Chapter V

The energy transformation challenge

Summary

- The latest estimates confirm that trends in emissions are likely to lead to increases in world temperature which could have catastrophic consequences. Even after accounting for recent mitigation policies—including expanded use of renewable energy sources and improvements in energy efficiency—the accumulated concentrations of emissions will be well above the safety mark of 450 parts per million of carbon dioxide equivalent by 2050.
- Pathways to an energy transformation for sustainable development are multiple: there is flexibility in the energy technologies that need to be available and in the sectors in which energy efficiency should improve, and there are options with respect to the economic, social and cultural envelopes that could contain the increase in emissions, while still allowing for a rise in welfare.
- Despite their variety, sustainable pathways share some common ground. First, the sooner policies scale up, the greater the technological flexibility will be and the less costly mitigation will become. Second, policies increasing efficiency in the delivery of energy services can go a long way. Indeed, if it chooses to, the world can avoid the use of controversial technologies with high risks and high costs, including nuclear power and carbon capture and storage.
- This Survey finds a certain degree of technological over-optimism in the assessment of sustainable pathways. While technology per se might not be the main limiting factor, its implementation faces challenges. In this regard, our analysis is less sanguine about the economic, social and cultural hurdles to be overcome in implementing the decisive and coherent national policies that are called for, as well as in securing the commensurate level of international cooperation. The world needs a public investment-led big push, capable of catalysing private sector investment and innovation so as to sustainably transform the energy system.
- The sustainable energy transformation is consistent with economic and social inclusion; moreover, policies promoting economic and social inclusion can, in some cases, also result in reduced emissions. Universal access to clean cooking fuels and electricity can be consistent with measures to contain the increase of emissions and, pertinently, this can be achieved at a comparatively modest investment cost:
- The investment necessary to render the energy system sustainable is, in principle, affordable. However, the full costing of investment needs calls for resource allocations several times larger than the direct energy investments that are needed to keep the world on a sustainable pathway. Additional investments needed to achieve universal access to modern energy by 2030 are, in comparison quite affordable.

Introduction

The world economic system is in need of deep transformation as a means of re-establishing a balanced relationship with the Earth's boundaries while accommodating the legitimate development aspirations of the billions of people who would like to have access to quality and nutritious food, decent clothing and shelter, health, good-quality education, water and sanitation, and modern amenities. At the heart of this transformation lies the revamping of the world "energy system," as it is energy that underpins the production of the goods and services that sustain human life. The energy system harnesses natural resources and transforms them into energy carriers, to be used by the appliances and machinery that provide energy services, such as heat, refrigeration and transport. Providing energy services to current and future generations requires energy systems that are sustainable, in terms of both the use of natural resources and the disposal and absorption of the pollutants associated with the generation and use of energy. To the extent that an energy system is engaged in multiple interactions with the economy, society and the environment (including interrelations with other physical resource and commodity systems), the only way to build sustainability in the energy system is to introduce sustainable management of those economic, social and environmental interactions.

The transformation of the energy system should be a core element in any agenda for sustainable development that aims at improving the living standards of people within a framework of equity and environmental sustainability. In the context of the Secretary-General's Sustainable Energy for All Initiative and at other occasions, explicit energy goals (or targets) are needed to eradicate dependence on traditional use of biomass as a source of thermal energy; to improve access to reliable and adequate quality electricity; and to ensure that unreliable or low-quality energy sources do not compromise the opportunities of those among the working poor who are self-employed or run household enterprises.

Achieving these objectives entails confronting the challenge of formulating policies that adequately resolve the issue of potential trade-offs and take advantage of potential synergies. Policies need to explore possible synergies with other development goals, by promoting, for example, health, education, training and employment creation through improvement of workers' skills in the areas of design, deployment and maintenance of sustainable energy systems.

The evidence for climate change and human-activity generated emissions

A large number of studies have examined current energy trends and found them to be outright unsustainable. They do, however, offer alternatives and have proposed a variety of paths that have the potential to re-establish a balance between human activity and Earth's carrying capacity. Presented below are some of the major institutional exercises focused on energy trends and alternative sustainable pathways.[1]

1 The release by the Intergovernmental Panel on Climate Change of its Fifth Assessment Report (to be finalized in 2014) will further enrich our understanding of sustainable paths.

The room for effective action is shrinking

The latest assessments of energy trends confirm the urgency of transformative action to prevent undue accumulation of CO_2 and risky increases in temperature

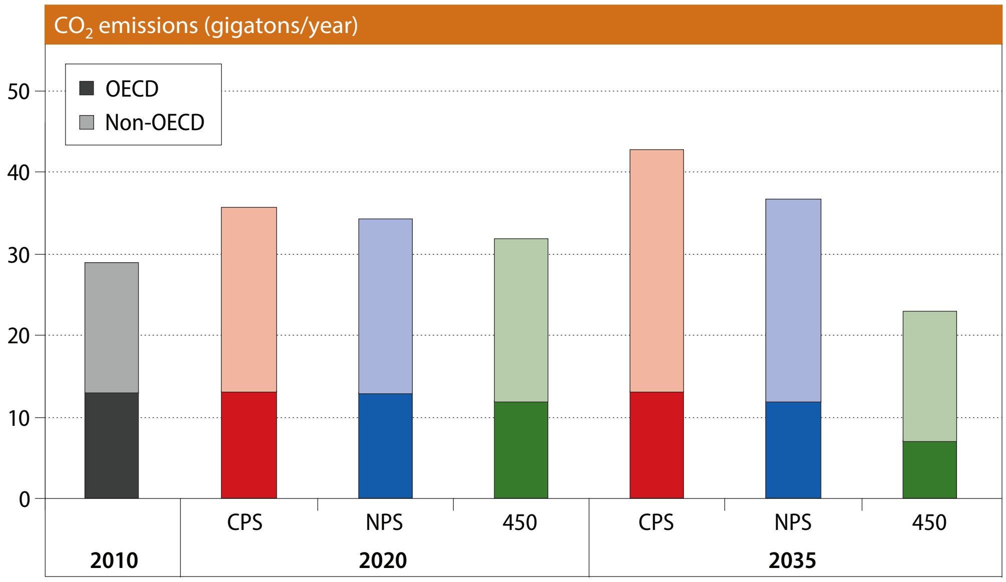
The growing body of analytical evidence provided by the scientific community unmistakably confirms that current incremental policies will not suffice to keep human impact within the Earth's boundaries. If current trends continue, the further infringement of those boundaries will lead to a dangerous increase in the risk of devastating consequences. If one looks at the rise in the use of renewable energy, the advances made in reducing pollution in many cities, the increase in the number of protected areas, the implementation of policies to improve sustainable use of natural resources, and the adoption of international agreements to improve environmental sustainability, the world is probably greener today than it would have been if no actions had been taken. Certainly, the world is, increasingly, using energy more efficiently and there has been a 25 per cent improvement over 1980 efficiency indicators. Some countries, notably China, and some regions have achieved large improvements. However, even after taking into account all of these actions, the likely outlook does not meet desired emissions reduction targets. Simulations incorporating current economic and demographic trends, energy policies, emissions levels and current commitments indicate that present efforts do not suffice to maintain accumulated emissions within acceptable boundaries and safe temperature limits. Introducing policies and regulations that can effectively bring about a shift to a sustainable energy path is becoming evermore urgent.

World Energy Outlook 2012 (International Energy Agency, 2012) considers two baseline scenarios and presents estimates extending to 2035. The "current policies scenario" includes the implementation only of policies that had been adopted by mid-2012. The "new policies scenario" includes all policies in the current policies scenario plus a cautious implementation of recently announced policy commitments and the expected impact of adopting new technologies (ibid.). In a sense, then, the second baseline scenario takes an optimistic view of recent policies and technology development, mainly because it assumes that they will be fully implemented. A comparison of these baseline scenarios highlights two important points. First, new policy and technology developments are important steps in the right direction, for they imply a noticeable lessening in the increase in emissions between 2010 and 2035 (figure V.1). Second, even after optimistically accounting for recent green developments, the world is still a long way from a sustainable pathway, as emissions will still be well above the sustainable prescribed level. While the current policies scenario implies a long-term average increase in global temperature of 5.3º C, the updated new policies baseline scenario softens the impact on world temperature by 1.7° C, yet still leads to a risky increase of 3.6° C. Based on scientific assessments, it has been established that world temperature should not increase by more than 2º C.

A comprehensive review by the Intergovernmental Panel on Climate Change (2012c) of 16 global energy-economy and integrated assessment models found a remarkable increase in the use of renewable energy in many baseline scenarios. Based on the increases in the use of renewable sources of energy foreseen by such baseline scenarios, by 2030 the level of use of renewables will have doubled. Under other scenarios, the use of renewable energy will be 3 or even 4 times the current level. Yet, again, these baseline scenarios result in emissions implying dangerous increases in world temperature.

The baseline scenario presented in *OECD Outlook 2050* (Organization for Economic Cooperation and Development, 2012c) implies that concentrations of

Figure V.1
Global energy-related CO_2 emissions by scenario, OECD and non-OECD, 2010, 2020 and 2035



Source: International Energy Agency (2012), p. 52, Figure 2.2.
Note: NPS = new policies scenario; CPS = current policies scenario; 450 = 450 scenario.

greenhouse gas emissions will rise to 685 parts per million (ppm) of carbon dioxide equivalent (ppm CO_2e) by 2050 and to over 1,000 ppm of CO_2e by 2100, well above the internationally agreed target of cumulative concentrations of required 450 ppm of CO_2e by 2050 required to stabilize world temperature (Intergovernmental Panel on Climate Change, 2007b). These increases in greenhouse gas emissions will lead to temperature hikes ranging between 2.0º C and 2.8º C by 2050 and between 3.7º C and 5.6º C by 2100. The predicted business-as-usual emissions are thus likely to trigger increases in world temperature with potentially disastrous consequences for the environment and people's well-being: aggravated losses of biodiversity, increased pollution in cities, heightened competition for water and a doubling of the number of premature deaths.

The projections and reviews of scenarios undertaken by the United Nations Environment Programme (UNEP) (2012b) also suggest that current policies and underlying trends fall short of what is required to prevent risky increases in world temperature. UNEP scenarios are presented in conformity with countries' emissions reduction pledges under the United Nations Framework Convention on Climate Change,[2] i.e., from the time commitments were made to the year 2020. According to UNEP estimates, current commitments are insufficient and will likely lead to a rise in temperature of more than 4° C. To stay within the safe temperature range, the world needs to reduce emissions by another 14 gigatons (Gt) of CO_2e ($GtCO_2e$)/year by 2020, beyond current commitments to reductions in emissions.

The many paths to a sustainable energy transformation

There are a large number of pathways towards transforming the energy system so that the world can achieve sustainable development

There has been progress in the understanding of the changes that will be required to achieve a sustainable energy transformation that keeps the Earth within safe boundaries. One overriding message from the hundreds of scenarios that have been produced by scientists is that the world can follow a large number of paths to achieving sustainability.

2 United Nations, Treaty Series, vol. 1771. No. 30822.

The IPCC special report on renewables (2012)

The IPCC special report on renewables (2012c) looks at 164 scenarios presenting the results of policies aimed at increasing the role of renewables in the energy system. Under more than half of these policy scenarios, there is a significant increase in the use of renewables with figures ranging from 64 exajoules (EJ)/year to more than 173 EJ/year and in some instances to 400 EJ/year over current levels (figure V.2). The share of renewables in the energy mix will increase in these scenarios from 13 per cent in 2008 to more than 17 per cent and 27 per cent in 2030 and 2050, respectively. The most ambitious scenarios project renewables sources accounting for about 43 per cent and 77 per cent of total energy in 2030 and 2050, respectively.

The IPCC review suggests that scenarios aimed at controlling emissions more strictly require an energy mix with a higher share of renewables. To what extent renewables can contribute to the control of emissions is still somewhat uncertain, however. For any single level of emissions, there is a wide range of renewable energy combinations that are compatible with that level of emissions; such large variation reflects the difficulty in modelling the environmental impact of renewables, which in part stems from uncertainties surrounding the deployment of renewable technologies (see legend in figure V.2). While there is a need to increase our understanding of the interactions between renewable energy and emissions, the IPCC review suggests a large potential for increasing the use of renewables.[3]

United Nations Environment Programme emissions gap report

Noting the slow progress in international negotiations on reducing emissions, the UNEP report (2012b) looks at scenarios where some important actions to curb emissions occur only after 2020.[4] Comparing these scenarios with scenarios under which most of the significant environmental policy actions occur before 2020 helps highlight important trade-offs. The first observation is that under scenarios assuming strong mitigation only after 2020, there is obviously more flexibility given to the type of changes in the energy system that need to take place in the short term. The trade-off is that under these scenarios, there is greater pressure to accelerate progress after 2020, with the world becoming more dependent on technological breakthroughs to be able to achieve the required reduction in emissions. For example, the UNEP report concludes that not a single later action scenario published up to 2012 can meet the target of controlling the rise in world temperature without bio-carbon capture and storage (United Nations Environmental Programme, 2012b, p. 29). A similar trade-off applies to policy options and societal choices: the widening of options in the short term narrows the room for future policy action (because higher emissions increase the risk of rising temperature and climate changes).

