Chapter I
Introduction: why a green technological transformation is needed

Summary

- The cumulative effects of the degradation of the Earth's natural environment has increased the scale of the sustainable development challenge enormously. Provisioning for human life using the current technology is expected to be increasingly infeasible as population continues to increase and the harmful impacts of human production and consumption multiply.
- Business as usual is not an option. An attempt to overcome world poverty through income growth generated by existing "brown technologies" would exceed the limits of environmental sustainability.
- A global green technological transformation, greater in scale and achievable within a much shorter time-frame than the first industrial revolution, is required. The necessary set of new technologies must enable today's poor to attain decent living standards, while reducing emissions and waste and ending the unrestrained drawdown of the earth's non-renewable resources.
- Staging a new technological revolution at a faster pace and on a global scale will call for proactive government intervention and greater international cooperation. Sweeping technological change will require sweeping societal transformation, with changed settlement and consumption patterns and better social values.

The development challenge and the emerging environmental crisis

The current pattern of economic growth has led to the environmental crisis

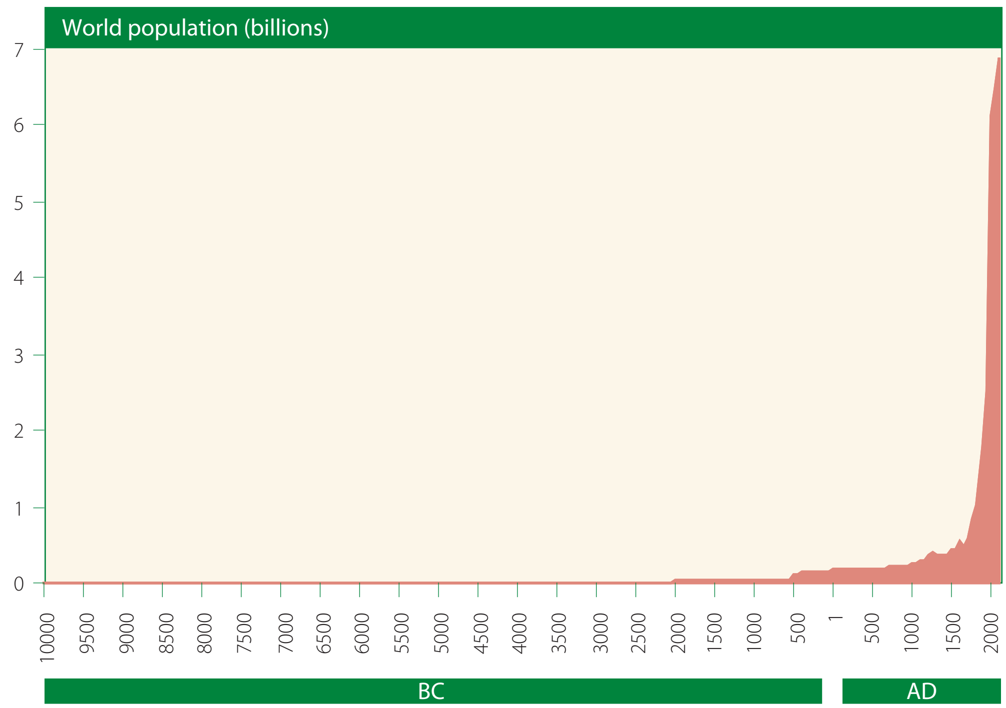
Since the first industrial revolution, major transformations in energy technology (from muscle power to water, then steam, and later hydrocarbons) and other innovations have generated substantial increases in production and human activity. However, the same technologies that enabled the quantum increases in material welfare have also come at a lasting cost with respect to the degradation of the world's natural environment. To continue to tread the pathways of past economic development would further enhance pressure on natural resources and would destabilize the Earth's ecosystem. Even if we were to now stop global growth engines, the depletion and degradation of the world's natural environment would continue because of existing consumption habits and production methods. Much greater economic progress is needed in order to lift the poor out of poverty and provide for a decent living for all, including the additional 2 billion people who will inhabit the planet by mid-century. Hence, there is an urgent need to seek out new development pathways that will ensure environmental sustainability and reverse ecological destruction, and at the same time serve as the source of decent livelihoods for all of today's population and for future generations.

Unremitting increases in population and income

The increases in population and production have exhibited a "hockey stick" pattern

Both population and incomes have grown exponentially over the past two centuries. While world population size had remained relatively stable for much of human history, it started to increase at an accelerated pace with the first industrial revolution (figure I.1).[1] The world population increased from about 1 billion in 1800 to about 6.5 billion by 2010 and is likely to increase, according to United Nations projections, to about 9 billion by the end of this century.

Figure I.1
Exponential population growth in the modern era



Sources: For 10,000 BC-1749, United States Census Bureau online (www.census.gov/ipc/www/worldhis.html); for 1750-1949, United Nations, "The world at six billion" (ESA/P/WP.154) (12 October 1999), table 1; for 1950-2010: United Nations, Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2010 Revision (medium variant) (New York, 2011).

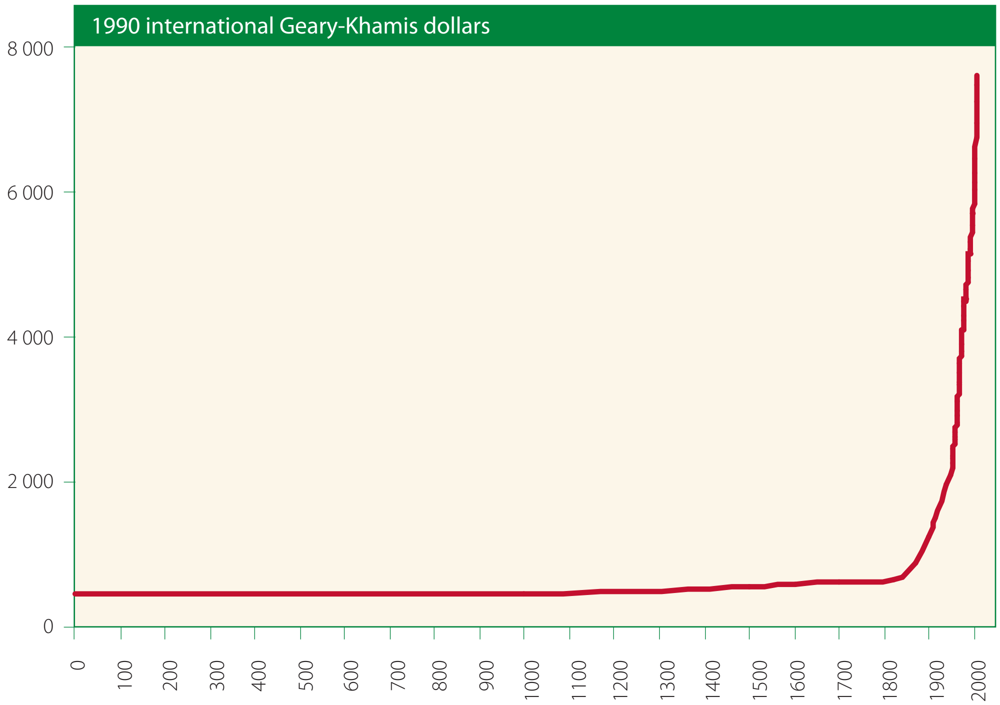
Similarly, human per capita welfare is believed to have increased at a very slow pace for most of human history, having taken off only with the industrial revolution.[2] Since 1820, income growth, like population size, has exhibited a "hockey stick pattern" (see figure I.2), with per capita income increasing 24 times faster than during the period 1000-1820.[3]

1 It is estimated that even in 10,000 BC, at the onset of the Neolithic revolution, the world population was only about 1 million. Population increased with the successes of Neolithic agriculture and the Bronze- and Iron-Age civilizations. However, even at the onset of the first industrial revolution (1750 AD), world population was limited to only 750 million. Since 1820, population has increased at the rate of 1 per cent per year, a rate that is 6 times higher than that prevailing during the period 1000-1820 (Maddison, 2007, p. 69).

2 According to Maddison (2007), average world income increased by only about 50 per cent between 1000 and 1820 AD. His research suggests that annual per capita income of most ancient societies was about 400 international PPP dollars (IPPP$). DeLong (1998) places this figure much lower, at IPPP$ 90. In any case, until 1820, economic growth, by and large, was extensive, serving mainly to accommodate the fourfold increase in population.

3 Since 1820, per capita income has increased by 1.2 per cent per year (Maddison, 2007).

Figure I.2
Accelerated growth of world per capita income in the modern era



Source: Maddison data on population and GDP. Available from http://sites.google.com/site/econgeodata/maddison-data-on-population-gdp.

Lopsided distribution of population and income growth

The distribution of income and population growth has been very uneven

Most of the observed per capita income growth has been concentrated in the currently developed part of the world (figure I.3). Much smaller gains have been observed in much of Asia, Africa and Latin America. Income growth in developed countries was accompanied by drastic declines in birth and mortality rates and increases in longevity, accelerating a demographic transition. By contrast, developing countries still face much higher birth rates relative to mortality rates, coupled with the slower income growth and, as a result, see much faster population growth (figure I.4).[4] This lopsided distribution of income and population has aggravated the environmental crisis in many ways.

Environmental impact of increased population and income

The limits of the Earth's capacity as "source" and "sink" are being reached …

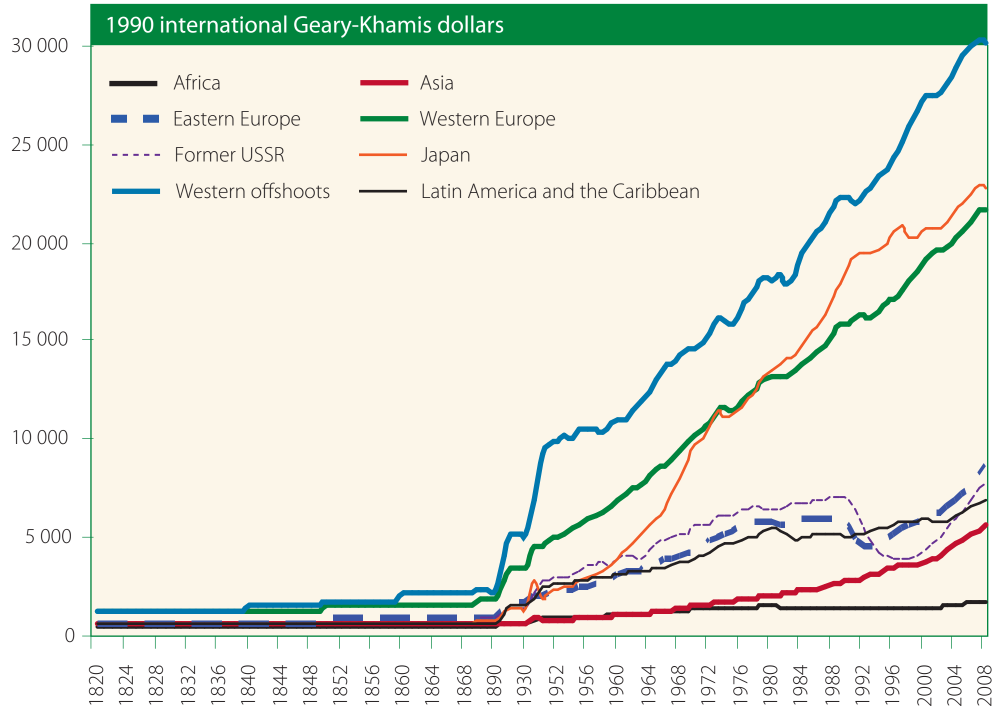
The Earth has a double function in ensuring human survival—serving as both "source" of the natural resources necessary for, and "sink" for the waste (including pollution) generated by, production and consumption. The impact on that double function of dramatic increases in population and average income, in combination with other conducing factors, has sown the seeds of an environmental crisis.

