 2.7 gha per person (a global hectare is a hectare with world-average capacity to produce resources and absorb wastes, Ewing *et al.,* 2008). On the supply side, the total biocapacity was 13.6 billion gha, or 2.1 gha per person, made up of cropland, grazing land, forest and fishing grounds. Our demands thus exceeded the planet's regenerative capacity by over 30 % (compared to 25 % in 2003). The growth of Ecological Footprint over time is shown in Figure 1a, where one planet represents the biocapacity of the planet based on contemporaneous management schemes and extraction technologies.

The second measure is the Living Planet Index (LPI), which tracks the populations of 1686 vertebrate species across all regions of the world (Collen *et al.,* 2009). It indicates that global biodiversity has declined by nearly 30 % over just the past 35 years (see Fig. 1b). The LPI shows that wild species and natural ecosystems are under pressure across all biomes and regions. As human appropriation of the planet's resources increases, so we can expect increased impacts on the living organisms whose abundance in ecosystems is critical in maintaining habitat stability and in providing the ecosystem services that underpin human well-being.

So what does the future hold? Figure 2 projects the growth in the Ecological Footprint up to 2050 based on a set of moderate scenarios for future demands on renewable resources. Based on this, our annual demands on the planet's regenerative capacity will exceed that capacity by 100 % by the mid 2030s, or, in other words,

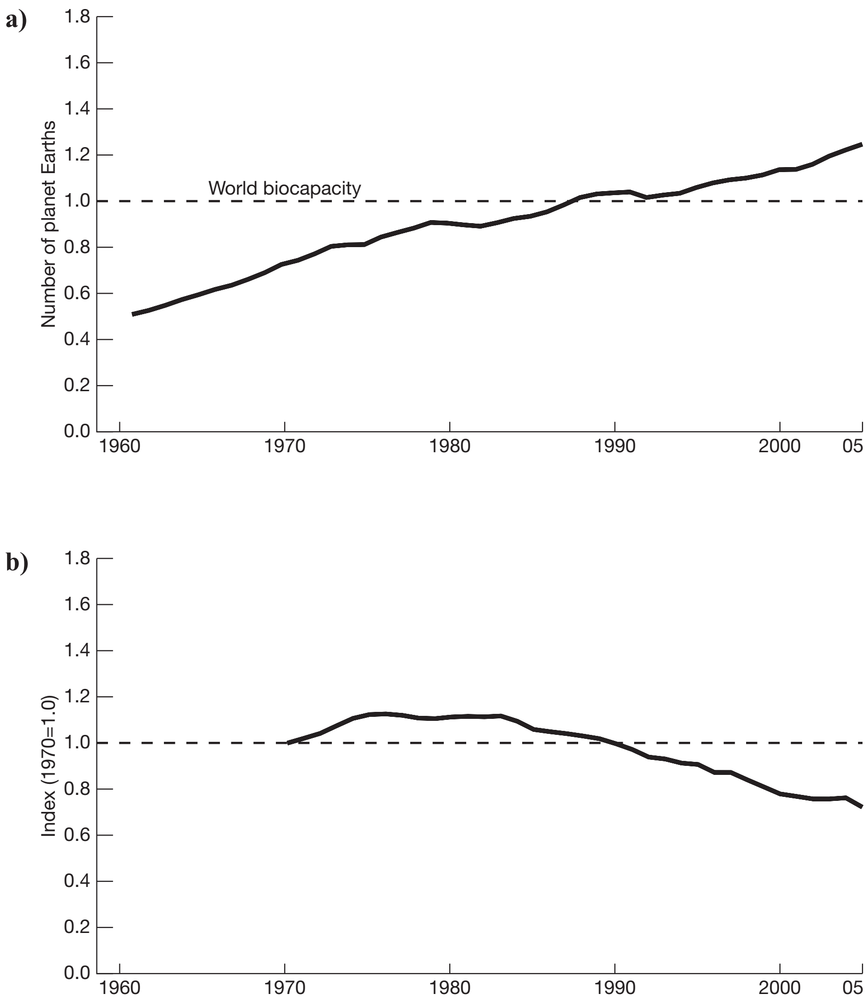


**Fig. 1.** Evolution in (a) humanity's Ecological Footprint and (b) the Living Planet Index. Changes in footprint are expressed in number of planet Earths where one planet represents the biocapacity available in a given year. (*Source:* WWF *et al.,* 2008)

we would need two planets to keep up with our demands for natural resources and waste assimilation.