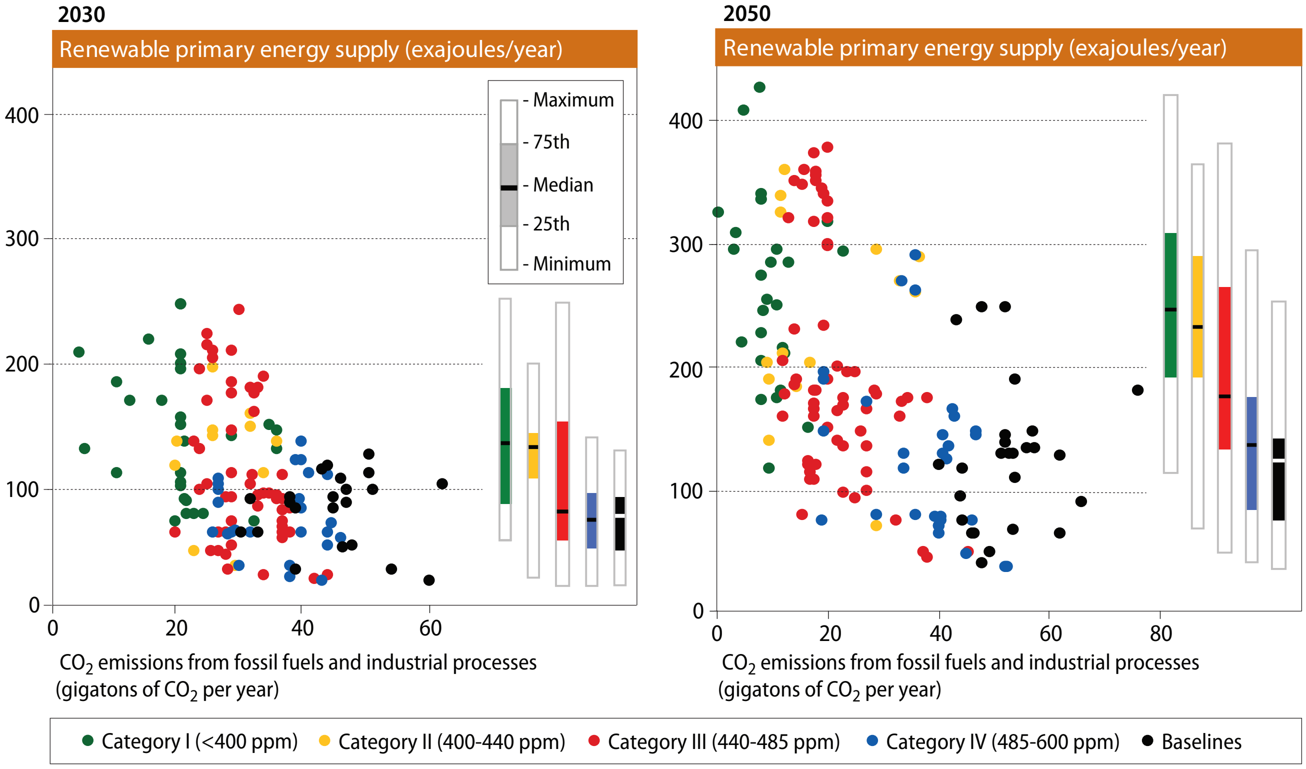
OECD Environmental Outlook to 2050

OECD Environmental Outlook to 2050 (2012c) analyses the costs and benefits of an array of policies aimed at transforming the energy system and avoiding high climate change risks. The OECD core scenario makes several assumptions: (a) that mitigation options are

3 See also the discussion in IEA (2012b), chap. 7 entitled "Renewable energy outlook".

4 There are only a handful of studies that have examine this type of scenarios, including Vuuren and others (2013), Organization for Economic Cooperation and Development (2012c), and Rogelj, McCollum and Riahi (2013).

Figure V.2
Global renewable primary energy supply (direct equivalent) versus fossil fuel and industrial CO_2 emissions, 2030 and 2050



Source: Intergovernmental Panel on Climate Change, 2012c, p. 21, figure SPM.9.

fully flexible, (b) that all the necessary cooperation exists to implement an all-encompassing and harmonized global carbon market and (c) that least-cost mitigation options are adopted. The core scenario is set to achieve the target of keeping the CO_2e concentration at 450 ppm. To achieve the target, this scenario simulates a set of policies that could achieve such a target, including actions to establish a global carbon price, followed by immediate use of least-cost mitigation options in all sectors and regions, and gradual progress in the decarbonization of the energy sector—stimulated by higher carbon prices, extensive use of low-cost advanced technologies, including biomass energy with carbon capture and storage. While the cost to the economy of keeping emissions in check under these assumptions would not be large, it would vary significantly across regions. Costs would entail reductions of 2050 gross domestic product (GDP) ranging from -2.1 percent for OECD countries to -8 per cent for Brazil, India, Indochina and China eliminated, with other regions facing reductions of -4.4 per cent.[5]

OECD explicitly probes the effects of policies designed to curb emissions and the impact that such policies would have on biodiversity, whose boundaries are among the Earth's most severely infringed. Under the OECD baseline scenario, by 2050 the world will have lost 10 per cent of biodiversity, over and above the already reduced level for the year 2010. The set of policies and technologies that lead to limiting emissions to 450 ppm of CO_2e in the OECD core scenario are unfortunately incapable of addressing the loss

5 Reductions in the Russian Federation are of the order of -6.5 per cent (see Organization for Economic Cooperation and Development (2012c), p. 115, figure 3.18, panel B).

in biodiversity. The OECD core scenario reduces the loss of biodiversity by 9.9 per cent relative to the biodiversity in baseline 2010, that is, there is a net gain of 0.1 percentage points over the baseline projection to year 2050. A more detailed look at the simulation helps reveal potential trade-offs. Most policies and positive climate change effects under this scenario reduce the loss of biodiversity by 1.5 percentage points with respect to the 2050 baseline projection, but more intensive use of bioenergy under this scenario effectively adds 1.4 percentage points to the loss of biodiversity. Combining these two figures yields the above-mentioned 0.1 percentage point net gain. Thus, the use of bio-energy to help reduce emissions involves a trade-off of increasing biodiversity loss. Simulations using technology combinations that rely less importantly on bio-energy result in larger net gains. On the other hand, complementary policies can be of great assistance. When the core 450 scenario is reinforced with increases in land productivity, ranging between 3 and 18 per cent depending on type of land and region, the net loss in biodiversity is reduced by 1.2 percentage points.

Global Energy Assessment

The *Global Energy Assessment* (International Institute for Applied Systems Analysis, 2012) builds 60 scenarios that include fundamental changes in energy and development policies, e.g., policies related to the energy sector, changes in the user-end point demand for energy, and changes in the transport sector, as well as policies broadening access to modern energy, enhancing energy security and keeping emissions within safe levels (Riahi and others, 2012). The 60 scenarios are organized around three sets of options. The first set of options includes different combinations of changes in the course of the evolution of the supply of and demand for energy. At one extreme, the world relies mainly on improvements in the supply of energy to meet the needs of a growing and increasingly more affluent world population: the supply path. At the other extreme, the world population is still growing and is becoming more affluent but in this case, measures are taken to improve efficiency in the use of energy: the efficiency path. Between the two extremes, there is a mix of improvements in supply and demand: the mix path. Of particular relevance to an increasingly urbanized world (see chap. III), each of these three configurations of demand- and supply-side changes can be deployed along with two different transport sectors systems: one that continues to rely on conventional technologies and fuels (liquid) and one that uses advanced technologies and fuels (hydrogen and electricity).

The set of three supply and demand possibilities and the set of two transport options, as described, define six technological paths. For each of these six paths, the exercise considers 10 possible variations in the portfolio of technologies, e.g., one where all technologies are available, one comprising all but nuclear, one comprising all but carbon capture and storage (CCS), etc. In total, 60 alternative paths are considered. The results of running these 60 scenarios are measured with a checklist to determine whether or not they meet sustainability goals. Four sustainability goals are defined: (a) to attain almost universal access to electricity and clean cooking fuels by 2030; (b) to ensure that the majority of the world's population live in areas that meet the air quality guidelines of the World Health Organization (WHO); (c) to limit global average temperature increase to 2° C (with a likelihood greater than 50 per cent); and (d) to limit energy trade and increase the diversity and resilience of the energy supply. Scenario results are subject to the test of meeting all four defined sustainability goals. A total of 41 out of the 60 scenarios successfully meet the test, underscoring the view that there are a variety of paths towards keeping emissions and the rise in temperature within safe limits.

The most important insight provided by this ensemble of scenarios is that the world can go a long way towards controlling emissions if there are adequate investments in energy efficiency. The 60 scenarios can be divided into 20 scenarios within the supply path, 20 scenarios within the efficiency path and 20 within the mix path. While all 20 scenarios that emphasize measures for efficiency in demand meet all four sustainability goals, 13 out of the 20 scenarios that assume a mix of supply and demand changes meet the goals and only 8 of the scenarios emphasizing the supply side pass the sustainability test.

The explanation for these results is that the increase in energy efficiency provides enough room for all combinations of the two transportation paths and all five technology portfolios to meet the sustainability goals. If gains in efficiency are small, however, the world becomes more dependent on the capacity to increase the supply of clean energy, which depends in turn on the ability to innovate and adopt new technologies. If substantial efficiency improvements are ruled out, the number of scenarios that meet all four sustainability goals are reduced to only two, regardless of whether or not it is possible to migrate from conventional to modern transport systems.

Another important insight that can be derived from this exercise is that the technologies with greater technological, economic and social uncertainties—nuclear energy, carbon capture storage (CCS), and bio-energy with carbon capture storage (BECCS)—are not indispensable for achieving the four sustainability goals adopted in the Global Energy Assessment exercise. That is, even if the world phases out nuclear energy and/or discards the option of carbon capture storage and bio-energy with carbon capture storage, the four Global Energy Assessment sustainability goals can still be achieved as long as it keeps the demand for energy low and renewable technologies are implemented as assumed in scenarios. The main lesson is that if the world cannot control the demand for energy with efficiency measures, then nuclear, carbon capture storage and bio-energy with carbon capture storage technologies will have to be accepted.[6]

Sustainable energy with economic and social inclusion

Since the IPCC Fourth Assessment Report review (2007b), many energy and climate scenarios have included the assumption that countries' GDP will converge towards the top. Take, for example, the Global Energy Assessment and OECD modelling. The Global Energy Assessment scenarios assume that the country or region with the lowest income will have a GDP per capita of 8,000 purchasing power parity (PPP) United States dollars by 2050 and US$ 26,000 in ppp prices by 2100. This means that regional income disparity, measured as the ratio of the top to the lowest income per capita, will drop from 17 in 2010 to 6 in 2050 and to 3 in 2100. The OECD modelling assumes that by 2050, the lowest country or region GDP per capita will be US$ 13,000 ppp and the ratio of the top to the lowest income per capita will have decreased, in ppp terms, from 12 in 2010 to 6 in 2050. The OECD modelling, explicitly builds changes in GDP based on the effects of a set of growth drivers, including the age structure of the population, the labour-force participation and unemployment rates, and education attainment, among others. The procedure explicitly discusses the role of important interactions determining growth, such as the slowing-down effect that ageing has on growth and the upward effect that education

6 Consistent with the known economic, social and cultural difficulties associated with the use of some of the proposed technologies substituting fossil fuels, the IEA (2012b) sustainable scenarios do not include nuclear energy and carbon capture and storage.

attainment has on labour productivity and thereby on growth. The assumption of GDP convergence is driven by the assumption of convergence in education.

The fact that these models include numerous scenarios where emissions meet the 450 ppm target and income convergence is still allowed for, implicitly demonstrates that environmental goals are consistent with inclusive economic growth. IPCC (2007b) found that models assuming GDP convergence tend to yield lower emissions mainly because the increase in income is allowed to occur in countries where emissions per capita (emissions/population) and the intensity of emissions (emissions/GDP) are lower because resources and technologies are allowed to flow to countries and regions where availability is more restricted.[7] Hence, convergence of GDP per capita not only is consistent with, but might also actively contribute to, environmental sustainability.

Not only is economic and social inclusion, including upward convergence of GDP, consistent with the curbing of greenhouse gas emissions, but it can also be an active contributor in this regard

The relevance of GDP convergence to environmental sustainability goes beyond the reduction of between-country inequalities. Within each country, appropriate and coherent policies promoting upward income convergence can result in great progress towards implementation of an inclusive development agenda. To the extent that social and economic inclusion indicators correlate with GDP per capita, reaching a GDP per capita floor of say 10,000 PPP dollars by 2050 might also mean that the incidence of one dollar-per-day income poverty would be about 5 per cent (figure V.3; see also World Bank (2012b), p. 5, figure 0.2). Similar patterns would apply to other indicators such as child mortality, female literacy, education attainment, health outcomes and access to water and sanitation, among others. All of this suggests that economic and social inclusion, including upward convergence of GDP, is consistent with—and can even be a net contributor to—the curbing of greenhouse gas emissions. Consistency, however, is not equivalent to sufficiency. Economic and social inclusion politices will have to be designed and implemented as the world transforms its energy system.

Income convergence allows for convergence in human development but does not assure it, particularly under conditions of persistent and, at times, aggravating inequalities (see chap. I). Climate change/energy/economy models have also looked at issues of energy and environment-related poverty.