The hockey-stick patterns of population and income growth are mirrored by the exponential increase in energy consumption (figure I.5).[5] Increased energy consumption has led to a commensurate increase in emissions of carbon dioxide (CO_2) into the

4 Between 1750 and 2008, the combined populations of Europe, North America and Oceania increased almost sevenfold, from 167 million to 1,103 million, while the combined populations of Asia, Africa and Latin America (including the Caribbean) increased ninefold, from 624 million to 5.6 billion.

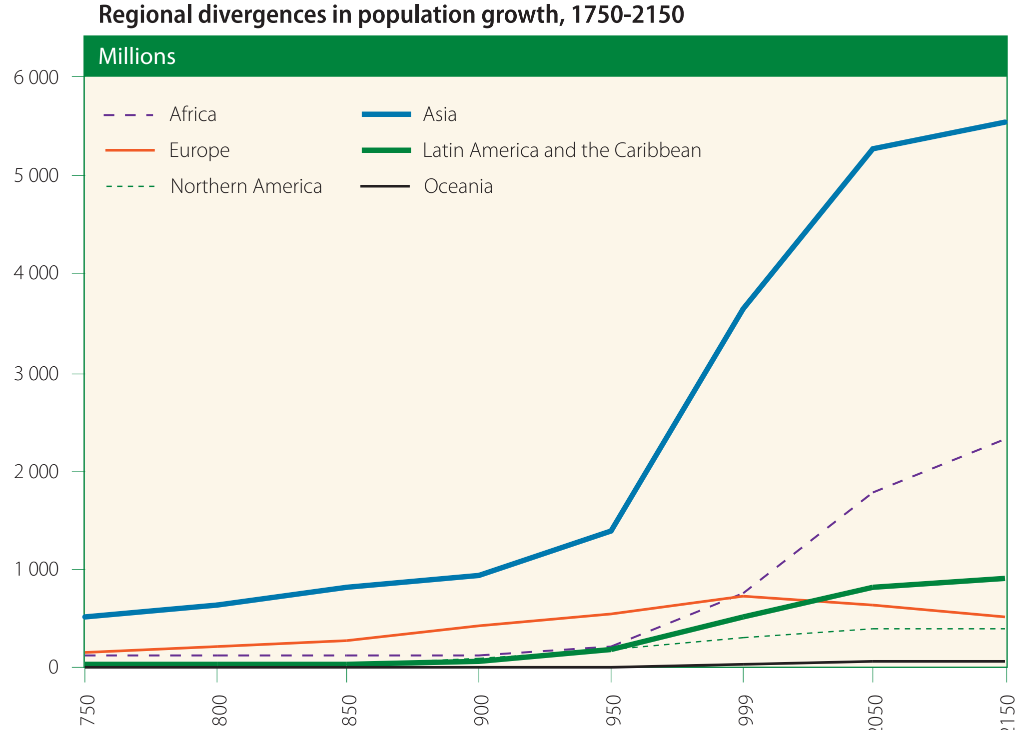
5 Primary energy consumption had increased from a little over 10 exajoules (EJ) in 1850 to about 500 EJ by 2000.

Figure I.3
Diverging growth of per capita income, by region, 1820-2008



Source: Maddison data on population and GDP. Available from http://sites.google.com/site/econgeodata/maddison-data-on-population-gdp.

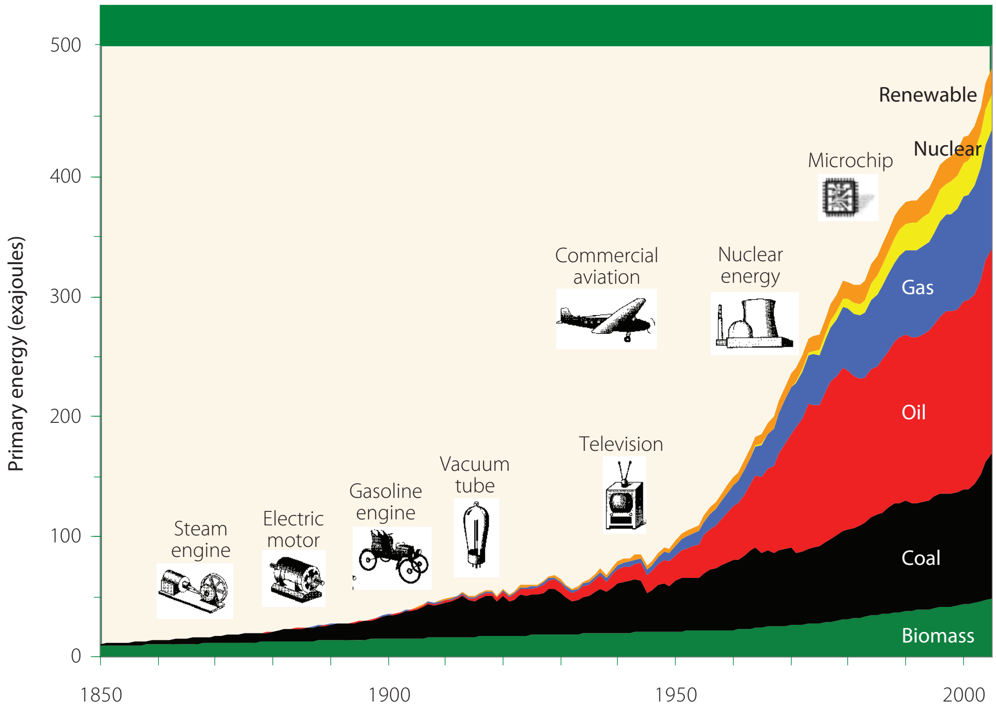
Figure I.4
Regional divergences in population growth, 1750-2150



Source: United Nations, "The world at six billion" (ESA/P/WP.154) (12 October 1999), table 2.

Note: Population estimates beyond 2008 are based on the medium-variant projection of the Population Division, UN/DESA.

Figure I.5
Rise in energy consumption since the first industrial revolution



Source: United Nations (2009), figure II.4.

atmosphere, from a pre-industrial level of about 260 parts per million (ppm) to close to 400 ppm in 2010 (figure I.6).[6] Rising concentrations of CO_2 and other greenhouse gases have caused a similarly steep increase in average global temperatures, which are now about 1° C above those observed around 1850 and in the centuries before (figure I.7). With trends in greenhouse gas emissions continuing, global temperatures are set to increase further, and will likely average between 2° C and 5° C above pre-industrial levels by the end of the century (figure I.8), surpassing the limits for a stable climate and becoming high enough to cause cataclysmic changes (United Nations, 2009). The extreme weather events whose incidence has increased in recent years prove how devastating these changes can be (see chap. IV).

There also has been a secular rise in the volume of waste accompanied by alarming changes in its composition. Waste is becoming increasingly non-biodegradable, toxic and radioactive. For example, non-biodegradable plastic now far outweighs such natural materials as timber, paper, iron, copper, lead, aluminium, phosphorus and potash in GDP (figure I.9).

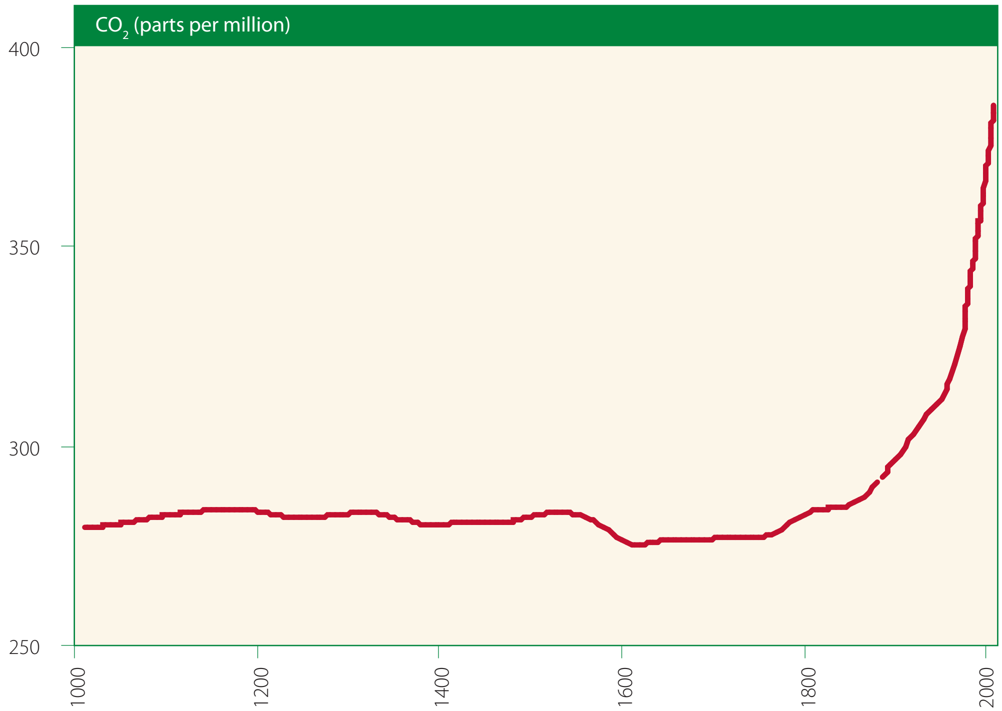
… causing severe damage to the planet's environment and ecosystem

This brief survey demonstrates that, since the first industrial revolution, there has been a switch from an almost horizontal to an almost vertical pattern of rise in population, income, resource use and waste dumped into the Earth's ecosystem. This switch has caused irreparable damage to the Earth's ecosystems and is knocking it off balance. According to the Millennium Ecosystem Assessment (2005):

- Sixty per cent of a group of 24 ecosystems are now degraded or exploited beyond ecological limits