While appealing in its simplicity, this business-as-usual scenario is conservative in that it assumes only very limited feedback between anthropogenic pressures and future bio-productivity. In practice, excessive demands on natural systems – measured as overshoot in footprint terms and shown as accumulated ecological debt in Figure 2 – are already compromising and will continue to compromise the planet's regenerative capacity.

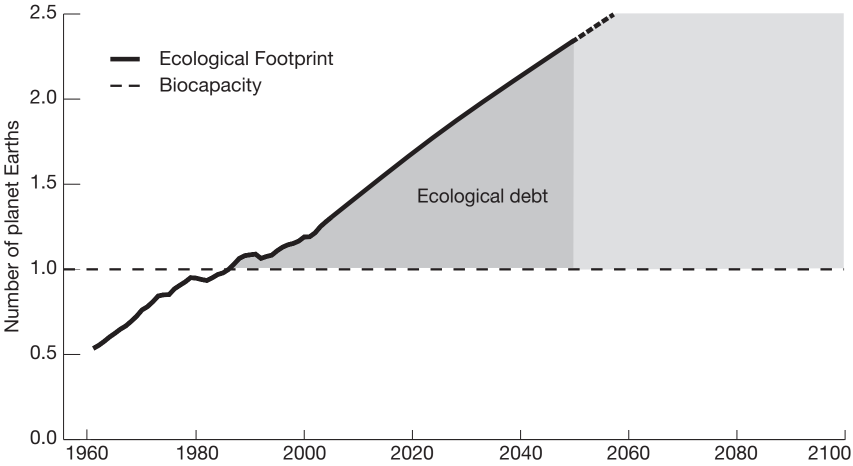


**Fig. 2.** 2050 scenario for ecological overshoot based on projected carbon emissions (Nacicenovic and Swart, 2000), moderate population growth (United Nations Population Division, 2006), utilization of food, fibre and forest products (FAO, 2002; FAO, 2006), and fisheries (Worm *et al.,* 2006). Changes in footprint are expressed in number of planet Earths where one planet represents the biocapacity available in a given year. (*Source:* WWF *et al.,* 2008)

We can already see how the direct impacts of resource over-extraction, ranging from fisheries collapse (e.g. Worm *et al.,* 2006) to deforestation, are undermining ecosystem services. A simple analogy could be pulled up between drawing on natural capital and drawing on capital in the bank, but in reality things are not so straightforward. For example, there are significant time lags between cause and effect for many pressures, the effects of changing atmospheric chemistry on ocean chemistry being a classic example. In addition, responses to environmental pressures are frequently synergistic and non-linear; scientists talk of thresholds, tipping points and discontinuities (e.g. Folke *et al.,* 2002). Extensive changes in marine ecosystem structure as a result of fisheries pressure (e.g. Sherman, 1994; Worm *et al.,* 2006) and arctic amplification with near-surface temperature rises in the region nearly two times the global average (e.g. Graversen *et al.,* 2008) are examples of such complexity.

Furthermore, not all anthropogenic pressures are readily measured in Ecological Footprint terms. One notable omission is the discharge of pollutants other than carbon dioxide, including other greenhouse gases, toxic chemicals and radioactivity. Similarly, conventional footprint accounting does not take measure of the now pervasive but indirect environmental effects of agricultural production, ranging from soil erosion to hydrological changes and biodiversity loss, nor of factors which may limit biocapacity, such as water availability, an issue of growing concern in the face of climate change (IPCC, 2007). The contribution of such factors to overshoot will eventually be seen in national footprint accounts as results of declines in biocapacity. More sophisticated projections of overshoot are now being developed using dynamic footprint accounting which attempts to incorporate the influence of land use and disturbance, species diversity, and pollution (Lenzen *et al.,* 2007).

### *An interconnected world*

Just as conventional trade statistics describe the growth and changing patterns of international trade, ecological and water footprint analyses are revealing the way in which we draw on the environmental assets of other countries and regions to support our consumption patterns. Ecological Footprint accounts show that countries are increasingly relying on one another's biocapacity to support their preferred patterns of consumption. In 1961 the total footprint of goods and services traded internationally was 8 % of humanity's total footprint. By 2005, this had risen to more than 40 % of a much greater footprint. The imports of high-income countries averaged 61 % of their total consumption footprint.