We begin by recalling that the Global Energy Assessment exercise specifically included elimination of energy poverty among its four goals and found that 41 of its 60 scenarios fulfilled all four goals, i.e., universal access to electricity and clean cooking fuels by 2030; compliance of cities with WHO air quality guidelines; limiting the global average temperature increase to 2° C; and limiting energy trade and increasing the diversity and resilience of the energy supply.[8] Although the 60 scenarios incorporate the economic and social inclusion dimensions of sustainable development and establish whether or not they are compatible with the 450 ppm target, the exercise does not indicate what specifically would be required to achieve economic and social inclusion in an environmentally sustainable path. To address this question, the Global Energy Assessment compared two scenarios, one including policies to achieve universal access to clean fuels and stoves for cooking and access to electricity with another incorporating none of these policies. The

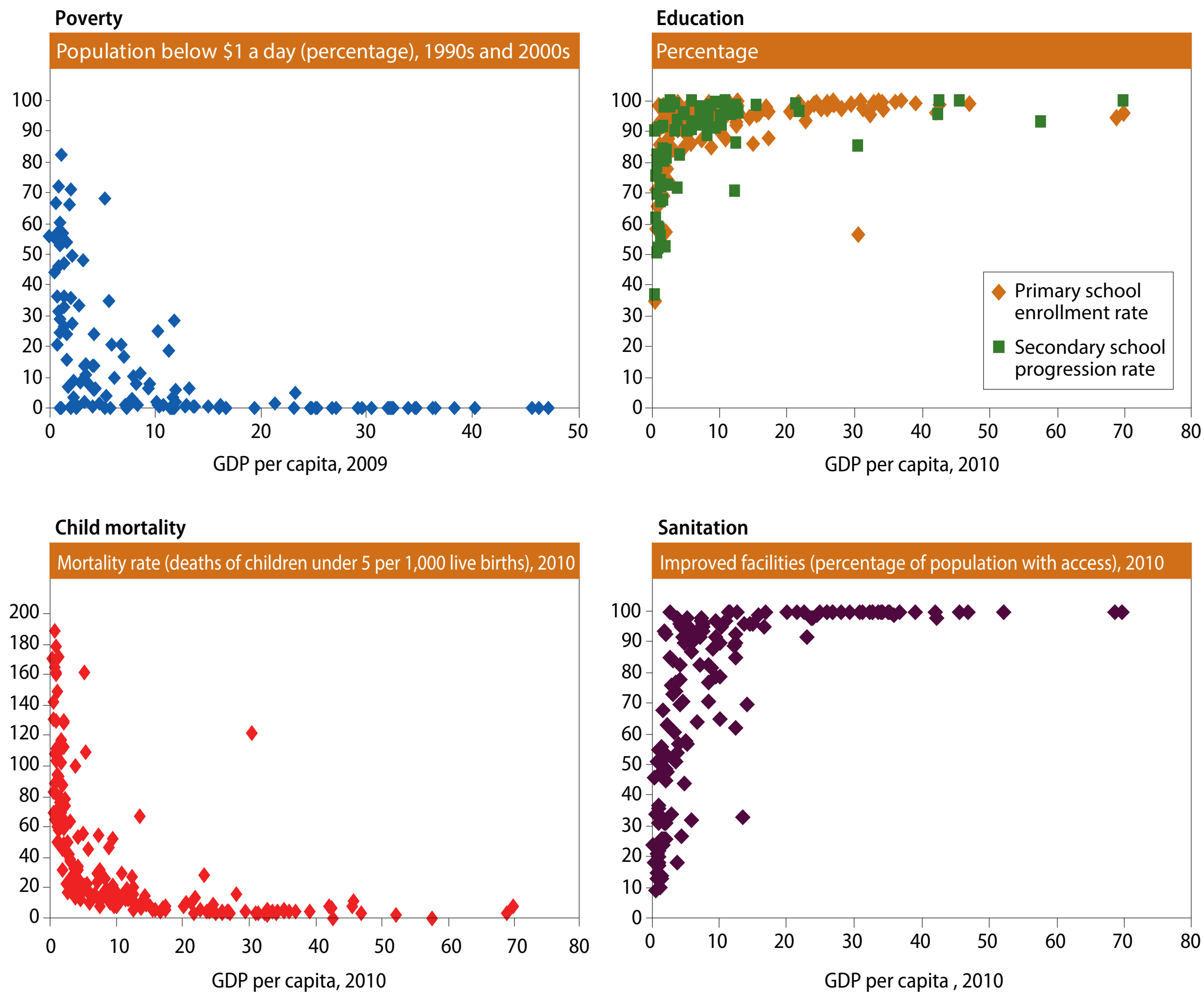
7 In general, scenarios featuring between-regions/between-countries income per capita convergences result in lower emissions because slower growth rates in lower-income countries tend to be associated with slower adoption of low-emissions technologies (Intergovernmental Panel on Climate Change, 2007b, chap. 3, p.177). Accordingly, the more inclusive the income paths underlying energy transformation scenarios are, the larger the gains in the stabilizing of emissions.

8 Rogelj, McCollum and Riahi (2013) also find that access to modern energy, as reflected in the United Nations Sustainable Energy for All Initiative (United Nations, 2012d), is consistent with environmental sustainability.

analysis was carried out for three key regions—sub-Saharan Africa, South Asia and Pacific Asia—where access to modern energy is a critical issue.

The results of the comparison indicate that with the absence of energy poverty policies, 2.4 billion people will still rely on solid fuels for cooking by 2030 (figure V.4), that is, 300 million more people than the 2.1 billion so reliant in 2005. The implementation of the most ambitious package providing clean energy fuel, which combines microfinancing and fuel subsidies to cover the upfront costs of enabling access to modern energy and the purchase of appliances (assuming a 50 per cent fuel subsidy in relation to market prices), has the potential to ensure access to modern energy services for 1.9 billion people who

Figure V.3
Income per capita, and social and economic inclusion



Sources: World Bank, "Global poverty and inequality: a review of the evidence," *World Bank Policy Working paper*, No. 4623 (2008); and World Bank, World Development Indicators.

would otherwise still rely on solid fuels for cooking.[9] This set of policies, however, will still leave 500 million people without access to clean cooking fuels.

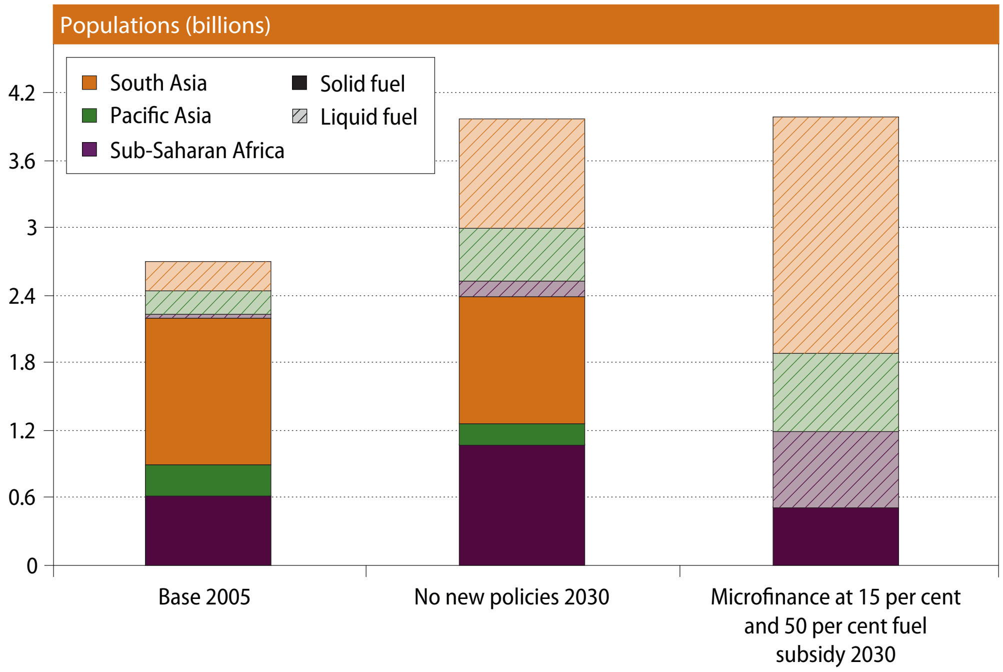
Separately, the Global Energy Assessment looks at access to grid-electricity in the rural areas of three regions: sub-Saharan Africa, Pacific Asia and South Asia.[10] The baseline scenario indicates that in the absence of access to electricity policies, between 70-85 per cent of the rural population of sub-Saharan Africa and 18-23 per cent of the rural population of Pacific and South Asia will still be deprived of electricity by 2030. Implementing policies aimed at providing universal access to clean cooking fuels and electricity in these three regions will have no visible impact on emissions. Actually, greenhouse gas emissions will be slightly lower than the emissions under the baseline scenario.

Providing the world's poor with access to clean cooking fuel and electricity is possible without significantly changing global emissions

The International Energy Agency (IEA) *World Energy Outlook 2012* provides an interesting perspective on access to modern energy and the climate change implications thereof. The IEA core new policies baseline scenario predicts that by 2030, 1 billion people will still be without electricity and 2.6 billion people will lack clean cooking facilities. The simulation of a scenario with granting universal access to clean cooking fuel and electricity indicates that these policies can be implemented without significantly increasing emissions.

OECD Environment Outlook to 2050 examines the benefits of combining environmental policies and policies aimed at reaching the Millennium Development Goal of access to water and sanitation. The report presents a scenario where the number of people

Figure V.4
Impact of access policies on cleaner cooking in three developing regions



Source: Riahi and others (2012), p. 1,263, figure 17.31.

9 The Global Energy Assessment acknowledges that fuel subsidies are controversial (see, for example, International Monetary Fund (2013)), but subsidies in this simulation are used to make access to modern fuels affordable. Other policies specifically designed to address poverty and environmental sustainability, such as tailored cash transfers, might be more appropriate.

10 Owing to lack of reliable data, the analysis leaves out the provision of off-grid electricity, which could be a more appropriate and lower-cost alternative.

without access to improved water in 2005 will have been reduced to half by 2030, followed by universal access to an improved water source and basic sanitation by 2050. The benefits of such a scenario include prevention of premature deaths, better health conditions and economic rewards to such sectors as fisheries and tourism (Organization for Economic Cooperation and Development, 2012c, p. 247).[11]

The brief and selective review of sustainable pathways towards transforming the energy system has yielded the following insights: (a) long-term trends are not sustainable even if the effects of recent mitigation policies are taken into account; (b) transformative changes can follow multiple paths; (c) transforming the energy system is consistent with increasing economic and social inclusion; (d) a closer look at available scenarios warrants the conclusion that not only is mitigation consistent with economic and social inclusion but, in some instances, it also benefits from economic and social inclusion; (e) all feasible paths require policies, resources and international cooperation well beyond current standards and trends. In sum, full sustainable development is possible, but it needs strong policy interventions at global and country levels.

The challenge of transforming the energy system

Successful mitigation and sustainable development face multiple challenges. To begin with, there is the challenge of ensuring that people and policymakers learn from scientific and factual evidence and modify their views and current consumption patterns accordingly. Yet, even if the world is fully convinced of the environmental risks of continuing current trends, the task is daunting. The task involves the timely transformation of the energy system. The accomplishment of this task involves a complex and potentially lengthy process. The "energy system" harnesses natural resources and transforms them into energy carriers to be used by the appliances and machinery that provide energy services, such as heat, refrigeration and transport, among others (see box V.1 on the energy system). Providing energy services to current and future generations requires sustainable energy systems. To the extent that energy systems have multiple interactions with the economy, society and the environment (including interrelations with other physical resource and commodity systems), the only way to build sustainability in the energy system is to introduce sustainable management of those economic, social and environmental interactions. In the present section, we discuss issues regarding two challenges to the transformation of the energy system: the technological challenge and the economic, social and political challenge.

The technology challenge

Technology per se is not the limiting factor. The most difficult obstacles to the implementation of sustainable technologies lie in the economic, social and cultural domains

It is widely acknowledged that many of the technologies necessary for supporting sustainable development are already available. The challenge is how to improve these technologies, how to accelerate cost reductions and achieve meaningful changes, how to integrate them along coherent development paths that respond to specific local and sectoral needs, and how to provide incentives and mechanisms for rapid innovation, diffusions and knowledge-sharing (United Nations, 2011b, p. ix).

11 It should be noted that if instead of access to improved water, the focus shifts to access to safe water, the reduction in mortality rates would be stronger (Organization for Economic Cooperation and Development, 2012c, p. 303).

Climate change-energy models, which look carefully at available and foreseeable technologies, confirm the view that technology is not the main obstacle. For example, the Intergovernmental Panel on Climate Change Special Report on Renewables (2012c), looked at four illustrative scenarios in which emissions were controlled and the use of renewables increased significantly, and noted that in these cases only 2.5 per cent of the globally available technological potential was used (Intergovernmental Panel on Climate Change, 2012c, p. 23 and 796). The UNEP 2012 emissions gap report estimates that the technological potential for reducing emissions between now and 2020 to be anywhere between 14 and 20 $GtCO_2e$, which is enough to accomplish the emissions reductions of 8-13 $GtCO_2e$ that still need to be achieved beyond current reduction commitments. These two examples confirm that current or foreseeable availability of technologies is not the obstacle to achieving environmental sustainability, but also suggest that a significant degree of uncertainty still pervades the assessment of technical possibilities.