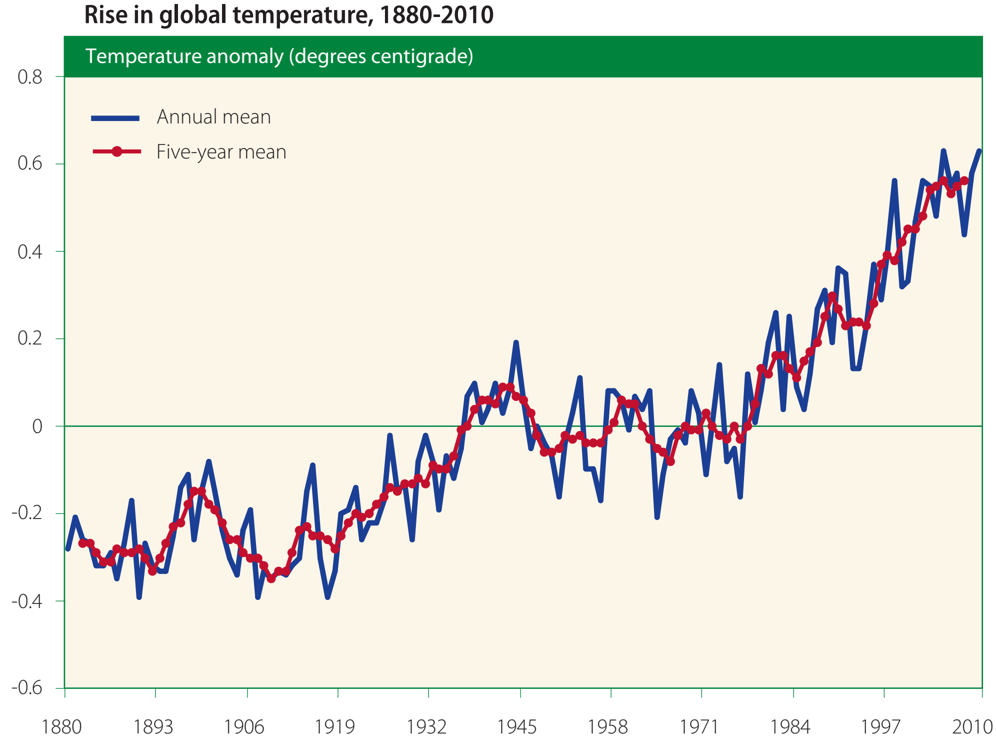
6 From a pre-industrial level of less than 5 gigatons (Gt), which is roughly the atmosphere's absorptive capacity, the amount of CO_2 emitted has increased to about 40 Gt.

Figure I.6
Rise in atmospheric carbon dioxide concentration, 1000-2008



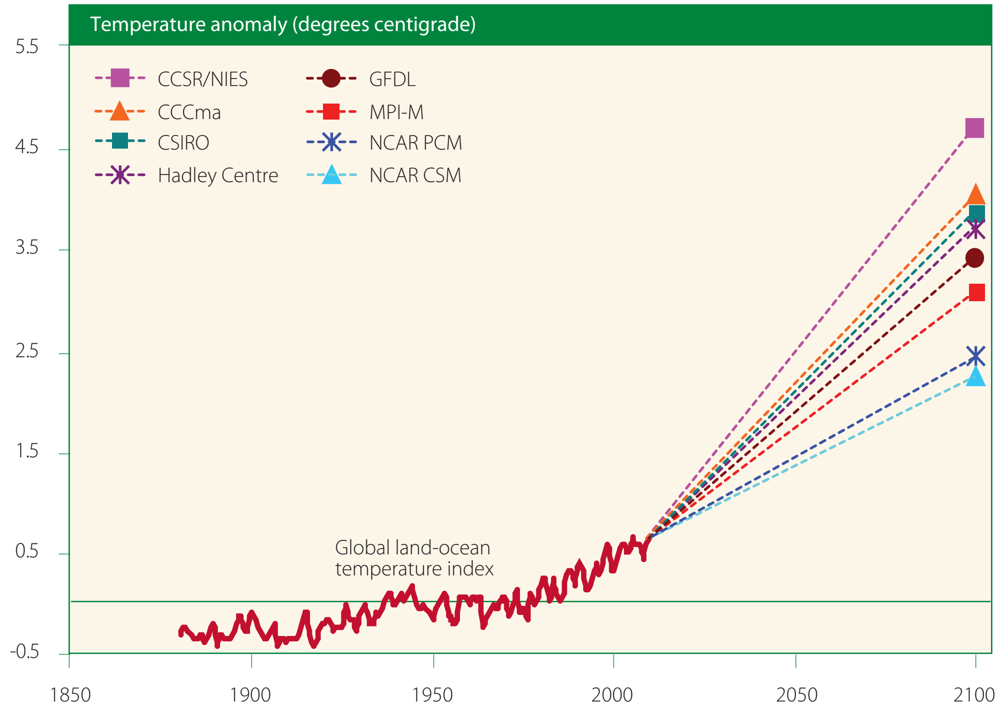
Source: United States Department of Energy, Carbon Dioxide Information Analysis Center (CDIAC). Data available from http://cdiac.esd.ornl.gov.

Figure I.7
Rise in global temperature, 1880-2010



Source: National Aeronautics and Space Administration, Goddard Institute for Space Studies (GISS). Data available from http://www.data.giss.nasa.gov/gistemp/graphs.

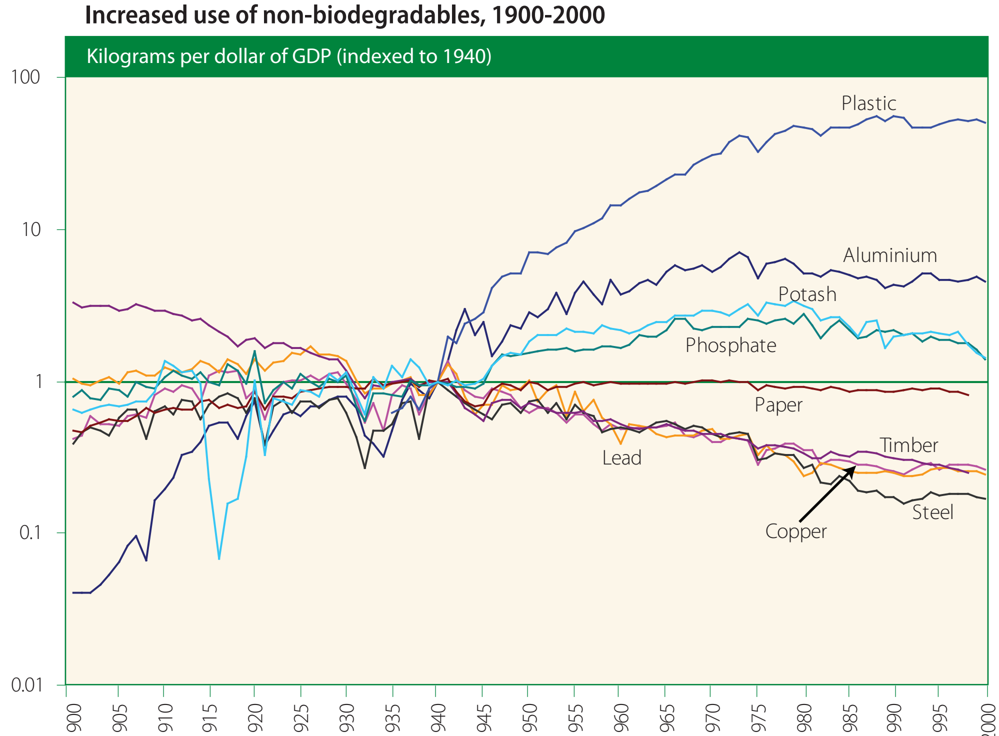
Figure I.8
Observed and projected rises in global temperature, alternative scenarios, 1850-2100



Sources: For 1850-2010: Goddard Institute for Space Studies (GISS): data available from http://www.data.giss.nasa.gov/gistemp/graphs; for 2100: data available from http://en.wikipedia.org/wiki/File:Global_Warming_Predictions.png.

Note: All the predictions shown in this figure are based on the A2 scenario of the Intergovernmental Panel on Climate Change (IPCC) (see IPCC, 2007b, for details). This scenario is based on specific assumptions about, inter alia, the future growth of output and population, and integration of the global economy. Variations among the predictions come from different assumptions regarding emissions and their impact on temperature rise.

Figure I.9
Increased use of non-biodegradables, 1900-2000



Source: Wernick and others (1997).

- The world has lost 50 per cent of its wetlands since 1900
- More land was converted to cropland in the 30 years after 1950 than in the period 1700-1850
- Forest area has shrunk by about 40 per cent over the past 300 years
- Twenty-five countries have completely lost their forests and 29 countries have less than 10 per cent forest cover
- The current species extinction rate is about 1,000 times higher than the rates that prevailed over the planet's history
- The world has lost 50 per cent of its mangrove forests since 1980
- Agriculture accounts for 70 per cent of worldwide water use
- Dams contain four times more water today than in 1960
- There is now from three to six times more water in reservoirs than in natural rivers

The pandemic spread of diseases and the extinction of species are imminent threats

The ecological degradation and destruction, as detailed above, are having alarming effects on the Earth's function as a source of natural resources, including through the adverse impacts on the quality of land, land-use patterns and food production, which are aggravating food insecurity (as discussed in chap. III). The risk of non-linear changes which could provoke sudden catastrophes and destabilize ecosystems has increased substantially. The collapse of fisheries, the pandemic spread of diseases and the extinction of species are imminent threats. Ecological degradation and destruction are aggravating human vulnerability, particularly for those people who are forced to settle in areas susceptible to risk. For example, the degradation of mangrove forests was one of the reasons for the high toll exacted by the Indian Ocean tsunami of December 2004 (see chap. IV for a discussion of rising trends in the frequency and intensity of natural disasters and their impact).

Clearly, the current hockey-stick pattern of development with its concomitant steep rises in resource use and waste is not sustainable. The question is what can be done to ensure that development does not exceed the limits of the Earth's carrying capacity while assuring that all of its inhabitants have fulfilling lives, based, inter alia, on the convergence of the living standards of currently developed and developing parts of the world.

Sustainable development and the green economy paradigms

The concept of sustainable development

Sustainable development entails combining economic and social development and environmental protection

The argument that the current pattern of development is not sustainable had already been made several decades ago, but has yet to lead to a change of direction. To amalgamate existing forces and direct them towards implementation of new policy approaches, the World Commission on Environment and Development (the Brundtland Commission), in its 1987 report entitled *Our Common Future* (World Commission on Environment and Development, 1987), proposed the now widely agreed definition of the concept of sustainable development as the process that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 8). However, this definition, while being widely accepted, gave rise (owing to its somewhat general focus) to many different interpretations and explications.[7] Nevertheless, within the framework of the international agreement reached at the 1992 United Nations Conference on Environment and Development, as reflected in its adoption of the Rio Declaration on Environment and Development (United Nations, 1993) and Agenda 21 (ibid.), the concept of sustainable development is perceived as encompassing the pursuit of three goals: economic development, social development and environmental protection.

Sustainable development is also a goal of developed countries

The Brundtland Commission report paid particular attention to the interrelationships among these three goals, noting two-way connections between any given pair.[8] In particular, noting that social development was necessary for sustaining both economic development and environmental protection, the Commission observed that “(a) world in which poverty is endemic will always be prone to ecological and other catastrophes”[9] and that “the distribution of power and influence within society lies at the heart of most environment and development challenges”.[10] It also emphasized that sustainable development is not a goal applicable only to developing countries but must be a goal of developed countries as well.