We are also increasingly relying on the water supplies of other countries to support our lifestyles. The water footprint of a country is the total volume of water used globally to produce the goods and services consumed by its inhabitants (Chapagain and Hoekstra, 2004; Hoekstra and Chapagain, 2007). Part of this footprint, the external water footprint, results from consumption of imported goods, or in other words, water that is used in the country which produces these goods. Worldwide, the external water footprint accounts for 16 % of the average person's water footprint, though this varies enormously within and between countries. Twenty-seven countries have an external water footprint which accounts for more than half of their total water use.

As we externalize our water footprint and Ecological Footprint we also externalize the environmental impact associated with the goods and services we consume. A significant part of the Ecological Footprint is made up of carbon emissions that enter the global atmosphere, but food and fibre imports represent direct pressures on the ecological assets of other countries. The impact of the water footprint depends on where and when water is extracted. Water use in an area where water is plentiful is unlikely to have an adverse effect on people or the environment, but the same level of water use in an area experiencing water shortages may result in the drying up of rivers and the destruction of ecosystems, with associated loss of ecosystem services, biodiversity and livelihoods.

The global commodity markets and agricultural policies that sustain our consumption patterns generally overlook the environmental, economic and social costs to producer countries and the global environment. Production of palm oil for margarines and biscuits, soy production for animal fodder, shrimp farming, timber trade and biofuels are driving the destruction of some of the world's most valuable and biodiverse ecosystems.

### *Footprint, income and development*

Sustainable development has been defined as 'improving the quality of human life while living within the carrying capacity of supporting ecosystems' (IUCN *et al.,* 1991). One can see the difficulty of this challenge by mapping development progress against growth in footprint (WWF *et al.,* 2006).

Countries' progress towards sustainability can be assessed using the Human Development Index (HDI) as a measure of quality of life and Ecological Footprint as a measure of demand on supporting ecosystems (see Fig. 3). An HDI value of more than 0.8 is considered to be 'high-human development'. A footprint to global biocapacity per capita ratio of less than one is sustainable insofar as that it is replicable at a global level.

Figure 3 illustrates that as regions develop their footprint quickly becomes unsustainable. In fact, no region meets both criteria for sustainable development. Asia Pacific and Africa have been successful in achieving significant increases in HDI while still living within the available biocapacity per capita, but neither region meets the criterion for human well-being. North America and Western Europe have continued to achieve gains in human development, but their footprints soared disproportionately over the same period and are now several times greater than sustainable levels. In 2003, just one country met both criteria for sustainable development (Moran *et al.,* 2008).

Figure 4 shows how relative contribution of population and per capita footprint in driving overall national footprint has evolved in countries in different income categories (based on the World Bank's 2005 categorization). On a global scale, both population and average per capita footprint have increased since 1961. Since around 1970, however, population growth has been the principal driver in the growth of total footprint. Despite advances in agricultural productivity, the more than doubling of world population between 1961 and 2005 has its corollary in the halving of the average available biocapacity per capita.

The principal driver of increased footprint in high-income countries has been the growth in per person footprint, which grew by 76% from 1961 to 2005. The 15% of the world's population that live in high-income countries account for 36% of humanity's 2005 total footprint. In contrast, the principal driver of footprint in low and medium-income countries, as well as at a global scale, has been population. Population in low-income countries nearly trebled between 1961 and 2005 while in