Climate change-energy models coincide in pointing out that implementing in the real world the modelled assumptions represents a daunting task. There are technical and engineering obstacles that need to be overcome in order to implement the new technologies (see United Nations, 2011b, pp. 54-58 and United Nations, 2012b). Still more challenging are the unavoidable economic, social and cultural obstacles that will need to be overcome in order to implement new technologies that are to replace the currently dominant fuel-based technology envelope. Obstacles include not only the entrenched interests of the energy industry but also challenges associated with shifts in land use and changes in the economic structure and its associated consumption patterns. Finally, one should not forget that implementation challenges are exacerbated by the fact that changes need to take place in a short period of time (United Nations, 2011b).

The kinds of economic, social and cultural changes that might be involved in switching energy sources are suggested by the following illustration. A technically feasible large-scale plan intended to supply energy from solar sources to 1 billion people in Europe and North Africa and half a billion in North America will require an expanse of solar farms in the Sahara desert and North America equivalent in size to the State of Arizona. The economic, social and political challenges associated with changing land-use patterns so that such large extensions of land can be allocated to the generation of solar energy attest to the magnitude of the obstacles that need to be overcome when scaling up renewable energy alternatives (United Nations, 2011b, pp. 55-56; MacKay, 2009). Another illustration is provided by the seemingly simple substitution of fossil fuel-driven automobiles with electricity-propelled cars. Even if technically feasible and environmentally sound (see MacKay, 2009, pp. 126-132), such a change will not occur unless the retail network that supplies gasoline is altered and the auto repair sector revamped, changes that would require significant investments and might be strongly resisted by vested interests. However, such large investments might be made attractive if the full cost to the environment is properly internalized in the price of buying and using fossil fuel-driven cars.

This simple example also helps to illustrate the role of cultural factors. It is often suggested that a shift to electric automobiles would be out of the question until electric cars could perform at par with fossil fuel-driven cars, as if cultural norms were static and unchangeable. This claim ignores the fact that preferences could (and probably should) change in favour of clean transportation and that it might be possible to change behaviours, tastes and social views if consumers were confronted with prices for fossil-fuelled cars that fully reflected emissions and other environmental costs. If this was the case,

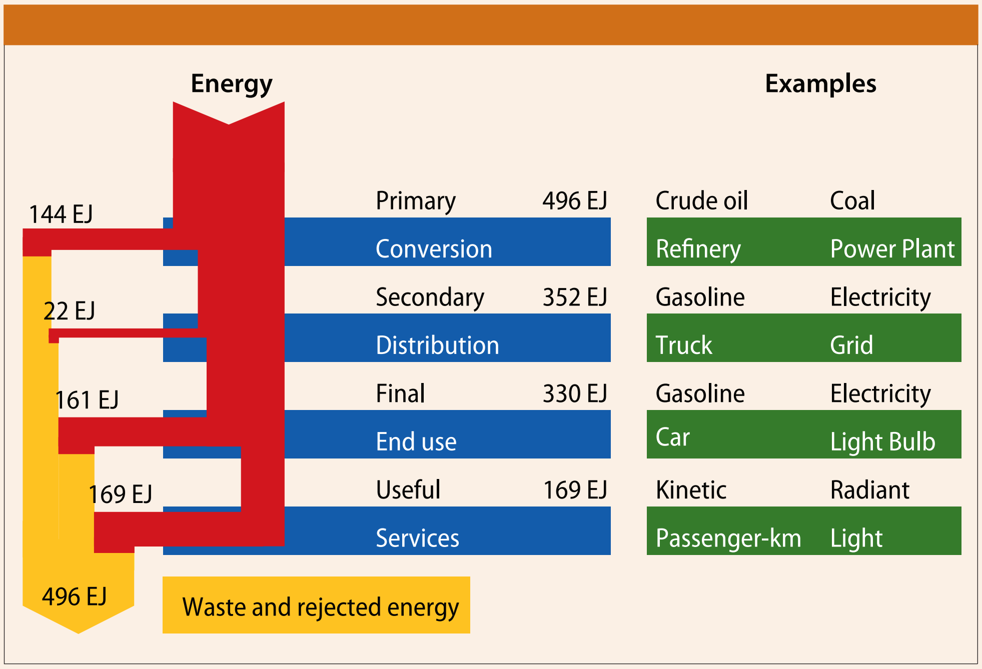
Box V.1

The energy system[a]

The energy system constitutes the ensemble of production, conversion and use of energy and is thus closely linked to the Earth's carrying capacity and to the economic, social and cultural organization of human life (figures A and B). The energy system comprises primary energy resources (e.g., coal, oil and gas) which are converted to energy carriers (e.g., electricity, gasoline and liquefied gas). These carriers then serve in end-use applications for the provision of various energy forms (e.g., heat, transport and light), required to deliver final energy services (e.g., thermal comfort, transportation and illumination).

Energy conversion technologies are the critical component defining the energy system: the energy systems can be characterized by the dominant set of technologies used to convert primary energy resources into useful energy (secondary energy). Energy systems can be further differentiated into the energy supply sector and the end-use energy sector. The energy supply sector encompasses the extraction of energy resources (involving so-called upstream activities), their conversion into suitable forms of secondary energy and their delivery to the locus of demand (involving so-called downstream activities). The end-use energy sector, in turn, handles with the provision of services such as cooking, illumination, heating, refrigerated storage and transportation. The ultimate goal of the energy system is to meet the demand for energy services required to satisfy human needs.

Figure A
Global energy flows of primary to useful energy, including conversion losses (waste and rejected energy), in exajoules (EJ) for 2005

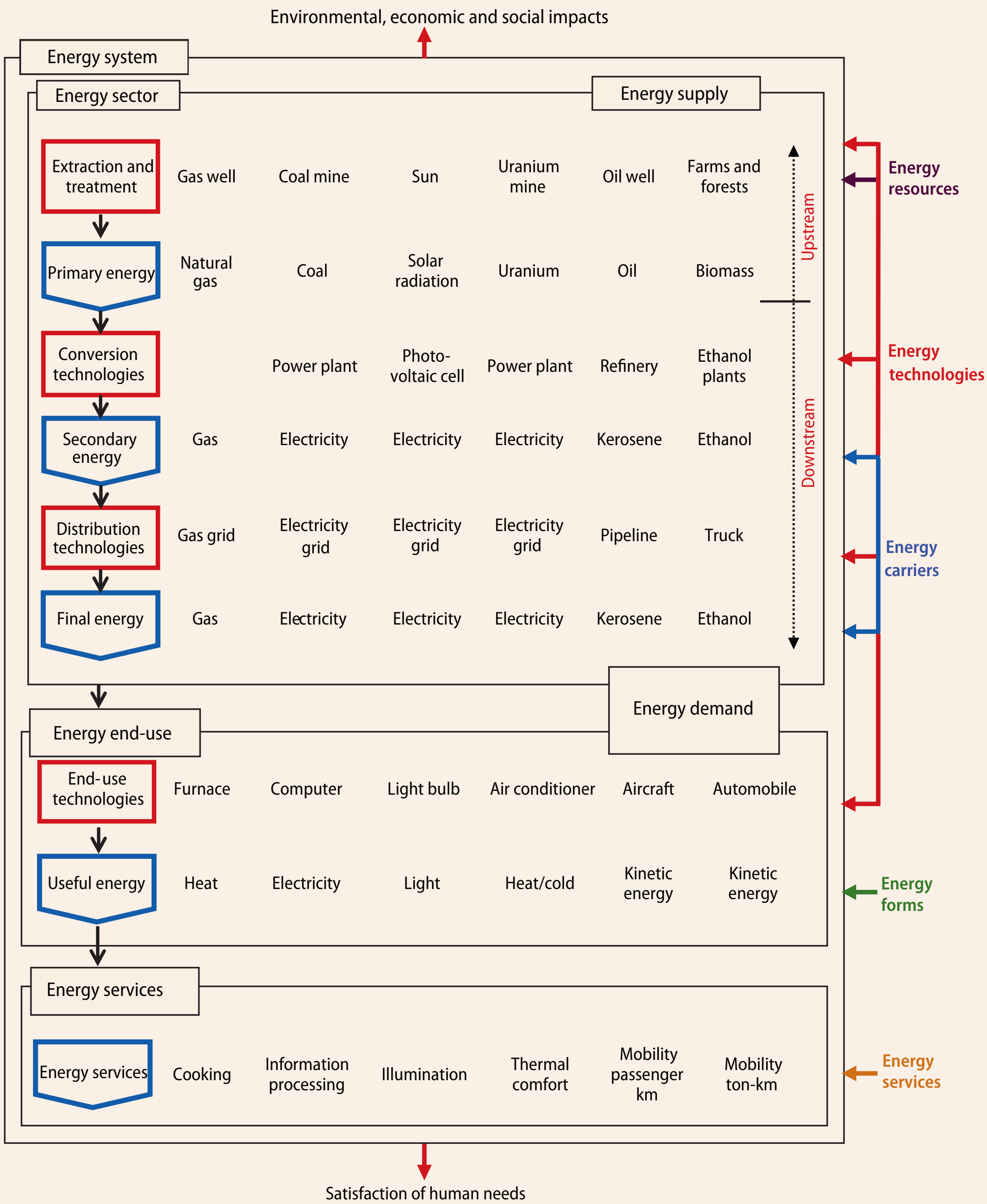


Source: Grübler and others (2012a), figure 1.2, p. 104.

a This box draws heavily on Grübler and others (2012a).

Box V.1 (cont'd)

Figure B
Schematic diagram of the energy system: illustrative examples of the energy sector and energy end use and services



Source: Grübler and others (2012a), figure 1.1, p. 104.

many consumers might find the current performance of electric cars acceptable. In this regard, an example of a rapid change in preferences is reflected in the 2008 introduction of a policy combining bonuses and penalties in France. Reportedly, the introduction of the policy coincided with a sudden 5 per cent drop and subsequent reductions in new cars' average CO_2 emissions (Durremayer and others (2011), p. 8; World Bank 2012b, p. 56).

The investment challenge

The initial investment needed to sustainably transform the energy system implies a significant increase in energy-related investments

Despite the sixfold increase in global investments in renewable energy in the period 2004-2011, investments leading to sustainable development still fall far short of what is needed. The range of estimates is large, reflecting uncertainties about costs that are still not well known; but the large range also reflects differences in approaches and modelling techniques.[12] Investments needed to transform the energy system are usually classified as ranging between energy investments and additional other investments needed to transform this system. Estimates of each of these investments have to deal with a number of unknown or uncertain costs, which results in a large range of estimates, particularly on non-energy investments and investments in developing countries. Synthesizing the investment estimates of the Food and Agriculture Organization of the United Nations (FAO), IEA, OECD, and UNEP, a report of the Green Growth Action Alliance (World Economic Forum, 2013) indicates that the additional investments needed to put the world on a sustainable path are at least US$ 0.7 trillion per year between 2010 and 2030 (World Economic Forum, 2013). This US$ 0.7 trillion figure refers to additional investments that will be needed on a sustainable path in six sectors with readily available estimates (power generation, transmission and development, buildings, industry, transport vehicles and forestry). Estimates of additional investments in other sectors, such as water and agriculture, are not well known or not yet available, e.g., for roads, rail, airports and ports. The US$ 0.7 trillion figure, on the other hand, refers only to additional incremental investments—it does not include investment needed under the business-as-usual greening scenario.

To obtain a rough idea of total additional investments in energy-related sectors, one can simply impute the proportional increase in known sectors to those we still do not know and give a range for variation. Total energy-related annual investments in sectors for which there is an estimate amount to US$ 2.1 trillion in a business-as-usual scenario. In addition to this, US$ 0.7 trillion annual investments are needed in these sectors, an increase of 33 per cent, to set the economy on a sustainable pathway. Now, total business-as-usual investments in sectors for which the report does not include an estimate of additional sustainable investments add up to US$ 2.9 trillion. Applying the same proportional increase of known sectors gives an additional investment of US$ 1.6 trillion; and given the sector variability in additional investments, one can think of a range of from US$ 1.1 trillion to US$ 2.4 trillion (table V.1).

It is worth noting that these estimates confirm the view that investing makes good economic sense. The Green Growth Action Alliance reports that, for some sectors, total investments under a sustainable scenario might actually be lower than business-as-usual investments. For example, the IEA estimates compiled by the Green Growth Action Alliance suggest that annual green investments in power and transmission are 8 per cent lower than the business-as-usual figure (World Economic Forum, 2013, table 1.1). Investments might also be lower in, for example, infrastructure for the transport of oil and gas.