Finding ways to force action on the commitments set out in Agenda 21 required agreement by Member States on the concrete steps to be taken

The work of the World Commission on Environment and Development led to the decision of the Governing Council of the United Nations Environment Programme (UNEP), at is fifteenth session, to recommend to the General Assembly that it convene a United Nations Conference on Environment and Development (United Nations, General Assembly, 1989). The Conference, popularly known as the Rio Earth Summit, was held in June 1992. The aforementioned Rio Declaration on Environment and Development proclaimed, inter alia, the right to development (principle 3) and that, in view of the different contributions to global environmental degradation, States had common but differentiated responsibilities (principle 7). Agenda 21 laid out before the international community a very broad set of objectives to be achieved in the twenty-first century. Finding ways to compel action on the commitments contained in Agenda 21 required agreement among Member States on concrete steps towards development cooperation, or at least on concrete indicators. The formulation of the Millennium Development Goals in 2000 can be seen as a further step forward towards agreement on concrete indicators of achievement of social development targets.[10]

At the start of the twenty-first century, then, the world community had both a broad-ranging agenda for sustainable development encompassing economic development, social development and environmental protection; and a set of indicators for the achievement of specific social development goals whose pursuit has already spurred notable action and policy initiatives.

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7 For instance, for some, the concept of sustainable development implies that the current generation must leave for the next generation the same amount of “natural capital” as it had inherited from the previous generation. In other words, conservation of the stock of natural capital constituted a condition for development to be considered sustainable. See Pearce, Markandya and Barbier (1989) for a compilation and discussion of various definitions of sustainable development.

8 The distinction between “economic development” and “social development” as used here follows common usage in the mainstream literature, according to which reduction of poverty and inequality, increase in access by and empowerment of the poor and disadvantaged groups of the society, among other objectives, are to be considered a social (rather than an economic) goal. In contrast, other theoretical perspectives would regard poverty reduction, decrease in inequality of income and assets and improvement in access to productive resources as equally important *economic* goals and conditions for enhancing economic efficiency and growth.

9 See document A/42/427 of 4 August 1987, annex, overview, para. 27.

10 Ibid., chap. 1, para. 43.

The concept of a "green economy"

The concept of a green economy constitutes a response to the further aggravation of the environmental crisis

While the 'green economy' had been before,[11] its current application is sometimes associated with the 2008 crisis and the environmental sustainability context of the stimulus packages that were considered in an effort to overcome it. Influenced, in part, by the climate change-related negotiations on the eve of the fifteenth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change,[12] held in Copenhagen from 7 to 19 December 2009, many argued for making these stimulus packages "green". Some countries actually did make a conscious effort to include in their stimulus packages projects that would be directed towards protection of the environment and mitigation of climate change. Over time, other expressions besides green economy—such as green growth, green stimulus, green technologies, green sectors, green business and green jobs—have entered common parlance.

However, despite its increasing utilization, the concept of a green economy is not well defined. Noting the many different ways in which the concept is used, the Secretary-General, in a report to the General Assembly, concluded that "'green economy' is an omnibus term" (United Nations, General Assembly, 2010a, para. 57) and therefore asked for "greater conceptual clarity with regard to the links between a green economy and sustainable development" (ibid., para. 57(a)).

Insisting on the green economy concept can be risky for a variety of reasons

In general, the concept of a green economy is invoked in an attempt to stress environmental sustainability and protection while pursuing sustainable development. Possibly because of the lack of a clear definition, the current interest in greening economies has revived concerns and debates harking back to the days when the Brundtland Commission was struggling to effect a consensus on the concept of sustainable development. In the current debate, many developing-country representatives have expressed the view that the insistence on a green economy is risky for a variety of reasons (Khor, 2011a). They are concerned: (a) that it could lead to a one-dimensional focus on environment and a corresponding marginalization of social development goals, and that if adopted at the global level, a focus on the green economy might thereby undercut the importance and urgency of developing countries' right to development; (b) that such a focus could lead to a "one size fits all" approach through which developed and developing countries would be judged by the same yardstick, thereby diluting the aforementioned principle of "common but differentiated responsibilities" adopted at the Earth Summit; (c) that the efforts to green the world's economy could induce developed countries to impose new trade restrictions on developing countries; and (d) that a green economy framework could lead to the attachment of new policy conditionality to international development assistance (ODA) and lending to developing countries.

Green economy-related efforts should fit within the sustainable development framework

Such concerns can be addressed by ensuring that the green economy concept does not undermine a balanced approach to sustainable development. Enhancing economic growth, social progress and environmental stewardship can be seen as complementary strategic objectives. As already indicated, because of the exponential increase in the level of human activity, the limits of the Earth's capacity as both a source and a sink are being or already have been reached. Emphasizing the need for green economies can help focus attention on these constraints and limits. In this sense, the concept of a green economy stresses the importance of intergenerational equity in economic and social development, that is to say, ensuring that meeting the needs of the present generation does

11 See, for example, Pearce, Markandya and Barbier (1989).

12 United Nations, *Treaty Series*, vol. 1771, No. 30822.

not compromise the ability of future ones to meet their own needs; further, it is based on the presumption that the benefits of investing in environmental sustainability outweigh the cost of not doing so, because the cost of having to protect ecosystems from the damages associated with a "non-green" (brown) economy are larger that the projected costs of investing in sustainability.

The need for a fundamental technological and structural transformation

Remaining within the limits of the Earth's capacity requires …

To ensure that no limits are crossed that would destabilize the Earth's ecosystem, a fundamental technological overhaul and structural transformation of production and consumption processes towards a green economy will be needed, entailing achievement of at least the following five objectives:

(a) Reduction of resource requirements in general and of energy requirements in particular, in both absolute terms and relatively, per unit of output;

(b) Substitution of renewable for non-renewable resources, given the total resource use;

(c) Substitution of biodegradables for non-biodegradables, at any given level of output or waste;

(d) Reduction of waste (including pollution), at any given level of resource use;

(e) Protection of biodiversity and ecosystems.

… substitution of renewable resources for non-renewable ones

These green economy objectives are interrelated. For example, replacement of non-renewable by renewable resources helps to overcome resource constraints (first objective) and reduce waste (fourth objective). Similarly, reduction of resource extraction and waste generation is the most effective means of protecting biodiversity and ecosystems (fifth objective). To determine what is required to achieve these objectives, they must be examined in some detail.

Reducing resource requirements

There have been some increases in resource-use efficiency …

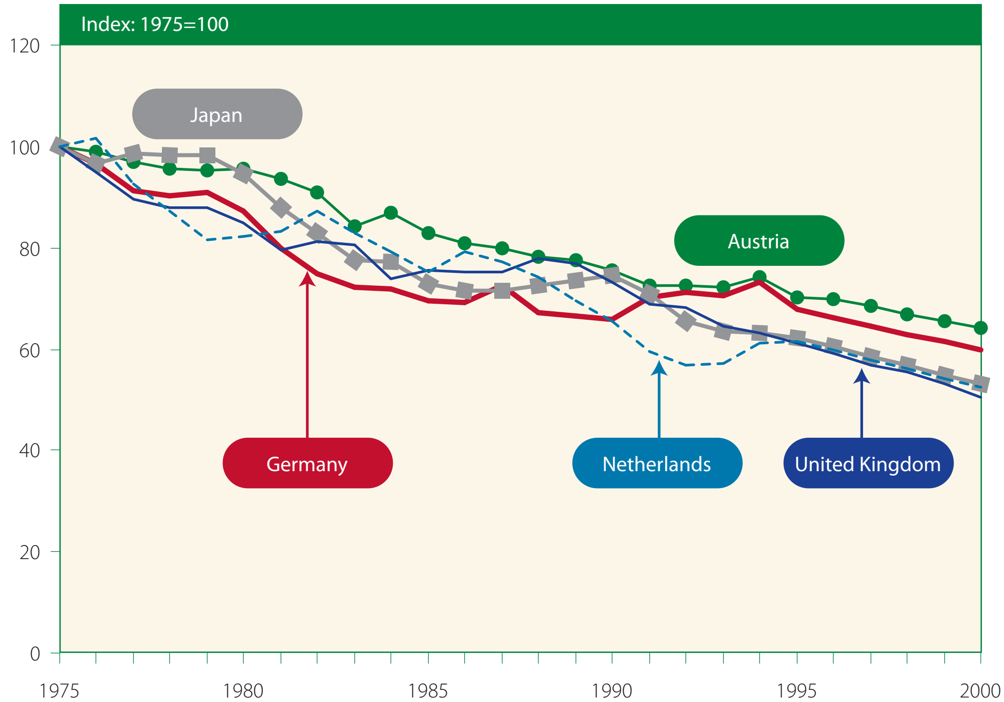
Reduction of resource requirements, in both absolute terms and per unit of output, should be a key objective of greening the economy. Many observers have pointed out that there is much scope for drastically reducing resource intensity of production and consumption processes; and there is considerable evidence of greater resource efficiency, reflecting trends towards a "decoupling" of the growth of resource use from output growth. For example, physical resource use per unit of output decreased by about half in Organization for Economic Cooperation and Development (OECD) member countries during the period 1975-2000 (figure I.10). Moreover, the energy intensity of output has decreased substantially since the 1970s, with global energy intensity now about 30 per cent lower than in 1970. Energy intensity in both the United States of America and the United Kingdom of Great Britain and Northern Ireland is about 40 per cent lower now than in 1980 (Jackson, 2009a, p. 48).[13]

… but no reduction in total resource requirements

However, despite this progress in reducing input intensity, the absolute worldwide volume of material and energy utilized in production and the amounts of waste

13 It should be noted, however, that much of the reduction in material and energy intensity of output in developed countries has been achieved by relocating material- and energy-intensive manufacturing operations within developing countries.

Figure I.10
Material intensity of output in OECD countries, 1975-2000



Source: Jackson (2009b), p. 70.

generated continue to increase, as evidenced, for example, by the continued upward trends in world consumption of metals such as iron, nickel, bauxite, copper and zinc (figure I.11). While fast growth in some major developing countries is responsible in part for this continued trend, the fact remains that in developed countries, too, resource use has continued to increase despite low population growth and improvements in resource efficiency in production (figure I.12). The evidence therefore makes it clear that despite some progress in relative decoupling, achieving the objective of absolute decoupling remains elusive.