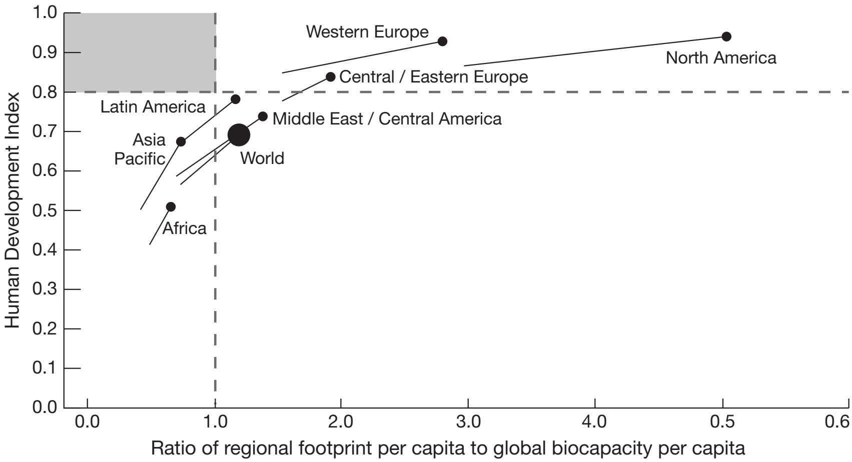


**Fig. 3.** Human Development Index (HDI) and Ecological Footprint. Points indicate values for 2003, and grey trailing lines show trends from 1975 to 2003. The shaded box represents a domain where both criteria for 'sustainable development' are met. (*Source:* Moran *et al.,* 2008)

middle-income countries it more than doubled. The per capita footprint of low-income countries actually decreased over this period while middle-income countries saw a 21% increase.

These data speak for themselves. Neither the rapid population growth nor the reckless consumption seen in different parts of the world are sustainable and both issues deserve our attention.

Clearly, a key challenge for this century is that faced by emerging economies such as China. China's per capita footprint and population roughly doubled between 1961 and 2005 producing more than a four-fold increase in its total Ecological Footprint. While population growth has remained steady, growth in per capita footprint has escalated in recent years and has overtaken population as the principal factor driving national footprint growth. China's HDI grew from 0.53 in 1975 to 0.77, at the threshold of high human development, in 2005. Will China now join the ranks of countries like Korea whose footprint growth has accelerated relative to its gains in HDI or will it find a 'third way' (see Potsdam Memorandum, this volume)? The challenge here is that of decoupling human development from footprint: how do we enable development without costing the Earth?

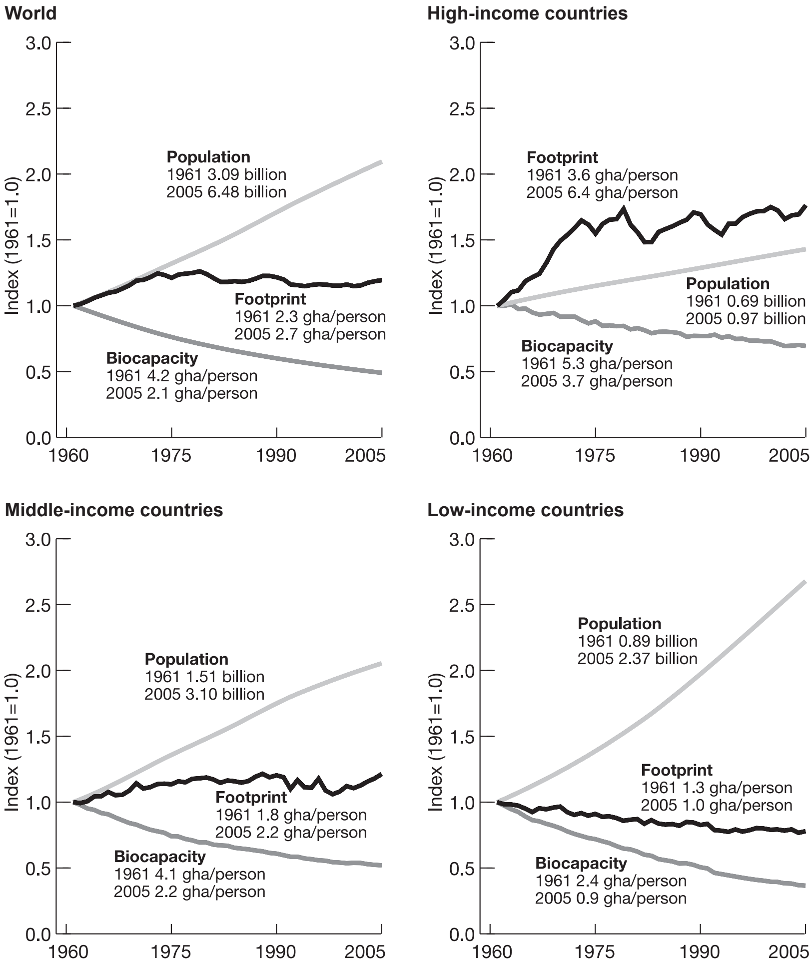


**Fig. 4.** Evolution of per capita footprint, biocapacity and population between 1961 and 2005 for the world and for high-income, middle-income and low-income countries. (*Source:* WWF *et al.,* 2008)