12 See, for example, the discussions of needed investments in United Nations (2011b), pp. 174-175.

Table V.1
Additional investments for sustainable development, 2010-2050

Billions of US dollars				
Sector	*Business-as-usual scenario*	*Additional investments on a 2°C scenario*	*Percentage change*	*Source*
Known additional energy investments for sustainability, 2010-2030				
Power generation	347	160	46.1	IEA
Power transmission and development	272	-21	-7.7	IEA
Energy total	**619**	**139**	**22.5**	**-**
Buildings	358	296	82.7	IEA
Industry	255	35	13.7	IEA
Building and Industrial	**613**	**331**	**54.0**	**-**
Transport: vehicles	845	187	22.1	IEA
Forestry	64	40	62.5	UNEP
Transport and Forestry total	**909**	**227**	**25.0**	**-**
Total known additional investment estimates	**2141**	**697**	**32.6**	**-**
Unknown additional energy investments for sustainability, 2010-2030				
Road	400	-	-	OECD
Rail	250	-	-	OECD
Airports	115	-	-	OECD
Ports	40	-	-	OECD
Transport	**805**	**-**	**-**	**-**
Water	1320	-	-	OECD
Agriculture	125	-	-	FAO
Telecommunications	600	-	-	OECD
Other sectors	**2045**	**-**	**-**	**-**
Total unknown green investment estimates	**2850**	**-**	**-**	**-**
Additional energy investments for sustainability, 2010-2030				
Needed at least*	4,991	697	14	-
Needed lower	4,991	1,148	23	-
Needed mid	4,991	1,625	33	-
Needed higher	4,991	2,361	47	-
Additional inclusion investments for sustainability goals, 2010-2050				
*Lower***	*Business as usual*	*2°C*	*Percentage*	
Clean cooking and electricity:				
Low a	15	34	125	IEA
Low b	n.a.	36	-	GEA
High	n.a.	41	-	GEA
Sanitation and water	n.a.	5	-	OECD

Source: Data from World Economic Forum (2013), p. 13, table I.1, compiling data from IEA, OECD and UNEP; inclusion investment estimates are from International Institute of Applied Systems Analysis (2012), p. 1258, table 17.13; data on sanitation and water from the Organization for Economic Cooperation and Development (2012c), p. 248.

* Only known investment estimates.

** Lower is calculated as the percentage of the first quartile, and higher as the third quartile of the six sector percentage changes.

Green Growth Action Alliance estimates, like any others, are contingent on the policy and technology assumptions of simulated scenarios. The Global Energy Assessment exercise provides useful insights on how assumptions about policies and availability of technologies can affect estimates of needed investments. The Global Energy Assessment estimates total energy supply-related investments at US$ 960 billion in 2010 (Riahi and others, 2012); a figure consistent with the Green Growth Action Alliance compilations. The annual average total energy investments in the baseline scenario is equal to US$ 1.8 trillion, while the mean of the annual total energy investments needed in sustainable pathways is US$ 2.4 trillion. This means the mean additional annual investment in the 41 scenarios is US$ 0.6 trillion (very close to the Green Growth Action Alliance at-least figure of US$ 0.7 trillion). Now, additional sustainable investments vary significantly depending on the assumptions about efficiency demand, mode of transport and portfolio of technologies: the range of additional annual investments in the 41 scenarios starts at the low figure of US$ 0.14 trillion but rises up to US$ 1.16 trillion.

Focusing on efficiency and investing sooner rather than later reduces the size of the total investment needed

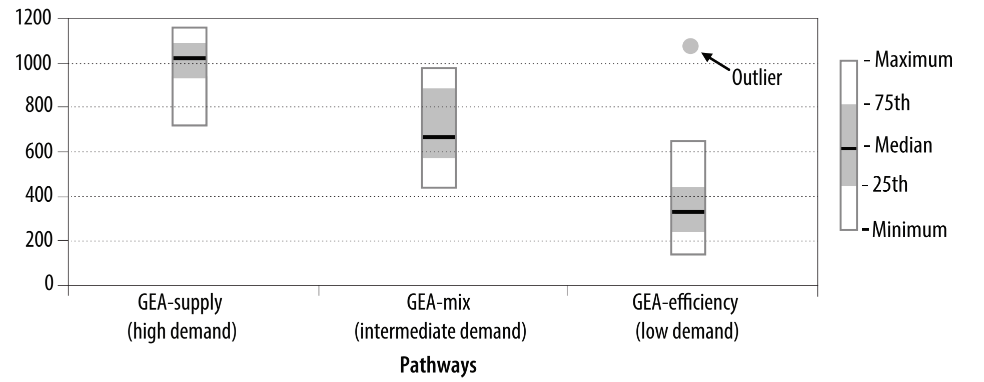
The main driver determining the magnitude of additional investments in the 41 scenarios is efficiency. Pathways stressing energy supply policies have investment tags ranging from US$ 0.72 trillion to US$ 1.16 trillion (figure V.5a). In contrast, pathways emphasizing efficiency tend to necessitate lower additional investments, ranging from US$ 0.14 trillion to US$ 0.65 trillion. Varying technology portfolios reveals interesting investment patterns. Confirming the importance of maintaining flexibility in technology choices, full portfolio pathways tend to have low additional investments (figure V.5b). Portfolios that discard carbon capture and storage technologies tend to have low additional investments, as these are expensive options. Running in the opposite direction, technology portfolios featuring restrictions in the capacity to use renewables or bio-energy raise the range of needed investments. The sharpest upward shift in the range of needed investment is associated with portfolios excluding carbon sink technologies. More restricted portfolios tend to result in some of the highest investment tags, particularly portfolios with no bio-energy, no sink or limited bio-energy. One extreme case illustrates well the importance of maintaining flexibility in technology portfolios. A high-efficiency technology pathway featuring technology restrictions, no bio-carbon storage, no carbon sink technologies and restricted use of bio-energy, turns out to carry an additional investment ticket of US$ 1.08 trillion, way above the US$ 0.32 trillion median investment of efficiency pathways (figure V.5a).[13]

The proportional size of sustainable energy investments is larger for developing than for developed countries

Energy investments differ, of course, by region (figure V.5c). To explore regional investments needs, we should focus on proportional changes, for both baseline and additional sustainable investments might vary significant across regions. While total energy investment in 2010 represents about 2 per cent of global GDP, energy investments in developing countries represent about 3.5 per cent of GDP, but only 1.3 per cent of GDP in developed countries (Riahi and others, 2012, p. 1253). In the Western European Union region, for example, rates are below 1 per cent of GDP, but in the sub-Saharan African region rates are above 3.5 per cent; oil producing regions are characterized by high investment rates, above 5 per cent of GDP (own estimates based on the Global Energy Assessment online database). Additional investments needed to achieve sustainability, relative to the baseline, across the

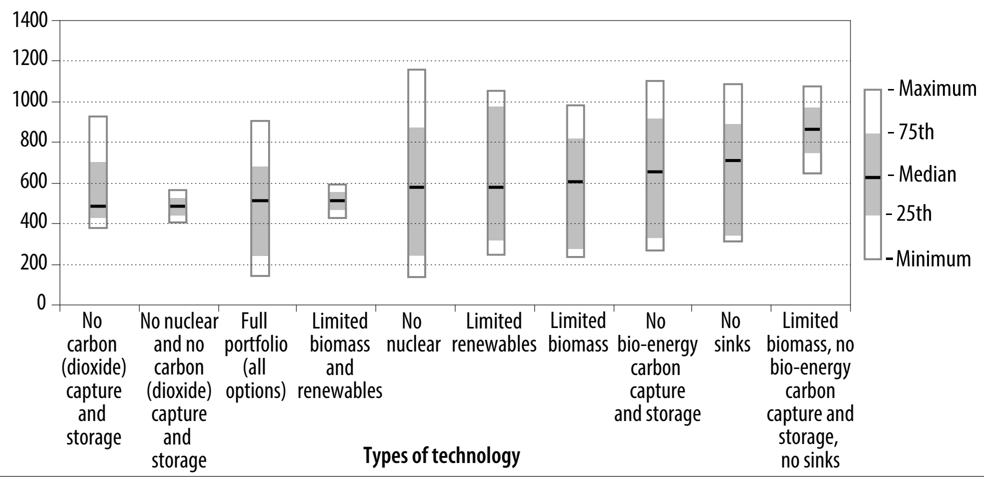
13 The largest investment tickets in Global Energy Assessment scenarios correspond to efficiency (US$ 0.29 trillion-US$ 0.80 trillion), renewables (US$ 0.26 trillion-US$ 1.01 trillion), and infrastructure (US$ 0.31 trillion-US$ 0.50 trillion) (Riahi and others, 2012, Table 17.13, p. 1258). Nuclear energy and carbon capture and storage imply investments ranging from no investment to US$ 0.21 trillion.

Figure V.5a
Additional investments in sustainable pathways, by supply, mix and efficiency policies
Billions of US dollars



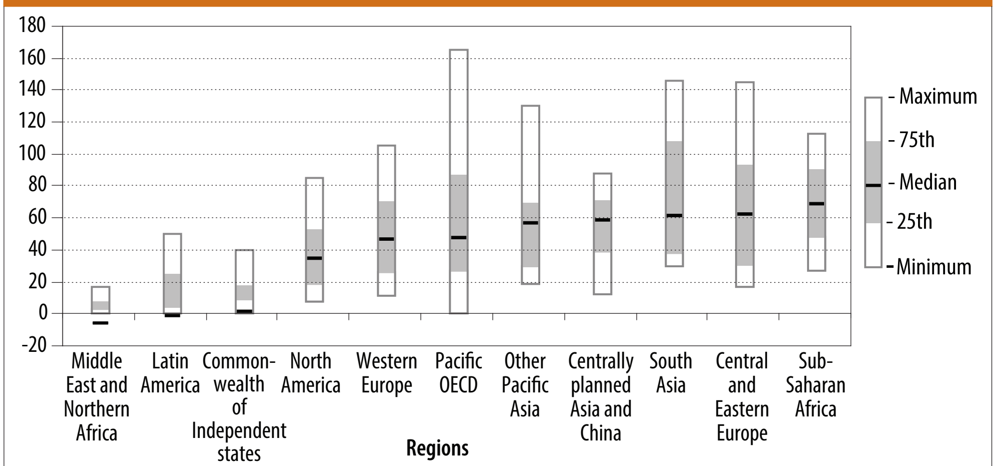
Source: See Global Energy Assessment 2012 online database http://www.iiasa.ac.at/web-apps/ene/geadb/dsd?Action=htmlpage&page=about.

Figure V.5b
Additional investments in sustainable pathways, by technology portfolio
Billions of US dollars



Source: See Global Energy Assessment 2012 online database http://www.iiasa.ac.at/web-apps/ene/geadb/dsd?Action=htmlpage&page=about.

Figure V.5c
Additional investments in sustainable pathways, by region
Billions of US dollars



Source: See Global Energy Assessment 2012 online database http://www.iiasa.ac.at/web-apps/ene/geadb/dsd?Action=htmlpage&page=about.

11 regions and 41 scenarios vary between -18 and 156 per cent.[14] Additional investments cluster in three regional groups: the first group, showing high relative investments, comprises sub-Saharan Africa, Central and Eastern Europe and South Asia; the second group showing medium relative investments, includes economies of centrally planned Asia and China, Pacific OECD, other Pacific Asia, Western Europe and North America, and; the third group showing low relative investments, includes the Commonwealth of Independent States, Latin America and the Middle East and Northern Africa. Minimum and maximum investments by region also tend to cluster in these three groups, albeit imperfectly (figure V.6a). Caution should be exercised when interpreting these estimates. For example, negative regional investments tend to be associated with regions that currently engage heavily in the production and export of fossil fuels, which suggests that the global shift to non-fossil fuel sources of energy implies disinvestment in current production capacity. More generally, caution should also be exercised when interpreting the investment tags for developing regions, as there is a tendency to underestimate required investments in energy infrastructure and shelter in developing countries (O'Connor, 2009).

The size of additional investments also varies with other factors, among which, timing is crucial. According to UNEP, the total cost of mitigation policies that begin only after 2020 is 10-15 per cent higher than the cost of policies that start mitigation promptly in 2013 (United Nations Environment Programme, 2012b, p. 28).[15]

A thorough accounting of energy-related investments and energy services-related investments might multiply by 10 the size of initial needed investments

Investments needed to transform the energy system include investments beyond sectors, namely, investments in rendering sustainable the demand for energy. Investments needed to change the demand for energy are likely to be significantly higher than investments in the supply of energy, but the size of the needed investments is also more difficult to estimate. The Global Energy Assessment report estimates that there are additional needed investments in the demand side of energy ranging from US$ 0.1 trillion to US$ 0.7 trillion (Riahi and others, 2012, p. 1254). These investments include those related to services on engines in cars, boilers in building heating systems, and compressors, fans and heating appliances in households, among others. Accounting for the full cost of demand-side energy technologies increases the investment figure by one order of magnitude, to a range between US$ 1 trillion and US$ 3.5 trillion (ibid.). These include investments in innovation, market formation and diffusion (Grübler and others 2012b, pp. 1691-1695 and 1713-1724).

In contrast, the cost of targeted investments to achieve economic and social inclusion is small. The Global Energy Assessment estimates that policies aimed at providing universal access to clean fuel cooking and electricity will require annual investments ranging between US$ 0.036 trillion and US$ 0.041 trillion (see table V.1 and the above discussion on inclusion). Similarly, IEA estimates at US$ 0.34 trillion the additional investments needed to achieve universal access to clean cooking fuel and electricity.[16] The OECD scenarios simulating policies designed to achieve universal access to an improved water source and sanitation by 2050 find that those policies will require additional annual

14 The range of additional needed global investments across the 41 scenarios varies between 8 and 64 per cent, with a mean increase of 33 per cent.

15 See also OECD (2012c) estimates of significant negative competitiveness and income impacts of delayed action (table 3.8, p. 127, and p. 129, figure 3.24).

16 Energy access is defined here as reliable and affordable access by a household to clean cooking facilities and a first electricity supply connection, with a minimum level of consumption (250 kilowatt-hours (kWh) per year for a rural household and 500 kWh per year for an urban household), which increases over time to reach the regional average.

investments of about US$ 0.005 trillion. One main message stemming from the reviewed scenarios simulating policies designed to achieve energy inclusion is that the investment needed to implement them is well within reach at the global scale.