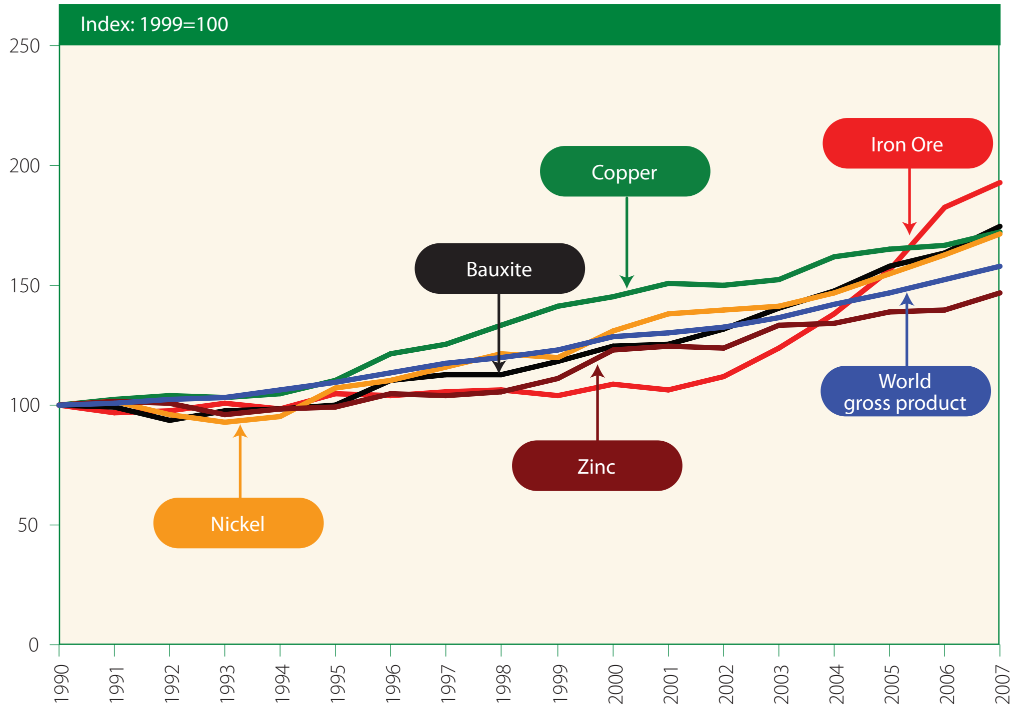
Substitution of renewable for non-renewable resources

The substitution of renewable for non-renewable resources can often lead to win-win solutions

The Earth's limits as a source of natural resources should be overcome further through the substitution of renewable resources for non-renewable ones. Since many renewable resources (for example, solar energy and wind power) are also less waste-generating, their substitution for non-renewable resources would result in a win-win solution, as it would allow constraints on the Earth's functions as both a source and a sink to be overcome.

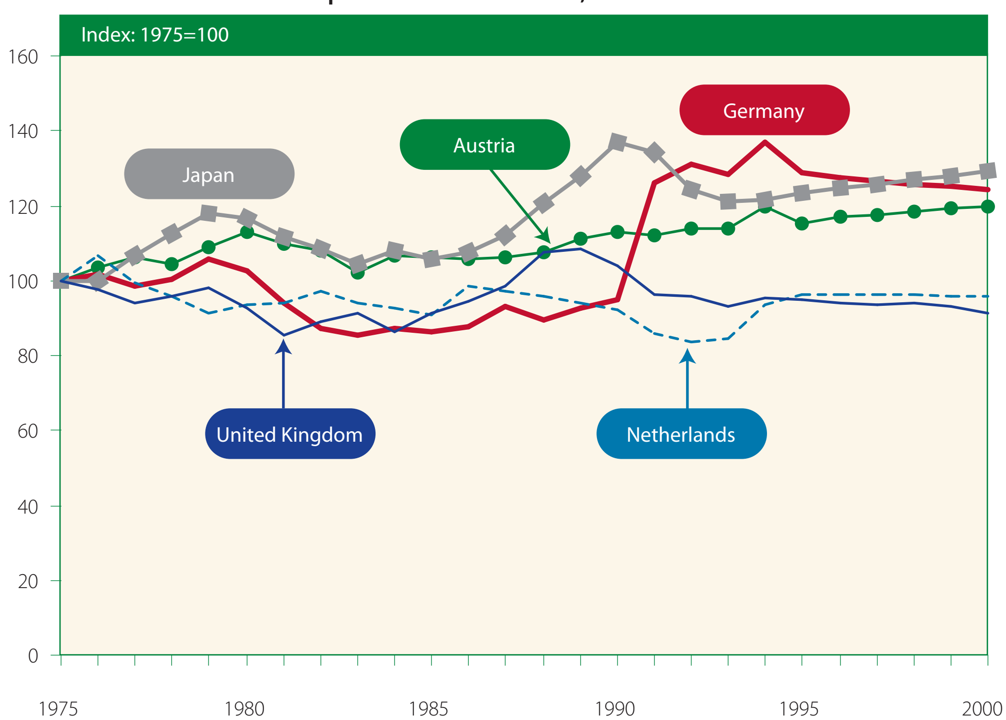
Thus far, progress in replacing non-renewable with renewable resources has been too slow to significantly reverse ongoing trends. Since the first industrial revolution, there has been an unremitting increase in the total use of non-renewable energy sources, especially of fossil fuels like coal, gas and oil; and the rate of increase in their use has accelerated since 1950. As a result, non-renewable carbon-intensive energy sources accounted for about 85 per cent of total energy use in 2000 (figure I.13). Weaning human societies away from non-renewable resources and guiding them towards renewable ones have therefore become urgent tasks.

Figure I.11
Global trends in primary metal extraction, 1990-2007



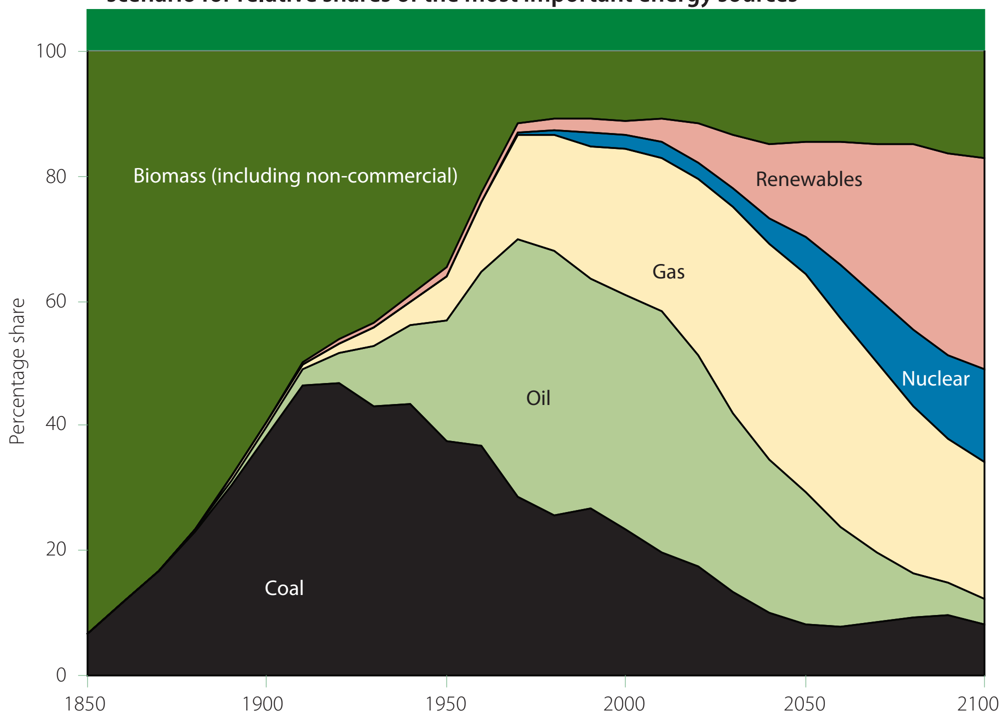
Source: Jackson (2009b), p. 74.

Figure I.12
Direct material consumption in OECD countries, 1975-2000



Source: Jackson (2009b), p. 72.

Figure I.13
History and possible future of the global energy system under the B1 stabilization scenario for relative shares of the most important energy sources



Source: United Nations (2009), figure II.6.
Note: B1 is one of the stabilization scenarios considered by the Intergovernmental Panel on Climate Change (IPCC). It is one of the ideal scenarios among the possible ones and stipulates fast economic growth, rapid changes towards a service and information economy, population rising to 9 billion by 2050 and then declining, a reduction in material intensity and the introduction of clean and resource-efficient technologies, and a more integrated world. Further details on B1 and other scenarios are provided in IPCC (2007a, p. 44).

The production of renewable energy can, in some cases, be more resource-intensive

However, in some cases, production of renewable energy (for example, certain biofuels) can be more resource-intensive, so that replacement of non-renewable with renewable resources will not necessarily reduce overall resource requirements. Nevertheless, substitution of renewable resources for non-renewable ones is always desirable when such substitution does not increase and in fact decreases the overall volume of resources used and waste generated.

Substitution of biodegradables for non-biodegradables

Substitution of biodegradables for non-biodegradables is an urgent task

Preponderance of non-biodegradables in output and waste volume has become a serious threat to the Earth's environment. As was shown in figure I.9, the weight of plastic in gross domestic product (GDP) has steadily increased over time and now far surpasses that of such natural inputs as timber, paper and metals. Unfortunately, most of the plastics currently used are non-biodegradable. Although some defenders of plastic maintain that widely used plastic bags will break down in 500 years, there is actually no reliable basis for such claims (Lapidos, 2007).

Fortunately, there is now increasing awareness of the harmful effects of plastic; as a result, many communities, cities and countries are taking measures to restrict its use. In the United States of America, for example, the State of California, in 2007, imposed restrictions on the use of plastic bags. Several cities in Europe have taken similar measures. Among developing countries, Bangladesh, for example, reimposed a ban on the use of plastic bags in 2002.

Technologies already exist to produce biodegradable plastics. Currently available degradable plastic materials are of two main types: polyester polymers (biodegradable) and synergistic and hybrid polymers (bio-based) (Alire, 2011; Kaeb, 2011).

Technologies for producing biodegradable plastics already exist

However, efforts to substitute biodegradable plastics for non-biodegradable ones face a number of hurdles, including the difficulty of finding appropriate substitutes for certain types of non-biodegradable materials currently used in a range of applications; and the fact that, although the production of biodegradable and bio-based substitutes is technically feasible, the cost of producing them is generally higher.

Reduction of waste

Although the limits to the Earth's capacity as a source of resources has received more attention historically, limits to its capacity as a sink for waste are now proving to be a more constant focus. That the limits of Earth's capacity as a sink are fixed is most evident in the context of the global warming threat, which is a direct result of excessive emissions of greenhouse gases, especially CO_2 into the atmosphere. The threat of exceeding the Earth's limits as a sink was made evident even earlier by the ozone hole resulting from excessive chlorofluorocarbon emissions. Thus, the reduction of waste (especially pollution) should be an overriding objective of the green economy.

The limits of the Earth's capacity as a sink for waste and pollution are fixed

The task of reducing CO_2 emissions is particularly daunting. To limit any further increases in the Earth's temperature to less than 2° C above the pre-industrial average, as agreed internationally, the concentration of CO_2 in the atmosphere should not exceed 450 ppm. With a projected world population of 9 billion by 2050 and assuming 2 per cent income growth per year on average between 2007 and 2050, the average CO_2 emission intensity per unit of output will have to decrease from 768 grams in 2007 to 6 grams by 2050 if destabilizing the climate is to be averted (figure I.14).