## Turning the tide: towards sustainability

### *An end to overshoot*

The above paragraphs have highlighted some aspects of the multi-faceted challenge we face in finding the 'third way' between environmental destabilization and persisting underdevelopment that the Potsdam Nobel Laureate Symposium was concerned with. The fundamental imperative for achieving sustainability is to ensure that humanity's global footprint stays within the Earth's capacity to sustain life, while achieving an acceptable standard of living for all.

Figure 5 charts a conceptual return to sustainability where humanity's footprint is reduced over the next three decades to fall within the planet's biocapacity. Instead of accumulating ecological debt we would maintain an ecological reserve, providing a buffer against environmental variability and shocks.

In the following paragraphs we present a two-pronged approach to maintaining and restoring the ecosystem services on which humanity depends, building on this conceptual framework of Ecological Footprint, biocapacity and overshoot but extending practical action beyond the metrics included in national footprint accounts.

### *Turning the tide on humanity's footprint*

Humanity's footprint is a product of population, consumption per capita and resource use and waste production intensity. Managing our footprint to sustain our natural capital requires re-examining the nature of the pressures exerted by each of the production sectors that meet our basic food, fibre and timber requirements: forestry, grazing, agriculture and fisheries. It means reconsidering the way we convert some of the world's richest ecosystems into built-up land and redefining the resource-intensive lifestyles that come with city living. And it means curbing the pollution that is overwhelming the assimilative capacity of natural systems and building up a toxic legacy for future generations.

We need to tackle all aspects of our footprint in order to sustain sustainable lifestyles, but one area deserves particular attention. In 2005, energy demands in our homes, industry and transportation represented the largest component of our footprint, with energy production from fossil fuels accounting for nearly 45 % of the global footprint. High-income countries saw a nine-fold growth in the carbon component of their footprint between 1961 and 2005: this is a development pathway the global community cannot afford to see replicated at a global scale. WWF developed a 'Climate Solutions Model' to illustrate how it is technically possible to dramatically reduce climate-threatening emissions from energy services while meeting the needs of both the developing and developed countries in the twenty-first century (see Box).

### *Building resilience*

While we reduce our footprint, we must also find ways to restore the Earth's ability to support us, its biocapacity. Biocapacity can at least theoretically be increased by enhancing either the area of land or water available, or the productivity of those lands or waters.

The major challenge to maintaining biocapacity is the ongoing destabilization of ecosystems and attrition of ecosystem services. A recent study suggests that by

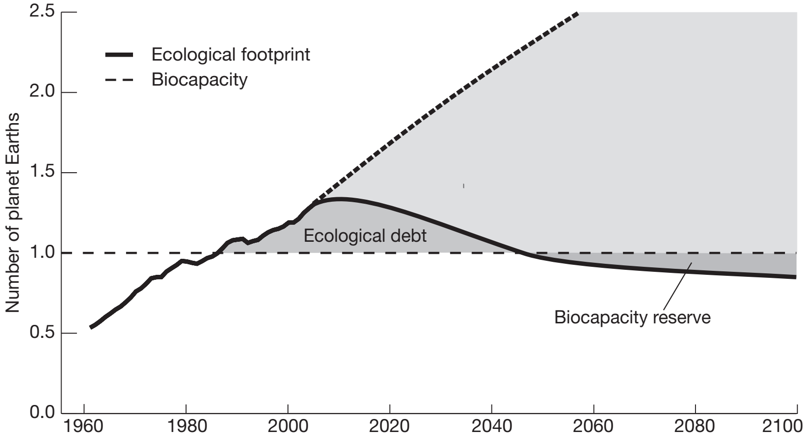


**Fig. 5.** A conceptual return to sustainability. (*Source:* WWF *et al.,* 2008)

**'Climate Solutions' – Meeting the Carbon Challenge**

Inspired by Pacala and Socolow's (2004) energy wedges, the WWF Climate Solutions Model explores whether it is possible to meet the projected 2050 demand for global energy services while achieving significant reductions in global greenhouse gas emissions through a concerted shift to already-available and more sustainable energy resources and technologies (Mallon *et al.,* 2007).