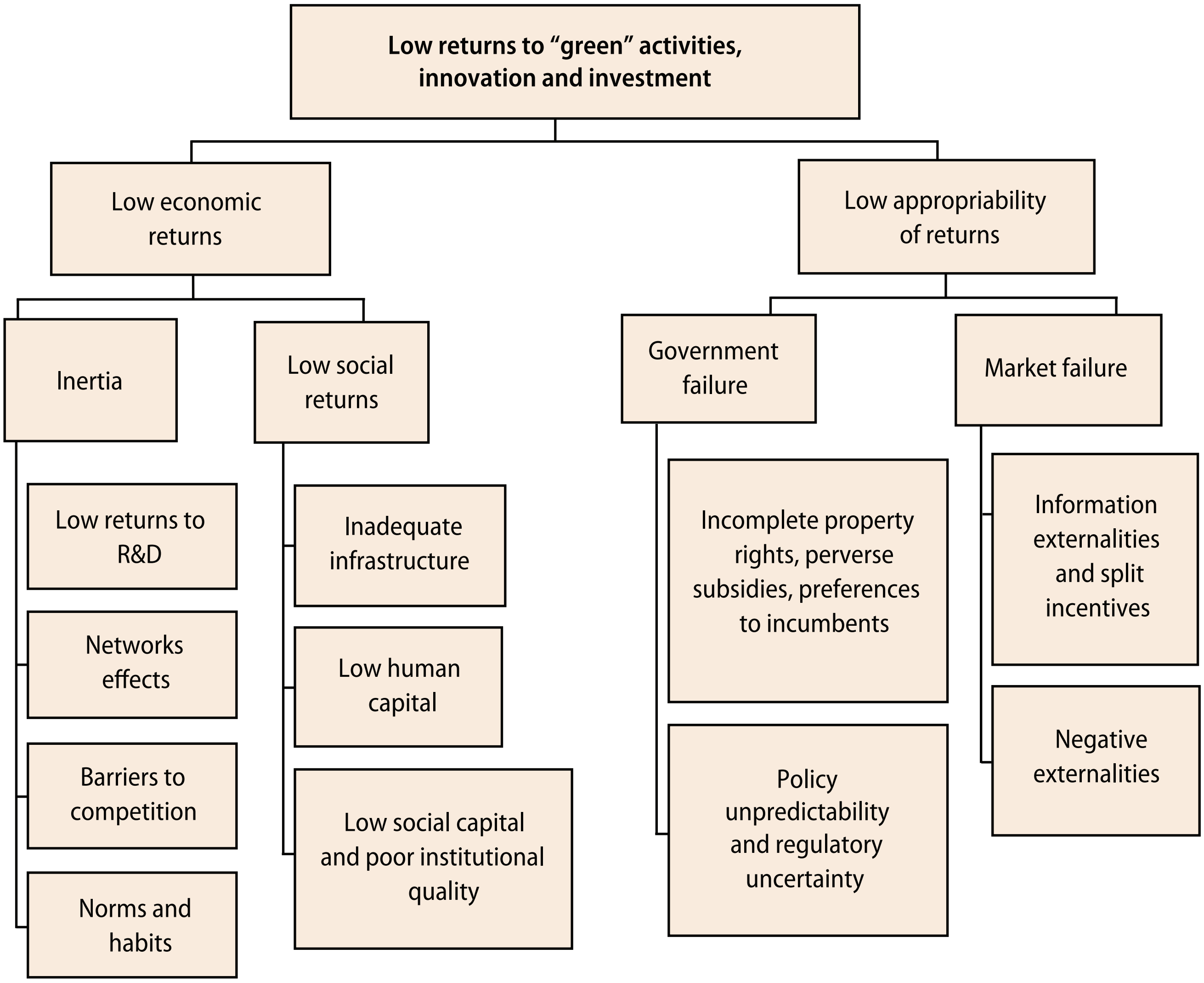
Implementing sustainable development

There is an emerging consensus that the world needs to urgently undertake to achieve transformative changes so as to avert increases in greenhouse gas emissions which have potentially catastrophic consequences. Climate change-energy models have made invaluable contributions to our understanding of the range of possible means of transforming the energy system. Less is known about how to proceed in countries and how best to organize international cooperation so as to effectively transform energy systems in developed and developing countries. Based on analytical contributions, a good number of policy proposals addressing the challenges of sustainable development were put forward in anticipation of the United Nations Conference on Sustainable Development. In the present section, we selectively look at three of those proposals and revisit the proposals broached in *World Economic and Social Survey, 2009* (United Nations, 2009) and *World Economic and Social Survey, 2011* (United Nations, 2011b). The three proposals selected encompass the green energy strategies of Organization for Economic Cooperation and Development (2011a; 2011b), United Nations Environment Programme (2011) and World Bank (2012c). These strategies, which are comprehensive in their coverage of issues, aim at rationalizing the transition from the current state to an alternative path on which the environment is taken fully into account. These exercises offer insights on alternative means of moving towards sustainable development strategies. The emphasis is on the short term: "green growth should focus on what needs to be done in the next 5 to 10 years." (World Bank, 2012b, p. 1). The *World Economic and Social Survey (2009 and 2011)* takes a more ambitious approach. It argues that the world needs a big-push investment-driven transformation of the energy system. We briefly highlight some of the arguments underlying these proposals.

Sustainable development pathways

OECD proposes to tackle the challenges with "an operational policy agenda that can help achieve concrete, measurable progress at the interface between the economy and the environment"; a green growth agenda (OECD, 2011b, p. 11). Policymakers seeking to harmonize the economic and the environmental goals in a green policy agenda face three obstacles, namely, (a) low returns to green investment, which leads to (b) lack of investment and (c) slow innovation. To overcome these obstacles, OECD proposes that use be made of a green growth diagnostic tool which classifies the main obstacles to green growth into those causing low economic returns and those causing low capacity to appropriate generated returns, or low appropriability of returns (figure V.6). The first obstacle (low returns) is further categorized as a problem related to: (a) inertia, as reflected in, e.g., low returns to research and development and the presence of barriers to competition; or (b) low social returns, as reflected in, e.g., infrastructure deficiencies and low human capital. The second obstacle, low appropriability of returns, is further specified as: (a) government failure, as reflected in, e.g., policy unpredictability and perverse subsidies; or (b) market failure, as reflected in, e.g., the existence of negative externalities and informational imperfections.

Figure V.6
Green growth diagnostic



Source: OECD (2012b) p. 128, figure 5.1.

Once the main obstacles have been identified, OECD proposes that effective institutional arrangements and policy packages be built for the transition towards green growth.

This policy package generates useful guidelines for building green-growth strategies for countries at different levels of development (table V.2). For example, developed countries may consider enhancing the link between R&D and technological innovation, investing in low-carbon infrastructures and using market-based pricing of externalities. Developing countries, for their part, could focus on policies designed to enable a shift away from carbon-intensive infrastructure, the promotion of energy efficiency, strengthening government capacities and providing incentives for the development, diffusion and transfer of technology. Least developed countries might consider discouraging open-access to natural resources, increasing productivity in the use of natural resources, designing adaptation strategies and investing in infrastructure to support market access (OECD, 2011a, pp. 1-15; see also OECD, 2011b).

The World Bank sees green growth as "the pathway to sustainable development" and "a vital tool for achieving sustainable development" (World Bank, 2012b, p. xi). It proposes a green growth strategy that rests on three pillars:

(a) Maximizing local and immediate economic or social benefits and avoidance of the lock-in of economies in fossil fuel technologies for several decades (this pillar seeks to prevent irreversibility in the adoption of energy systems and reduce inertia);

(b) Providing incentives to engage in smart decision-making. Examples of the measures covered in this pillar are green accounting (see box II.2), getting prices right so as to overcome behavioural biases, providing incentives and regulations to engage firms in green growth, and using regulations, innovation strategies and industrial policies;

(c) Addressing the problem of financing green growth through the adoption of innovative financing tools designed to tackle high upfront financing needs. The overall strategy allocates different priorities to developed and developing countries (World Bank, 2012b, pp.15-22; see also World Bank, 2012c).

One example of the priority-setting that could emerge from this policy framework, mainly under the second pillar, would entail a focus by developing countries, particularly low–income ones, on two actions: actions that create synergies across the environmental, social and economic dimensions of development; and actions that have high welfare benefits or do not carry large costs (table V.2). This policy framework would recommend developing countries to focus on, for example, measures to reduce local

Table V.2
Some guiding principles for establishing green growth strategies

		Local and immediate benefits	
		LOWER	HIGHER
		Trade-offs exist between short-and-long-term or local and global benefits	*Policies provide local and immediate benefits*
Inertia and/or risk of lock-in and irreversibility	LOWER (action is less urgent)	• Lower-carbon, higher-cost energy supply • Carbon pricing • Stricter wastewater regulation	• Drinking water and sanitation, solid waste management • Lower-carbon, lower-cost energy supply • Loss reduction in electricity supply • Energy demand management • Small-scale multipurpose water reservoirs
	HIGHER (action is urgent)	• Reduced deforestation • Coastal zone and natural area protectiion • Fisheries catch management	• Land use planning • Public urban transport • Family planning • Sustainable intensification in agriculture • Large-scale multipurpose water reservoirs

Source: World Bank (2012b), table O.1, page 17.

pollution, which could provide significant welfare benefits to poor families, by leading to improved health and hence improved labour productivity. As regards developed countries, the strategy suggests a concentration on policies that could exert a long-term impact on emissions.

UNEP closely associates green growth with a process "that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (United Nations Environment Programme, 2010b as quoted in United Nations Environment Programme, 2011, p. 102) and characterizes sustainable development as "improving the quality of human life within the carrying capacity of supporting ecosystems" (IUCN/UNEP/WWF (1991), as quoted in United Nations Environment Programme, 2011). UNEP further identifies a series of enabling conditions for a green economy, including reducing subsidies that are harmful to the environment, targeting public investments to green sectors, implementing government policies to encourage innovation and growth and establishing aggressive environmental regulation, among others (United Nations Environment Programme, 2011, pp. 22-23).

Transformative changes can be initiated through a public investment-led big push and decisive public interventions to promote technological innovation and implementation

World Economic and Social Survey 2009 and 2011 emphasize that prompt, integrated and decisive policies are needed to achieve sustainable development (see the discussion in United Nations, Department of Economic and Social Affairs, 2012). *World Economic and Social Survey 2011* specifically views the green economy approach as being fully compatible with sustainable development. Consistent with the magnitude of the investments needed, their urgency, and the broad implications for the rest of the economy and society, the view is that only a strong jump-start can effectively and in a timely manner extract the economy away from the inertia of business as usual and move it towards the transformation of the energy system. Transformative changes would be initiated through a public investment-led big push and decisive public interventions to promote technological innovation and implementation. This approach is not intended to substitute markets—on the contrary, it rests on the assumption that only clearly defined sustainable development policies can unleash the power of markets to bring about the needed energy transformation *on time*. As the *World Economic and Social Survey* acknowledges that a realistic and desirable path towards sustainable development must allow for rapid economic growth in the developing world, it argues that the transformation of the energy system must include policies crafted to allow developing countries to simultaneously build low-carbon energy systems and accelerate economic growth. It further argues that a carefully crafted public investment-led approach will not disrupt economic balances and could actually crowd in private investment. *World Economic and Social Survey* macroeconomic simulations of the big-push approach confirm the assumption implicit in climate-energy models that a low-carbon and converging sustainable development pathway is feasible (United Nations, 2009, particularly box IV.4).

The big-push approach is a realistic, well-grounded proposal which incorporates, inter alia, the historical lessons of the New Deal initiative (see United Nations, 2011b and United Nations, 2012b). The challenge, however, is much bigger now. When compared with that of the mid-twentieth century, the world economy is currently not only larger, but also more affluent, interconnected and natural-resource thirsty (see chap. I of this publication). Public-led investment has proved capable of accomplishing large socioeconomic transformations which would not have been feasible through implementation of incremental policies. A high degree of realism will be needed to properly gauge the dimension and complexity of the obstacles that the world needs to overcome.

The enabling conditions for the transformation of the energy system

Making low-carbon inclusive growth a reality requires putting in place the set of conditions needed to create an "enabling environment". Schematically, these enablers can be organized into four groups: policy space and coherence; international financing; international cooperation; and enabling international institutions: rules and norms. First, the transformation of the energy system will require a policy-setting framework within which developing countries can design and implement industrial policies to accelerate growth, foster green sectors and diversify the industrial and service sectors. Industrial policies have been and continue to be used across a wide range of countries, but many developing countries are constrained by international regulations and practices, notably in the trade and property rights domains. Second, there is a need to make adequate international financing available to developing—and, particularly least developed—countries; while domestic sources should be tapped to the extent possible, the size of investments required to promote sustainable development makes international finance indispensable. Third, designing national sustainable strategies demands the integration of complex processes across the macroeconomy, the energy sector, the deployment of technology, labour-market regulations, policies for social and economic inclusion, and the environment. Building national capacities and international cooperation in these areas will be important catalysts for the formulation of coherent sustainable national development strategies. Fourth, of particular importance is strengthening international cooperation to ensure that technological innovation and its adaptation occur where they are most needed and at the lowest possible cost. An important enabler will be a fluid process of technological innovation and adaptation facilitated by efficient technology transfer and cooperation at the regional and international levels.