The reduction in material and energy intensity of output has helped reduce, to a certain extent, the world average CO_2 intensity of GDP somewhat (figure I.15).[14] However, as was the case with resource use, the reduction in the carbon intensity of GDP growth has not resulted in a reduction in the global volume of CO_2 emissions (figure I.16). In fact, despite climate change-related efforts, the growth of CO_2 emissions seems to have accelerated since 2001. Ironically, much of this increase has been due to increased emissions by Annex 1 countries, which under the Kyoto Protocol to the United Nations Framework Convention on Climate Change[15] were obliged to reduce their emission volumes.

The reduction in material and energy intensity of output has helped to reduce the average carbon intensity of GDP

Moreover, the composition of waste has further worsened, with the rising share of non-biodegradables having already been noted. The increasing share of electronic waste ("e-waste"), often containing radioactive elements, is another growing concern. In general, waste is becoming more hazardous, toxic and radioactive (Baker and others, 2004).

Protection of biodiversity and ecosystems

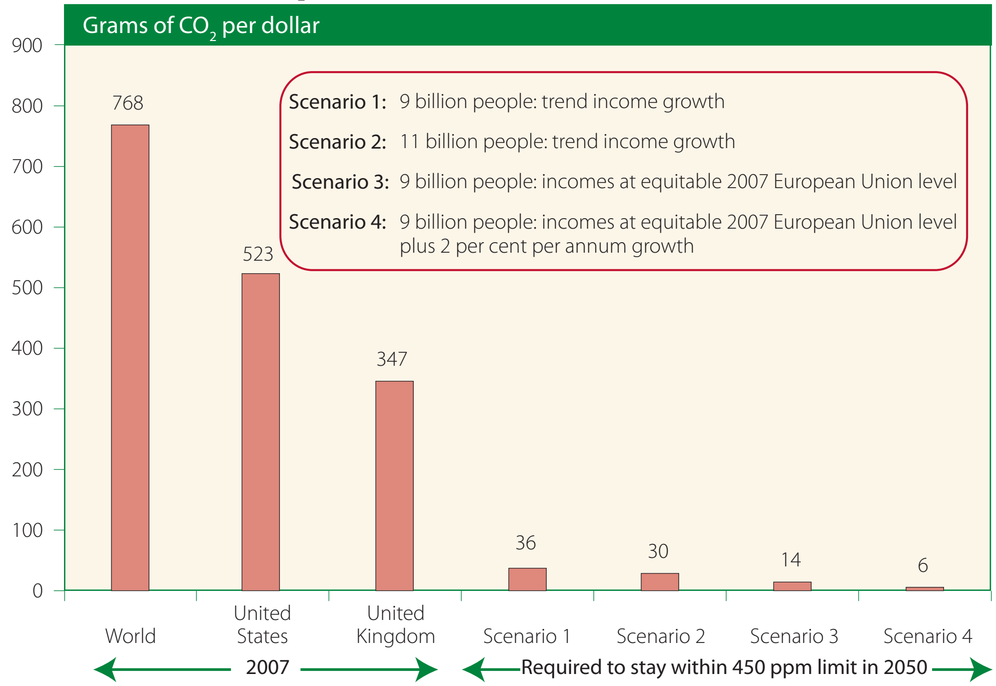
Agricultural production by its very nature depends heavily on the quality of the environment. Unfortunately, the modernization of agriculture, which has led to significant increases in food productivity, has not been conducive to conservation of natural capital, as

Unfortunately, the modernization of agriculture has not been conducive to the preservation of the natural capital

14 The global carbon intensity declined by about one quarter from just over 1 kg of CO_2 per United States dollar in 1980 to 770 grams in 2006. However, much of this decline seems to have been the result of a sharp decline in CO_2 intensity of GDP in China up to 2000, after which the country's downward trend suffered some reversals.

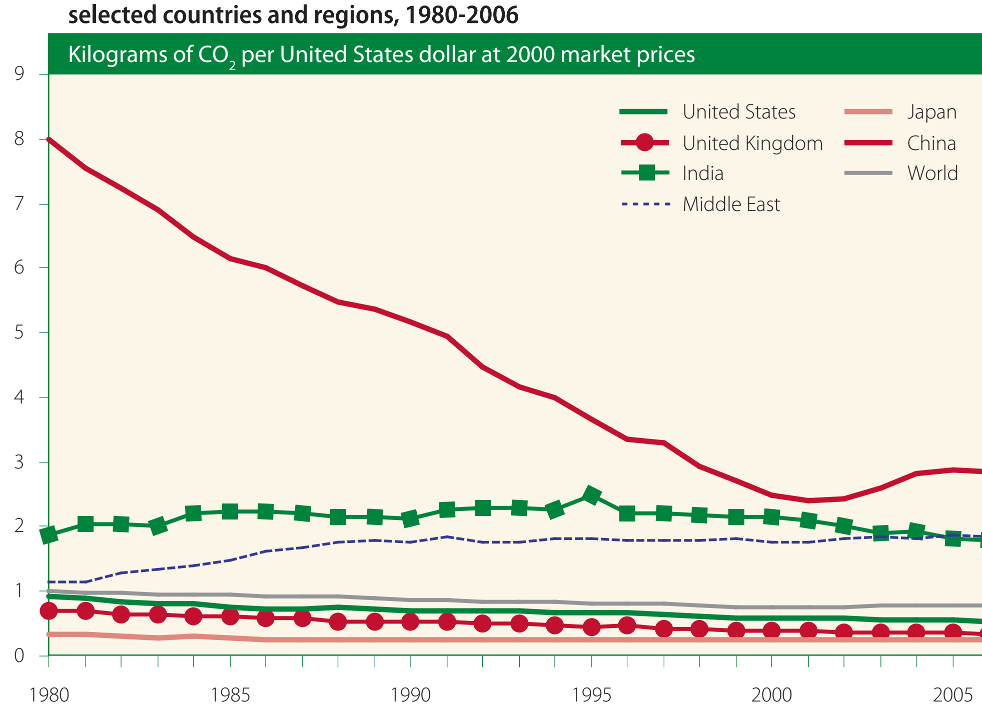
15 United Nations, *Treaty Series*, vol. 2303, No. 30822.

Figure I.14
Carbon intensities, current, and those required to stay within the 450 ppm limit of CO_2e concentrations under alternative scenarios



Source: Jackson (2009b), p. 81.

Figure I.15
Intensity of CO_2 emissions per unit of output, world and selected countries and regions, 1980-2006



Source: Jackson (2009b), p. 70.

discussed in chapter III. In many areas, modern technologies and production systems have accelerated land degradation, clearing and degradation of forests, depletion of groundwater sources and degradation of surface-water bodies, including rivers. Worldwide, the agriculture sector currently contributes about 14 per cent of greenhouse gas emissions, and related land-use and water management are not sustainable in many parts of the world. Deforestation and degradation of forests are contributing an estimated 17 per cent of global emissions, while causing the loss of habitat, species and biodiversity in general. At the same time, nearly 1 billion people are undernourished and face serious food insecurity. Global food production needs to increase by between 70 and 100 per cent from present levels by 2050 in order to feed a growing population. Thus, there is an urgent need to make agricultural production environmentally sustainable, while at the same time substantially raising productivity. It is hard to imagine how this can be achieved without a major overhaul of existing production systems, technologies and supporting infrastructure.

The incidence of natural disasters has increased fivefold since the 1970s, as analysed in chapter IV of this *Survey*. With a fair degree of certainty, this increase can be attributed in part to climate change induced by human activity. Deforestation, degradation of natural coastal protection and poor infrastructure have increased the likelihood that weather shocks will turn into human disasters, especially in the least developed countries.

Further, in any society, loss of natural capital affects the poor and vulnerable more than the well off. Because of their greater reliance on, inter alia, smallholder agriculture, open-capture fishing, harvesting of forest products, inter alia, the poor depend more on natural capital-related services.

Equitable growth within environmental boundaries

The world needs both "convergence upward" and "convergence downward"

Principle 7 of the Rio Declaration on Environment and Development, on the right to development, has often been interpreted in terms of economic "convergence", whereby developing countries would be helped in catching up with developed countries as regards income levels and living standards. "Convergence upward" would require income levels and living standards in developing countries to grow faster to enable the gap with those of developed countries to be closed. According to the parallel notion of "convergence downward", the per capita ecological footprints in developed countries should decrease so as to approach the low levels currently observed in developing countries.

Despite development efforts for more than half a century, progress with respect to development and poverty reduction remains uneven and patchy. Using the international poverty line of $1.25 per person per day (in 2005 purchasing power parity (PPP) value), as defined by the World Bank, 1.4 billion people, representing about 26 per cent of the developing world's population, lived in poverty in 2005. The incidence of poverty was 50.4 per cent in sub-Saharan Africa and 40.3 per cent in South Asia.

Economic growth is a precondition for poverty alleviation

Shared growth is necessary for poverty reduction

Economic growth is a precondition for poverty reduction and improvement in other economic and social indicators. In the recent period, this has been illustrated by the experience of East Asia, in particular of China. As a result of its faster economic growth for more than three decades, China has been able to lift about 600 million people out of poverty. The number of poor in China, as defined by the $1.25 cut-off, decreased from 835.1 million in 1981 to 207.7 million in 2005, which meant a drop in poverty incidence from 84.0 to 15.9 per cent. Similarly, in Viet Nam, the poverty rate declined from 90.4 to 17.1 per cent between 1981 and 2005. By contrast, sub-Saharan Africa, a region that failed to achieve fast economic growth, also failed to achieve poverty reduction. As a result, the number of poor in this region increased from 212 million to 388 million during 1981-2005.

There is hardly any evidence of the achievement of sustained poverty reduction without fast economic growth over several decades. The impact of economic growth on poverty reduction depends very much on how it is shared. As Besley and Cord, eds., (2007, p. 1) note: "Growth is less efficient in lowering poverty levels in countries with high initial inequality or in which the distributional pattern of growth favours the non-poor."

Growth in turn requires structural transformation and sector-specific policies

The capacity of an economy to generate new dynamic activities is key to its sustaining economic growth (Ocampo, 2011a). The emergence of new dynamic activities involves the movement of workers and resources from low-productivity to higher-productivity sectors, resulting in increased economic output and higher incomes. In a globalized economy, this process, in turn, requires identification of sectors in which a country has comparative advantage or in which the country can build up its comparative advantage for the future. Successful development and transformation therefore require the adoption of industrial (or production sector) policies and the necessary space within which to conduct such policies.

Growth and environmental protection

Growth must be achieved while at the same time respecting the limits of the Earth's capacity

Rapid economic growth, based on existing technology, generally requires more input and generates more waste. Because of this factor, it is often suggested that there will be a trade-off between economic growth and environmental protection. However, this need not be the case. The precise objective of investing in greater resource efficiency and sustainable development is to overcome the need for such a trade-off. Moreover, as such investments will generate new economic activities, continued economic growth (especially for developing countries) may well be feasible without surpassing the limits of environmental sustainability.