Figure 6 shows an output of the model which achieves reductions of 60–80% in carbon dioxide emissions by 2050 yet meets the three-fold increase in energy services projected in the IPCC's A1B scenario (Nakicenovic and Swart, 2000). The model embraces three parallel strategies:

- Breaking the link between energy services and primary energy production by expansion of energy efficiency in industry, buildings, and all forms of transport to stabilize the overall energy demand by 2025;
- Concurrent growth of low- to zero-emissions technolzogies through the use of renewable energies such as wind, hydro, solar and thermal, and bio-energy;
- An expansion of carbon capture and storage to phase out remaining emissions from conventional fossil fuels used for power and industrial processes.

In addition, an increase in the use of natural gas is proposed as an interim measure, creating a gas bubble which extends from 2010 to 2040.

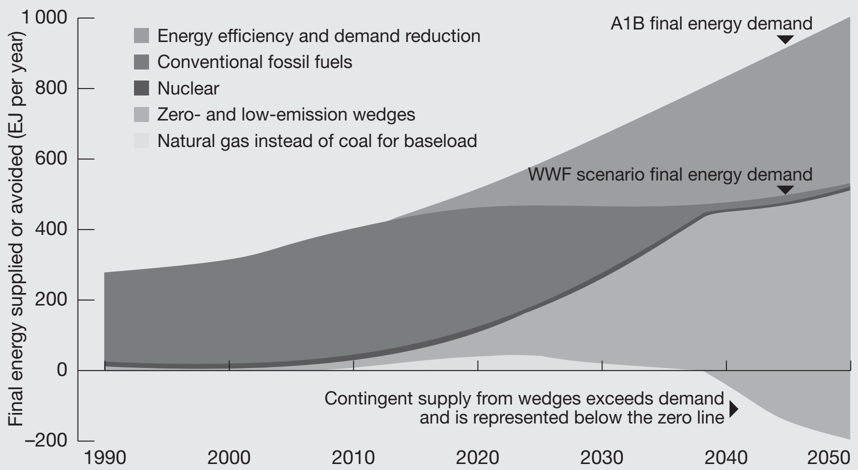


**Fig. 6.** Output of the WWF Climate Solutions Model. Energy efficiency and demand reduction (middle grey) allow the rising demand for energy services to be met by a more or less level supply of energy by 2025. This is complemented by introduction of zero- and low-emission energy supply technologies (light grey). By 2040, fossil-fuel use (dark grey) is reduced to a residual level for applications which are hard to substitute. The scenario provides spare capacity as a contingency, represented by energy supply in light grey shown below the x-axis. (*Source:* Mallon *et al.,* 2007)

2050 biodiversity decline will be the strongest negative influence on biocapacity as a result of the associated impacts on ecosystem functioning (Lenzen *et al.,* 2007). Yet, the global community is not on track to meet even the modest goal of the Convention on Biological Diversity, to reduce by 2010 the rate at which global biodiversity is being lost. Biodiversity conservation and ecosystem restoration can thus be seen as crucial management approaches in the face of growing pressures on ecosystems.

Practical measures to maintain and build resilience include putting in place effective protected area systems, integrated into surrounding landscapes, with the effective participation of local communities. But critical ecosystem services cannot be maintained simply through allocating specific areas to biodiversity conservation. Management and restoration of ecosystems, and measures to reduce direct and indirect pressures on biodiversity all have a role to play, and such efforts need to encompass highly modified landscapes as well as relatively pristine areas.

## A global agenda

In the face of growing human populations, uneven distribution of biocapacity and water resources, and the effects of climate change now being felt, the rising oil and food prices experienced in 2008 provided a glimpse of some of the stark choices that may face decision makers in the decades to come as they try to improve the quality of human life while remaining within the capacity of supporting ecosystems. The Earth simply cannot support the growing demands we are placing on its ecosystems; we are threatening our future prosperity and security.

In the following conclusive paragraphs we will set out four cross-cutting elements of a global agenda to reduce humanity's footprint and build ecosystem resilience.