The magnitude of the endeavour is such that neither Governments nor markets alone can tackle the desired energy transformation with success. While Governments and markets have been successful in increasing the world's aggregate affluence, they now need to ensure that the entire world population enjoys equitable well-being while re-establishing a balance with respect to the Earth's boundaries. This change in priorities will require a new institutional set-up to enable markets to carry out the required sustainable energy transformation. As the global trade system is an important component of the institutional framework within which markets operate, the world trade system should adopt sustainability as one of its fundamental guiding principles. Meeting the challenge of building policy coherent rules and interventions at global, regional and national levels will be critical to accelerating the required transformation of energy systems.

Coherent national policies for sustainable development

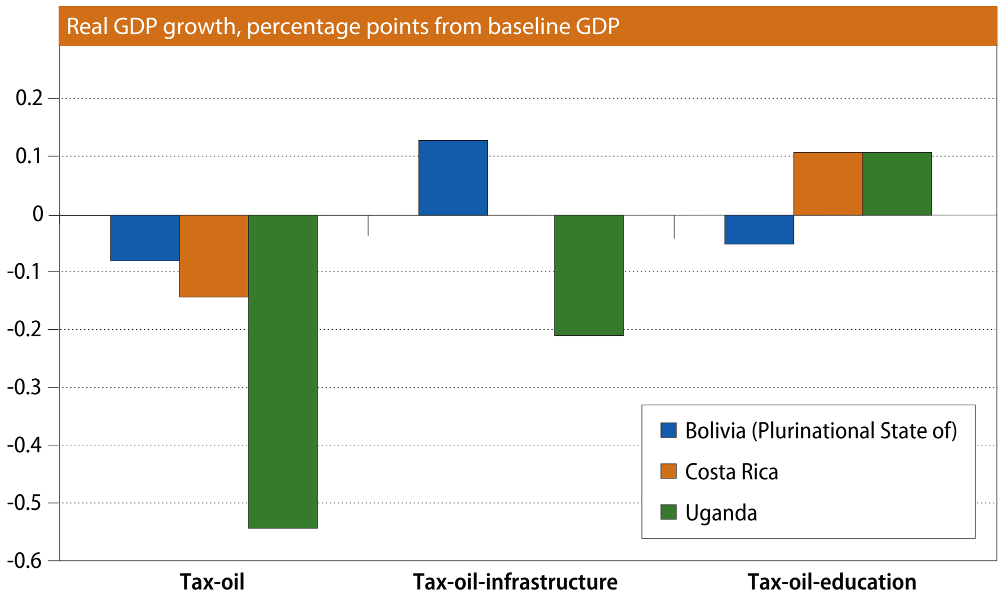
While global models have contributed significantly to the debate by laying out a number of recommendations on policies and measures for a sustainable energy transformation, there is a need to gain a better understanding of the design and implementation of energy transformation strategies at country level and how to best forge and harness international cooperation. A number of country experiences can shed light on policy alternatives. In the present section, we review some concrete experiences that illustrate the complexity of policy challenges and provide further guidelines for policy design.

The experience in using carbon taxes to pursue green-economy objectives has by now a record spanning more than two decades, mainly involving developed countries. More recently, a number of studies on carbon taxes in developing countries also started to emerge, most of them sponsored by Governments, international organizations and academia. China and South Africa, for example, have been considering the implementation of carbon taxes, but concerns about negative social and economic impacts in different areas have delayed their introduction (see, for example, "Mitigating circumstances", 2013; and Birdsall and MacDonald, 2013). Studies suggest that, while taxing carbon can contribute to curbing emissions, this seems to work better in combination with well-defined regulatory measures and complementary policies designed to offset (or compensate) the often regressive income distribution effects of carbon taxes.

There are opportunities to coherently combine low-carbon growth policies with strategies for economic and social inclusion

Furthermore, carbon or carbon-related taxes might represent an important source of revenue, which raises the issue of how to make best use of them. A simulation exercise probing the effects of raising the price of oil through a tax on domestic consumption in Bolivia (Plurinational State of) (a gas exporting country), Costa Rica (a country where 90 per cent of electricity is hydro-generated) and Uganda (a country dependent on oil imports to satisfy its energy demand) demonstrates the possibility of using carbon-related public revenues to finance economic and social inclusion programmes (see box V.2 entitled Taxing oil to invest in education). Under the simulation, taxes are increased up to the point where countries collect 2 additional percentage points of GDP in tax revenue. Simulations show that the introduction of this tax reduces oil consumption in productive sectors and among households, which has the effect of reducing emissions, but at the cost of decreasing GDP. Allocating additional revenues to investment helps to slow down the fall in GDP and, in some instances, even results in a net increase in GDP (figure V.7). Most importantly, the use of additional revenues to finance investments in education significantly improves education outcomes. Even though these simulations do not include the impact of higher education on labour productivity, it should be expected

Figure V.7
Impact on real GDP growth of a tax on oil and investment in education



Source: Box. V.2, table.

Box V.2

Tax oil to invest in education

Coherent policies to curb carbon emissions, promote economic growth and pursue human development: examples for oil-importing developing countries

The experience in using carbon taxes to pursue green-economy objectives has an interesting record spanning more than two decades of experience, mainly in developed countries. More recently, a number of studies on carbon taxes in developing countries have also started to emerge, most of them sponsored by Governments, international organizations and academia.[a] China and South Africa, for example, have been considering the implementation of carbon taxes, but concerns about negative social and economic impacts in different areas have delayed their introduction (see "Mitigating circumstances", 2013).

Fiscal policy can be instrumental for enabling developing countries to curb carbon emissions while such markets develop. Not only could fiscal policy contribute to reducing carbon emissions but it could also, if combined with a set of coherent policies, promote human development, and offset some of its potential economic costs. Three policy scenarios are simulated to illustrate that this may be the case, using an economy-wide modelling framework applied with data sets for three oil-importing developing countries (Bolivia (Plurinational State of), Costa Rica and Uganda).[b] These scenarios are compared with a baseline which delineates a continuation of currently expected economic growth and public spending interventions up to 2030.

In the first scenario (**Tax-oil**), the domestic price of fuel oil is increased by steadily raising (baseline) tax rates on domestic consumption and imports of oil in order to generate new revenue averaging 2.0 per cent of GDP per year during 2016-2030.[c] The new revenue is used to reduce the budget deficit. The second scenario is identical to the first except that new revenue, instead of financing the budget deficit, is used for financing investments in public infrastructure such as roads, bridges and electricity networks (**Tax-oil-infrastructure**). The third scenario is identical to the second except that the revenue is used to increase spending in education (**Tax-oil-education**). Public infrastructure and a larger pool of better-educated workers are drivers of productivity growth in the scenarios. Moreover, new public infrastructure—which facilitates access to and functioning of education centres—and increased service delivery in education favourably impact attendance and promotion in all school cycles.

The results show that, keeping all other things equal, unilateral fiscal policy restrictions on the domestic price of fuel oil would depress intermediate and especially final consumption of fuel oil in the three countries (figure A). Carbon emissions would consequently likely be curbed—by a margin not estimated here—but, on the other hand, industries that supply oil-intensive goods for the domestic market and exports would be penalized. In fact, GDP growth is 0.54 percentage points per year less in Uganda, and it also slows down in the other two countries, though by much less, as they also produce and rely on alternative sources of energy, i.e., fuel gas in the Plurinational State of Bolivia and hydroelectric power in Costa Rica (table).

The simulated price shock has been smoothed by spreading it out over a period of 15 years to make it more realistic. It is conservative in comparison with shocks that oil importing countries have endured owing to world oil price hikes. Using a similar economy-wide modelling framework, Sánchez (2011) shows that the negative impact on real GDP of the most recent oil price boom (2002-2008) has been substantial in six oil-importing developing countries, and as high as 2.0 to 3.0 per cent of GDP per year in some cases. In the first policy scenario presented here, however, real GDP is only 0.3-0.4 per cent per year below the baseline levels. The simulated fiscal policy will also be feasible should it not be used for protectionist purposes.

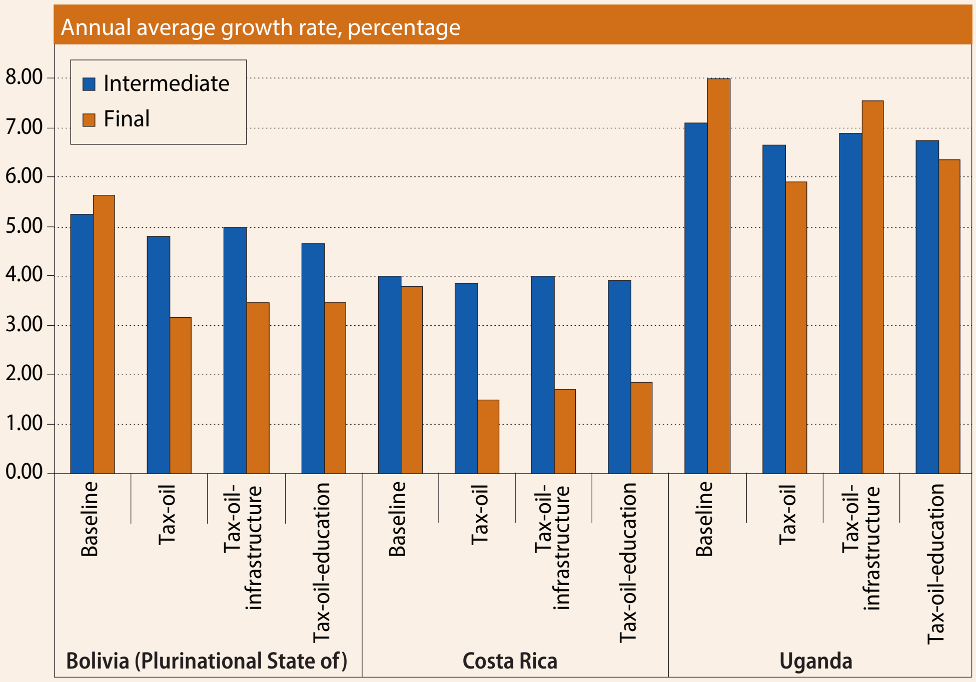
a See, for example, Alton and others (2012); Devarajan and others (2011); Gonzalez (2012); Jaafar Al-Amin and Siwar (2008); van der Ploeg and Withagen (2011), Resnick, Tarp and Thurlow (2012); Sumner, Bird and Smith (2009); and Yusuf and Ramayandi (2008).

b A dynamic economy-wide modelling framework called Maquette for MDG Simulations (MAMS) is used to generate the scenarios (Lofgren, Cicowiez and Díaz-Bonilla, 2013). Its application involves, inter alia, detailed (country-specific) microeconomic analyses of determinants of a set of human development indicators and productivity growth drivers such as the stocks of public infrastructure and highly educated workers. The application of this modelling framework with data for the three countries and extensions made to it are described in Sánchez and Cicowiez (2013).

c The domestic price shift directly affects domestic consumption of refined oil in all three countries, imports of refined oil in Bolivia (Plurinational State of) and Uganda and imports of crude oil in Costa Rica.

Box V.2 (cont'd)

Figure A
Real consumption of fuel oil in simulated scenarios, 2016-2030



Source: Box V.2, table.

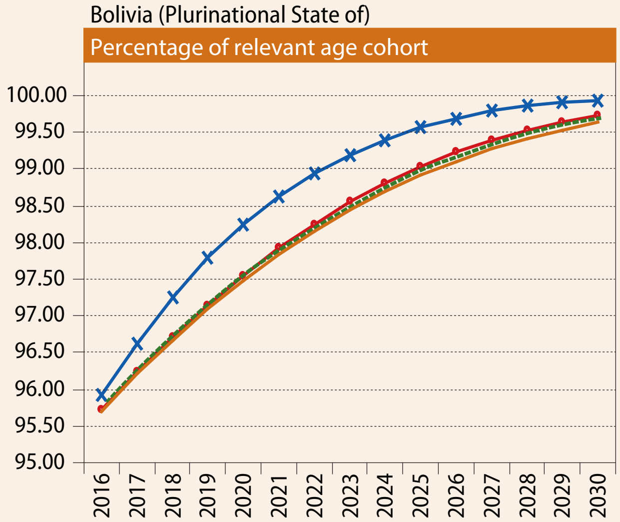
If, alternatively, the new revenue were allocated to investing in public infrastructure, on one hand, or to expanding service delivery in education, on the other, instead of using it to finance the budget deficit, the output loss would be offset partially or fully. This is mainly because such investments would spur productivity growth, but industries would also start employing more capital (table). Oil-intensive industries would also be favourably impacted by increased availability of public infrastructure or better-educated workers. Interestingly, consumption of fuel oil would continue to be unambiguously lower compared with the baseline (figure A). Increased public infrastructure or service delivery in education would also trigger a positive synergy with human development. Promotion in all cycles of education, for example, would increase remarkably owing mainly to more service delivery, but also to a lesser extent inasmuch as new roads facilitate access to and functioning of education centres (see figure B, for primary education).[d] Without these coherent policy interventions, taxing fuel oil consumption alone would actually reduce promotion rates in primary education, as household demand for education shrinks in tandem with the contraction of economic activity, as seen under the first simulated scenario.