A recent report of the United Nations Environment Programme (2011) estimates that 2 per cent of current world gross product (WGP) would need to be invested annually between now and 2050 in order to shift development onto a path of green growth and thereby address the current broad range of environmental concerns. Utilizing model-based projections, the report determines that the green economy scenario would permit the sustaining of higher—not lower—GDP growth than under the business-as-usual (BAU) scenario. These required investment estimates may be at the lower end, however. The *World Economic and Social Survey 2009* (United Nations, 2009) and chapter II of the present *Survey*, report that about 2.5 per cent of WGP (or about $1.6 trillion) per annum would need to be invested to effect the energy transformation necessary to meet climate change mitigation targets alone. This analysis further suggests that public investments would need to be frontloaded in order to unleash private sector financing. Moreover, simulations using the United Nations Global Policy Model showed that such a green investment scenario would accelerate economic growth in developing countries (ibid.).

While the outcomes of such scenario analyses rest on the assumptions embedded in the modelling frameworks, they do suggest that it may well be feasible to combine fast growth with environmental protection in developing countries.

Limits to growth in developed countries?

The assumptions underlying the aforementioned global sustainable growth scenarios include the supposition that green technologies can be effectively scaled up quickly and that their costs will not prove to be prohibitive. However, as discussed in chapter II, there are reasons to temper such technology-related optimism, as enormous technical hurdles need to be surmounted to accelerate innovation and ensure widespread application of resource-efficient and waste-reducing technologies, especially those related to energy. Hence, if, for instance, emission reduction targets cannot be met through accelerated technological progress in energy efficiency and renewable energy generation, it may be necessary to impose caps on energy consumption itself in order to meet climate change mitigation targets in a timely manner.

Quality of life does not necessarily increase beyond a certain level of material consumption …

Proposals to put limits on economic growth can be viewed in this context. Advocates of such an approach emphasize, in particular, a voluntary acceptance of certain limits to output and consumption growth by developed countries, so as to cap the production of waste and utilization of non-renewable resources. They base their proposals on a number of arguments: first, acceptance of limits by developed countries would make it easier for the world as a whole to stay within the Earth's carrying capacity; second, acceptance of such limits by developed countries would result in a freeing up of more space for the growth of developing countries, thereby facilitating convergence upward; third, acceptance of limits by developed countries would also facilitate convergence downward, through a more rapid reduction of the ecological footprint in developed countries; and fourth, voluntary limits to growth would be beneficial for developed countries themselves, because a further expansion of the current pattern of consumption would damage the quality of life rather than improve it. On these bases, voluntary limits to growth in developed countries could be beneficial for both developed and developing countries.

… suggesting that developed countries could focus on quality-of-life issues rather than on material growth

The argument that there are limits to growth is not a new one. In the 1970s, studies commissioned by the Club of Rome had drawn attention to the limits of resource availability. The follow-up studies reiterated the necessity for accepting limits to growth, while putting more emphasis on the limits of the Earth as a sink. The need to consider placing certain limits on the total volume of world output and consumption was also recognized by the Brundtland Commission in its report, which noted that the concept of sustainable development did imply limits, although they might need to be imposed gradually. The report recommended that "those who are more affluent adopt lifestyles within the planet's ecological means"[16] and, within the context of the responsibility of political leaders who felt that their countries had reached a "plateau", took note of the fact that "many of the development paths of the industrialized nations are clearly unsustainable".[17]

Does the quality of life stop improving beyond a certain level of per capita income?

Recently, a number of studies have put increasing emphasis on the fourth argument above for limiting growth in developed countries. To make their case, many of them presented evidence from cross-country data showing that the quality of life does not improve much beyond a certain level of per capita income. For example, taking life expectancy as an objective measure of the quality of life, it can be seen that life expectancy does not increase much beyond a per capita income level of about $10,000. Similarly, as indicated in chapter III of this *Survey*, cross-country evidence suggests that there are no significant additional gains in human development (as measured by the human

16 See A/42/427, annex, chap. 1, para. 29.

17 Ibid., Chairman's foreword.

development index) beyond the energy-use level of about 110 gigajoules (GJ) (or 2 tons of oil equivalent (toe) per capita).

While capping the use of energy and other resources by setting limits to growth in developed countries might have worldwide benefits, to many the prospect of "prosperity without growth" may not be very appealing. One reason for the difficulty involved entails what Jackson (2010) refers to as the "dilemma of growth"—the fact that while the current pattern of growth is unsustainable, the current structure of the economy and of society is such that an economy without growth is unstable. Acceptance and implementation of prosperity without growth will therefore require major structural transformations of economies and societies.

The great green technological transformation

With or without the acceptance of limits to growth in developed countries, putting global development on a sustainable path will require greening economic growth. The attainment of technological progress will be essential and in many respects will entail a major overhaul of existing production methods and consumption habits.

What kind of technological revolution?

Industrial development so far has meant material growth at the cost of environmental protection

As explained above, the technological overhaul is required to undo the undesired effects of the past technological revolutions, while preserving their positive achievements and propelling the relationship between humankind and nature to a new stage. Up until the first industrial revolution, humans had mostly been at the mercy of nature. The main source of energy was the muscle power of animals and of humans themselves. This dependence on muscle power limited the extent to which humans could extract natural resources and convert them into consumption goods. As a result, the material standard of living remained low for thousands of years. However, the fact that growth during the pre-industrial era was mostly horizontal, involving expansion into new territories and an increase in the density of population, does not mean that impressive technological achievements were not produced in this period.[18]

The first industrial revolution ushered in an era of dependence on fossil fuels

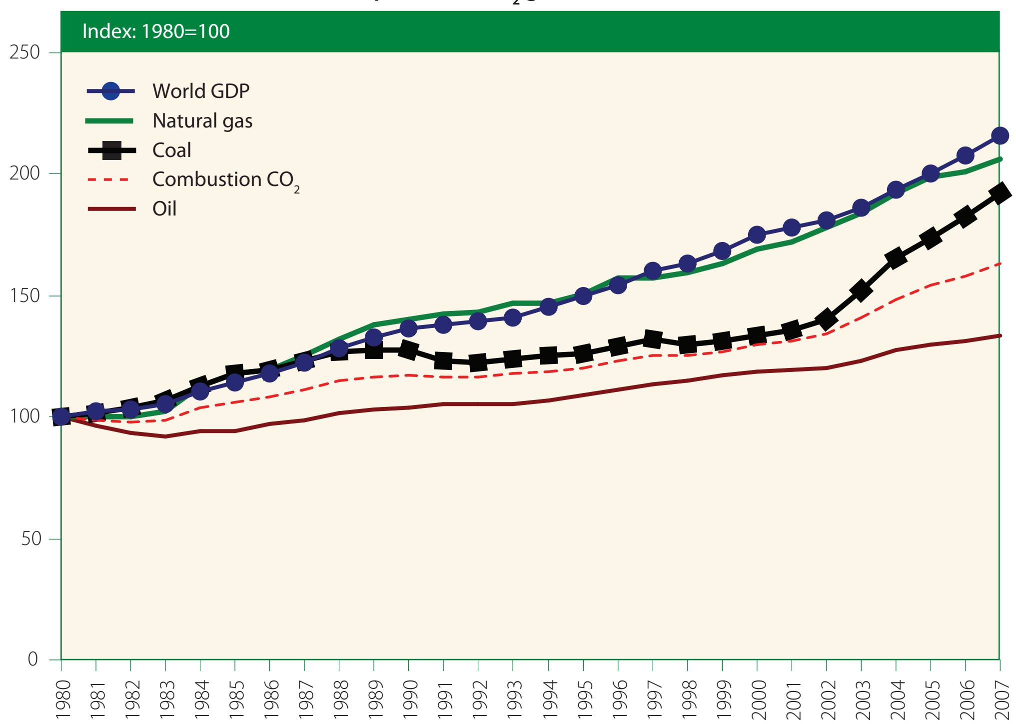
The technological revolution that was at the heart of the first industrial revolution succeeded in abolishing the sovereignty of nature, so to speak, and in establishing the supremacy of humans over it. Many have deemed this revolution a Faustian bargain, by which mankind opted for continuously increasing material consumption at the expense of nature. Subsequent technological revolutions have only expanded the capacity of humankind to impose its will on nature—a victory attested by a sharp rise in population and rising levels of income and consumption. However, a point has now been reached where humans need to restore the sovereignty of nature, not because they lack the capacity to go on conquering it but because overtaxing nature's capacity is detrimental to humans themselves.

What are the concrete dimensions of this new technological revolution? Understanding the character of past technological revolutions can help answer this question. The first industrial revolution had been preceded, accompanied and followed by many changes, including radical transformations in social organization and ideology, as aptly described by the nineteenth century classical economists and later by Karl Polyani (1944).

18 On the basis of the pre-industrial experience, the work of most classical economists was conceptualized in terms of a "stationary state" rather than of continuous growth.

From the technological perspective, however, the main change consisted in the replacement of muscle power by the steam engine as the main motive force. Yet, this came at a price, since steam engines require coal, which ushered in the era of humans' increasing dependence on fossil fuels. The subsequent invention of electricity permitted energy to be applied among a vast range of machines in terms of scale and application; but as generation of electricity also relies primarily on fossil fuels, their use has grown exponentially (figure I.15).

Figure I.16
Trends in fossil fuel consumption and CO_2 generation, 1980-2007



Source: Jackson (2009a), p. 50.

The second industrial revolution introduced harmful non-biodegradables

While the first industrial revolution changed the nature of the energy source, enabled production using machines (instead of muscle) and increased the importance of metal (which was necessary to produce those machines), the second industrial revolution's major achievement was the development of the chemicals industry, which resulted not only in the processing and refining of substances already available in nature but in the manufacture of new ones. Unfortunately, many of these new products, such as plastics, turned out to be non-biodegradable.

The introduction of new energy sources and new materials has gone hand in hand with the development of an ever increasing range of products, at least in developed countries. At the same time, progress has also led to the production of spurious articles of consumption and the shortening of product life, both of which have led to the waste of physical and human resources.

The new technological revolution has to overcome dependence on fossil fuels and non-biodegradables

The new technological revolution will have to reverse the undesirable impacts of the past technological revolutions, while preserving and enhancing their positive achievements, which means: reversing the dependence on fossil fuels; reversing the trend towards increasing use of non-biodegradables; conserving resources by reducing the resource requirement per unit of output and the production of luxury consumption goods, and by increasing the durability of goods produced; reducing waste by a switch to renewable inputs, and by making reuse and recycling of non-renewable inputs almost universal; reversing the process of land degradation and making it possible to feed the additional 3 billion people who will inhabit the Earth by 2050, without exceeding its capacity; and making it easier for societies, particularly in more vulnerable parts of the world, to protect themselves against natural hazards which are becoming more frequent.

To be successful in achieving the goals set out above, the technological revolution for a green economy will possess certain features that are critically different from those of previous revolutions.

A technological revolution like no other

A compressed time frame

Only three or four decades are left!