### *Global action*

We will only meet the challenge of sustainability if we find a way to mobilize global action. The most pressing need is for action to curb humanity's emissions of carbon into the atmosphere – which accounts for nearly half of our Ecological Footprint. Specifically, the transformations of technology and infrastructure needed to achieve the climate solutions outlined above depend on three policy imperatives. These are *strong leadership* to agree on targets, strategies and investments in energy development; *a global effort*, with every country acting in accordance with its local challenges and capacity; and *urgency,* to address the real-world constraints on industrial transition and the risks of becoming locked in to energy-intensive technologies (Mallon *et al,* 2007).

While the specific challenges faced by developed and developing countries differ, the scale and ubiquitous nature of environmental challenges – from global warming to resource depletion – call for a global response for political as well as practical reasons. Looking ahead to 2050, the world's leaders and society as a whole will need to face some thornier issues surrounding global sustainability that go to the very root of our identities and industrial economy, namely population growth and burgeoning individual consumption. This implies a fundamental transition, at a global scale.

### *Market transformation*

Success will also require that we find ways to harness global markets for the cause of sustainability. The pioneering efforts of the Forest Stewardship Council (for wood products) and the Marine Stewardship Council (for fisheries) are paving the way for a wide range of initiatives to create markets for companies who commit themselves to producing goods sustainably. A powerful blend of best practice, innovative partnerships and market opportunities offers a formula for transforming the production of commodities such as timber, pulp and paper, cotton, palm oil, soy and wild-caught and farmed seafood.

Further efforts are needed to increase the market share of ecologically and socially sustainable goods and services. These include developing positive incentives for provisioning and trade of these goods and services, removing trade-distorting and environmentally harmful subsidies, and establishing disincentives for providing goods and services that impede the long-term goal of achieving sustainability.

In the long run, we will need to develop more sophisticated tools to better account for externalities and resource scarcity in the pricing of goods and services. The concept of virtual water, originally developed in the 1990s to show how the import of water-intensive commodities can be an effective strategy for a country experiencing internal water shortages (Hoekstra and Chapagain, 2007), provides a basis for rethinking comparative advantage in trade of environmental assets.

### *Ecosystem-based management*

On the ground, or in the water, sustainability requires that we learn to manage natural systems on nature's terms – shifting from management of individual resources like timber or water to management of whole ecosystems. We need an ambitious effort to secure biodiversity and ecosystem services that takes us beyond traditional habitat and species protection measures to an integrated and system-wide approach to conservation. Ecosystem-based management is an adaptive approach that aims to achieve sustainable use of natural resources by balancing the social and economic needs of human communities with the maintenance of healthy ecosystems.[1] Implementing ecosystem-based management requires mainstreaming environmental protection and conservation action into decision making from local to regional levels, and requires new ways of working across sectors and between state and non-state actors.

### *Strategic alliance with the scientific community*

The final element is to reinforce science-based decision making. Environmental science has come of age in recent decades. Panels and processes such as the *Intergovernmental Panel on Climate Change* and *Millennium Ecosystem Assessment* have brought scientific understanding into the heart of the public debate and the

[1] Ecosystem-based management can be seen as the practical application of the ecosystem approach that has been adopted by the Parties to the Convention on Biological Diversity

policy process, and have succeeded in transcending the disciplinary silos that still characterize so much scientific endeavour. Their findings have had profound impacts on the way we think about our impacts on the planet and on the nature of our responses.

There is little doubt that investment in strengthening scientific capacity both in the developed and developing world could further inform our choices and broaden our options towards a more sustainable future. To be effective, a new global contract between science and society (see Part V, this volume) will entail a broadening of the dialogue between policy makers, NGOs and the media on the one hand and the scientific community on the other. This will assure that scientists are able to communicate in clear and compelling terms the actions that need to be taken to sustain human well-being and that policy makers and society as a whole are able to respond with confidence.

The level of economic and social transformation required to put humanity on the pathway to sustainability may look daunting, but we only need to look back a few decades to see just how fast our societies and lifestyle can change. Some of the ingredients of this transformation have been set out above, bringing with them new opportunities to harness technology and innovation, to rebuild our energy economy, to reinvigorate and reform our food production systems, and to build a future in which humans live in harmony with nature and the natural systems on which we depend. Climate change brings a fresh imperative and a renewed momentum to harness humankind's ingenuity: we believe the challenge can be met but our response in the next decade may determine whether we thrive or decline as a species.

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