Unlike previous technological revolutions, which were by and large spontaneously unfolding processes which could take as much time as they needed to attain their objectives, the green technological revolution must be carried out within a much more compressed time frame given the acuteness of the environmental crisis. Its gravity is reflected most clearly in the climate change threat, which, as already indicated, will require drastic cutbacks in greenhouse gas emissions by 2050 in order to avert risking catastrophic impacts. In other words, the related technological transformation will need to be accomplished over the next four decades. Many other dimensions of the environmental crisis—such as loss of species, land degradation and desertification, deforestation and loss of freshwater and groundwater reserves—call for a similar urgency and compressed time-frame. However, achieving the necessary technological transformation under such constraints will be a huge challenge, since it is well known that diffusion of technology is a slow process and that previous technological revolutions typically took much longer (about 70 years or more) (Wilson and Grübler, 2010; and chap. II).

Greater social guidance and a greater public role

Governments played important roles in past technological revolutions …

Contrary to conventional wisdom, Governments played an important role in previous technological revolutions. For example, machine-based cotton textile production during England's first industrial revolution would not have flourished without the support of the British Government's colonial and trade policies, which ensured that colonies served as sources of raw materials and as captive markets. Steam engines would not have developed as they had without the Government's decision to fit out all Royal Navy vessels with steam engines. The rise of the chemicals industry in the second industrial revolution derived great benefits from the protectionist policies of the Governments of the second-generation industrializing countries. More recently, the development of nuclear power plants has owed much to the war-related focus on the development of the atom bomb. Finally, the development of the Internet owes much to the communications-related projects of the United States Department of Defense. At the same time, a large part of technological diffusion has depended on market-based processes.

… and will have important roles in the technological revolution needed now

Governments will have to play a much more central role in inducing the technological transformation needed to achieve the objectives of the green economy for a number of reasons. First, there is the aforementioned matter of the faster pace required: The needed acceleration of technological innovation and diffusion is unlikely to occur if left to spontaneous market forces. Equally important is the fact that the natural environment is a public good and consequently not "priced" by the market. Although there are markets for green technologies, they are just developing through the implementation of government policy. Governments will then have a key role to play in promoting more extensive research and development and diffusion of green technologies, inasmuch as the benefits accrue to societies as whole. In addition, since existing brown technologies are presently locked into the entire economic system, a radical shift to green technologies will mean adjusting, improving or replacing much of the existing infrastructure and other investments. Such transformations will be costly and will require large-scale long-term financing, which it is unlikely will be mobilized in full through private initiatives. Hence, government support and incentives will be required. Thus, not only will strong technology policies be required, but they will need to go hand in hand with active industrial and educational policies designed to generate the necessary changes in infrastructure and production processes.

Industrial policies are necessary for inducing the new technological revolution

Industrial policies will be needed to actively promote production activities and processes that reduce resource requirements, substitute renewable inputs for non-renewable ones and replace non-biodegradables with biodegradables. Such active government intervention will be essential inasmuch as prices, as determined in unregulated markets, would not be reliable indicators of environmental impacts and long-term resource constraints and hence would be incapable of guiding decisions on incentives to investments and resource allocation for sustainable production. The core of this strategy should be a strong technology policy with a focus on adaptation and dissemination of green technologies and the treatment of green economic activities as "infant industries" which require appropriate support (subsidies, preferably time-bound, access to credit and perhaps some level of trade protection). A green industrial policy would give preference to new public and private investment that contributes to sustainable development, has good prospects as regards generating backward and forward linkages in the economy, and is aligned with broader development priorities. Such actions should be supported by public sector investments directed towards developing the necessary infrastructure and providing the poor with access to basic energy and water and sanitation. This would also include implementing appropriate regulation, pricing policies, taxes and subsidies designed to limit pollution and emissions, to control overexploitation of natural resources and to ensure that prices better reflect environmental values, as well as mainstreaming environmental criteria into government procurement policies. Under no circumstances, however, should the poor be penalized, especially when the products or services concerned are essential ones. Thus, if water is generally underpriced, then when its price is being revalued, a system of differential pricing should be put in place so as to ensure access for the poor.

Greater international cooperation

New technologies will involve "public goods" and, often, "global public goods" …

The green technological revolution will also necessitate greater international cooperation than was required in carrying out previous ones, as the result of several factors. First, the foci of many of the green technologies are regarded as public goods. The protection of these components of global commons, encompassing, inter alia, the atmosphere, oceans, open-capture fish stock, biodiversity and ecosystems, is not possible through efforts of individual nations only. Instead, cooperation of all nations is necessary for the development and deployment of technologies that can protect these commons.

… and hence the technological revolution will require global cooperation

Second, through international trade and investment, incomes and consumption in one country are linked to the ecological footprints left by the countries of production. Multilateral environmental agreements, trade and investment rules, financing facilities and intellectual property right regimes would all need to be aligned so as to facilitate the green technological transformation. Since the majority, though not all, of existing new technologies are owned by the advanced countries and the cost of stimulating green technological change will be much higher for developing countries relative to their incomes, there will be important distributional considerations associated with greening the global economy, which will also need to be addressed through financing facilities and other new mechanisms of international cooperation.

Developing countries will have an important, role to play as "partners" in the new technological revolution

The required greater international cooperation emphasized above must encompass greater cooperation between developed and developing countries. During previous technological revolutions, beginning with the first industrial revolution, the role of developing countries was a limited one. Mainly, they were relegated to the status of colonies supplying material resources and providing captive markets. Based on their historical role, these countries continue, generally, to be viewed primarily as receivers of the technologies produced in developed countries. However, if the technology revolution for a green economy is to be successful, developing countries will need to be true partners in developing, utilizing and generally sharing the new technologies.

In actual fact, developing countries themselves now constitute quite a diverse group, embracing a wide range of technological capabilities. Countries such as China, India and Brazil are already playing a leading role in developing, manufacturing, deploying and exporting (including to developed countries) various green technologies (such as solar panels, wind turbines and biofuel technologies). Moreover, global value chains, which extend across developed and developing countries and represent a new global division of labour, cannot be subsumed under the traditional technology transfer paradigm based on the "provider-receiver" relationship. Instead, many developing countries are already partners in the innovation, production and deployment of green technologies. This role will likely become increasingly important and its impact more widespread in the future. Further, even developing countries that do not participate in the current global division of labour associated with engagement in the development and production of green technologies can play a significant role as potential markets for these greener technologies. Expansion of scale is the most important means by which the current high cost of many green technologies can be brought down. The large populations of developing countries can provide that scale if they, too, develop and can afford these new technologies and products. Thus, adaptation of green technologies by agents in developing economies will be essential in accelerating the processes whose aim is to make the green technologies commercially viable.

The development-related aspirations of developing countries offer both a challenge and an opportunity in the context of the green technological transformation

Thus, the development-related aspirations of developing countries pose both a challenge and an opportunity for the green technological transformation. Those aspirations pose a challenge to the extent that the green economy-related objectives will have to accommodate developing countries' pressing need to achieve higher levels of material welfare. At the same time, their aspirations present an opportunity, because many developing countries are still at the early stage of urbanization, entailing the transition from traditional to modern fuels and other hurdles. Hence, switching (or leapfrogging) to green technologies may prove easier in some developing countries than in developed countries, which face the task of converting already built brown technologies and infrastructures into green ones. Developing countries can therefore provide experiences of greening which may be instructive for developed countries.

Societal transformations

Societal changes are necessary as both a precondition for and a complement of technological transformation

Greening the economy will require major societal transformations for reasons related to supply and demand. On the supply side, policies and institutions required to foster the necessary technological transformation may not be implementable without a societal transformation. On the demand side, consumption habits and living patterns must adapt to changes in the nature and packaging of products and modern conveniences. Moreover, as noted above, the desired technological transformation might not evolve at the necessary pace and scale, so that supply-side changes may not prove sufficient: demand-side changes would then be required, such as those discussed above under "limits to growth". These demand-side changes, however, could not be expected without a radical societal transformation. The examples below illustrate these interconnections.

Transforming settlement, transportation and consumption patterns

Societal changes can conduce to the achievement of necessary changes in consumption patterns

Much of the material and energy consumption of a society is determined by the settlement patterns, as illustrated by Japan's compact form of urbanization, which partly explains why the energy intensity of its economy is significantly less than that of the United States of America (Duro and Padilla, 2011). It is true that Japan's compact urbanization has been, to a large extent, dictated by the country's mostly mountainous physical terrain, where whatever limited space for settlement and urban development exists is found around the mouths of rivers. Nevertheless, Japan's experience does demonstrate that opting for compact urbanization is one way to keep material and energy requirements down.

Settlement and transportation patterns also influence consumption patterns. Spending on housing and household goods and services now constitutes the most important share of personal consumption. By contrast, the share of food in total consumption in developed countries is now very limited. Meanwhile, spending on housing and household goods depends critically on the size of houses, which depends in turn on the settlement pattern. Compact urbanization generally leads to apartment living, whereas urban sprawl leads to residence in large-sized houses, which require more energy, more furniture—more, in fact, of almost everything.

Urban income growth will generate shifting consumption patterns

The world is poised to experience further urban growth in the near future, especially in developing countries. Along with urban income growth, this will give rise to shifting consumption patterns. Protein-rich food consumption will rise, with commensurate increases in the pressure on land stemming from the demand for its use in livestock production. The demand for non-food consumption should also be expected to rise along with resource use and waste production, if the demand is to be satisfied through prevailing technologies. Such trends will enhance the need for the green technological transformation, but they would also suggest that policies designed to influence consumer behaviour will be just as critical in facilitating the transition towards a sustainable development path.

Changes in the social value system

Societal changes will require changes in social value systems

The required technological and societal transformations necessary for greening the economy and ensuring sustainable development and poverty reduction without exceeding the limits of the Earth's capacity will not be possible without changes in the social value system. Communities have to begin placing greater value on the Earth's natural environment as constituting a resource to be shared among current and future populations. Social and political discourse and public priorities must increasingly reflect such a change in values; and societies must ensure that the tools they use for measuring social and economic trends, such as the concept of economic output,[19] also reflect those values, so that feedback can be provided on the progress being made in respect of their integration in people's lives. Changing individual and social values is likely to be an even greater challenge than that of transforming technology, production processes and consumption patterns.

The agenda

The dimensions of societal transformation that have been presented in this chapter extend beyond the scope of the present *Survey*. Still, by keeping these issues in the foreground, this *Survey* will be better able to focus on the technological transformation challenge within a few key areas. Chapter II explores the issues of transformation as related to the energy sector, where progress is critical to overcoming poverty, mitigating global warming and protecting the Earth's natural environment. Chapter III, which calls for a truly green agricultural revolution, examines the challenges of protecting ecosystems and ensuring sustainable management of land and forests. Chapter IV focuses on how human societies can protect themselves against the increasing incidence and intensity of natural hazards, many of which arise through profligate resource extraction and waste generation. Chapter V examines in detail national institutional arrangements that are conducive to the necessary technological transformation. The final chapter considers the issues of global coordination and institution-building, which are vital to the achievement of the green technological transformation.

19 See United Nations and United Nations Environment Programme (2000) for an example of efforts directed towards integrating the environmental dimension with national income accounting; and also chap. 29 of the 2008 SNA (European Commission, International Monetary Fund, Organisation for Economic Cooperation and Development, United Nations and World Bank, 2009) (http://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf) where the concept of environmental accounting is fully embedded in the system of national accounts.