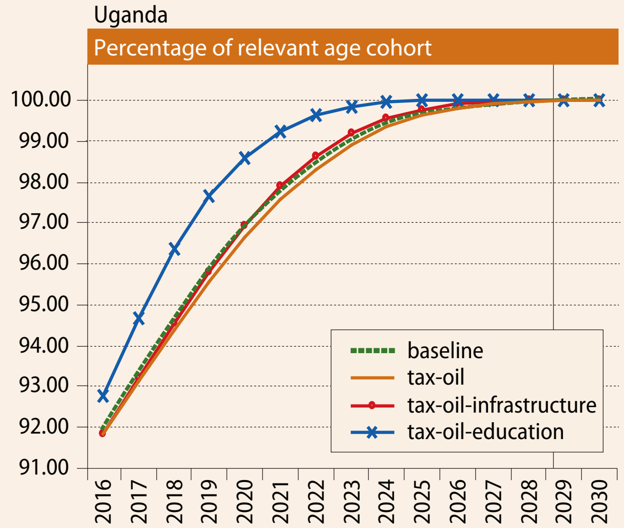
The new revenue from taxing consumption of fuel oil more could alternatively have been invested in other social sectors (health, water and sanitation, and so on) or used to enhance sectoral production capacity. For example, a scenario analysis similar to that presented here shows that investing 2 additional percentage points of GDP in Uganda's agriculture infrastructure would bring about productivity gains that contributed to agricultural output without expanding land use, while enhancing food security and even spurring export capacity (see box IV.2).

d There are additional gains—not shown here—in terms of human development when investments in public infrastructure are stepped up. Child and maternal mortality rates, for example, exhibit a reduction, as the increased stock of public roads, bridges and electricity networks facilitates access to and functioning of health centres and hospitals. The reduction in child mortality, a proxy for the health status of the student population, in turn, triggers a positive synergy for promotion rates and other educational attainment indicators.

Box V.2 (cont'd)

Figure B
Promotion rates in primary education in simulated scenarios, 2016-2030





Source: UN/DESA, based on application of MAMS for Bolivia (Plurinational State of), Costa Rica and Uganda.

Real GDP growth and its supply driving factors in simulated scenarios, 2016-2030

Period annual averages, per cent				
	baseline	*tax-oil*	*tax-oil-infrastructure*	*tax-oil-education*
		Bolivia (Plurinational State of)		
GDP at factor cost	5.00	4.92	5.13	4.95
Total factor productivity	2.61	2.61	2.78	2.63
Total factor employment	2.39	2.31	2.36	2.32
		Costa Rica		
GDP at factor cost	4.25	4.11	4.25	4.36
Total factor productivity	2.22	2.18	2.29	2.25
Total factor employment	2.03	1.93	1.96	2.11
		Uganda		
GDP at factor cost	7.00	6.46	6.79	7.11
Total factor productivity	3.71	3.42	3.67	3.74
Total factor employment	3.29	3.05	3.12	3.38

Source: UN/DESA, based on application of MAMS for Bolivia (Plurinational State of), Costa Rica and Uganda.

In the long run, the feasibility of the simulated policies will depend on countries' ability to shift towards alternative sources of energy. In a country like the Plurinational State of Bolivia, for example, taxing fuel oil more may eventually lead to an increase in the demand for gas, another fossil fuel. Thus, the shift to be pursued should be towards more environmentally friendly sources of energy. The case of Costa Rica is interesting in this respect, as over the years, nearly 90 per cent of this country's growing demand for electricity has been met through hydropower plants, the construction of which has taken into consideration their environmental and social implications. Thus, taxing fuel oil in this country may eventually incentivize further developments of environmentally friendly hydropower generation and energy efficiency.

that better education would result in higher incomes for higher-skilled workers over the medium and long terms. This exercise clearly illustrates the possibilities of combining low-carbon growth policies with strategies for economic and social inclusion.

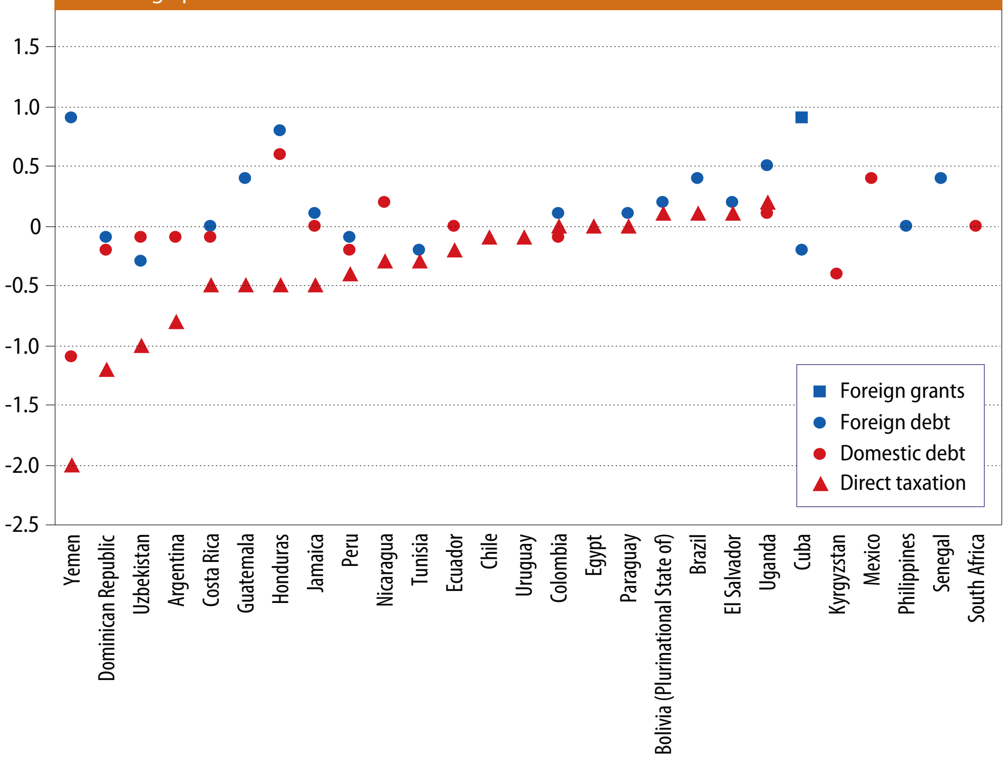
The reallocation of resources to investments with a long-term return, such as for infrastructure and education, should also include policies to enhance labour productivity. In addition to investments in formal education, investments in training and the adoption of the skills necessary to design, deploy and maintain sustainable energy systems are key components of a big-push approach to sustainable development.

Further insights centring on the challenge of pursuing sustainable development strategies can be derived from a series of studies that examined the economy-wide implications of accelerating the achievement of the Millennium Development Goals for education, health and sanitation under various financing strategies. These studies suggest that while important synergies arise from the simultaneous pursuit of these three goals, there are also noticeable trade-offs in relation to growth and macroeconomic balances. Simulation results indicate that the additional investment necessary to reach these goals are significant, in the order of 1-4 per cent of GDP (figure V.8).[17] In these studies, negative macroeconomic effects can be neutralized or even made positive, if countries finance additional investments with foreign grants.

In the *World Economic and Social Survey 2011* presentation, the big-push public investment-led strategy does not substitute for private investment and market

Figure V.8
Growth impact of policies aimed towards achieving the Millennium Development Goals, selected countries

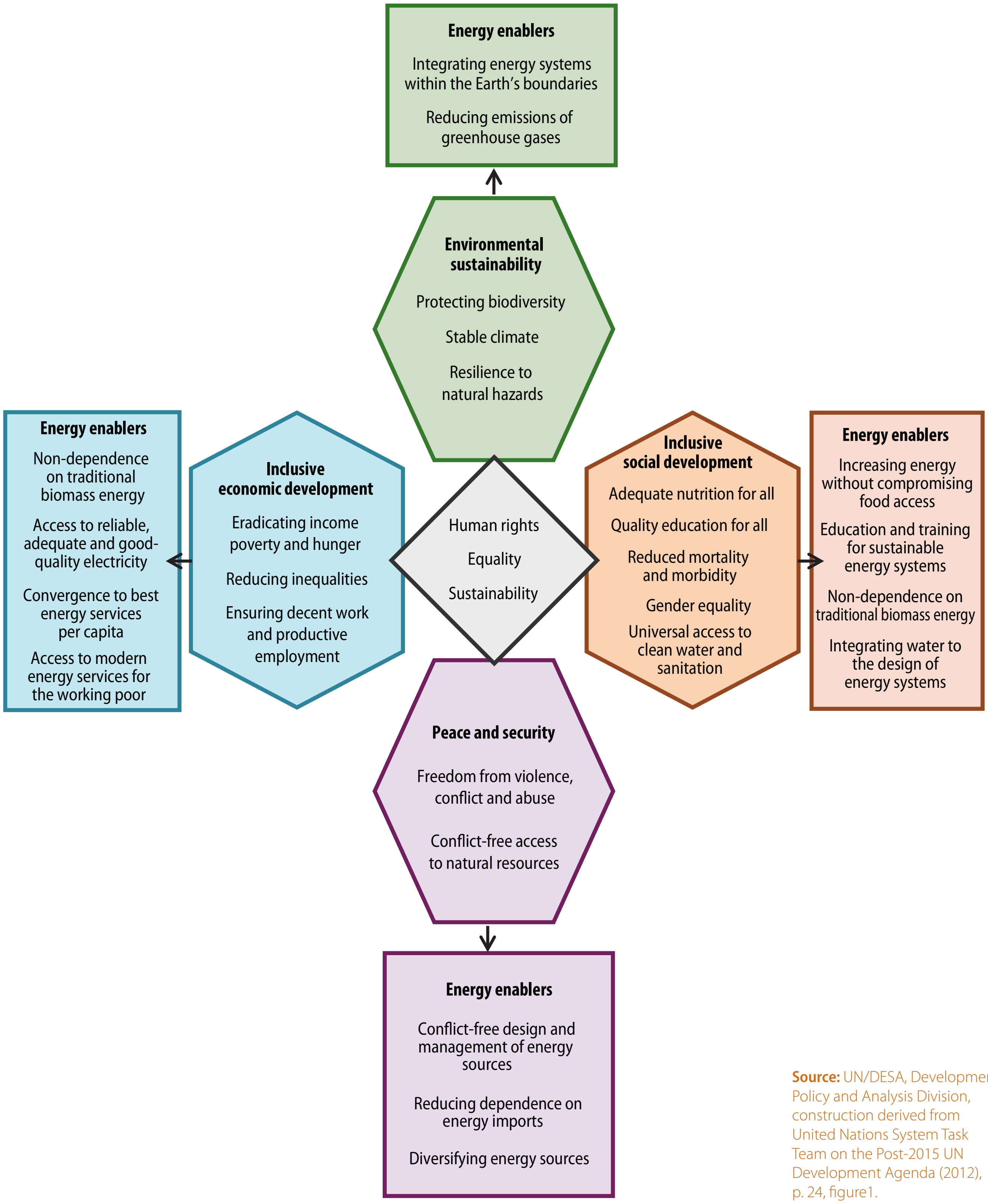
Percentage points from baseline GDP



Source: Based on MAMS simulation results reported in Sanchez and others (2010) and Sanchez and Vos (2013).

17 We leave aside extreme cases where expenditures relative to GDP are about 0.2 per cent and 8 per cent of GDP and above.

Figure V.9
Energy and the post-2015 vision



Source: UN/DESA, Development Policy and Analysis Division, construction derived from United Nations System Task Team on the Post-2015 UN Development Agenda (2012), p. 24, figure1.

contributions. Public investments are used to trigger the private investment and market forces that have so far lain dormant and hence are unable to generate the type of changes needed if world demand is to remain within the Earth's carrying capacity. However, policymaking also needs to deal with a host of market and public sector failures and to be able to elaborate well-crafted interventions, as proposed in the OECD, World Bank and UNEP green economy strategies. To illustrate the unexpected ways in which public sector interventions can spur market forces, it is useful to look at how a nationally oriented environmental policy in Sweden later developed into a market-mediated regional trash recycling activity (see box V.3 on policies and markets).

The potential relevance of the big-push approach and its emphasis on comprehensive coherent policies and strong international cooperation is illustrated by the case of Bangladesh which has rightly identified adaptation as the issue of utmost concern when dealing with climate change. Without losing sight of adaptation, the country has also been active in the area of mitigation, with such policies as the promotion of solar renewable sources (United Nations, 2011b). Furthermore, Bangladesh is considering an energy strategy aimed at guaranteeing the energy supply needed by the country to continue growing and improving energy security by reducing dependency on imports. One possible approach under consideration for achieving these goals entails basing the energy system on enhanced coal technologies. Use of enhanced coal technologies leads to a reduction in emissions relative to traditional coal technologies, but to an increase relative to pathways associated with renewable sources; and a more extensive use of renewables would reduce the locking in of the country to fossil fuel sources. In the absence of adequate financing and international support, however, Bangladesh should probably choose the enhanced coal energy pathway. Choosing a sustainable pathway might be realistic only under the conditions of a big-push strategy properly financed and assisted (see box V.4 on Bangladesh).

Policies designed to transform energy systems and deploy them in developing countries work best when they are comprehensive, strategic and systematic. Policymaking in these areas needs to overcome the tendency to oversimplify the planning framework

Box V.3

Policies and markets may provide unintended welcoming effects: Sweden is importing garbage to generate electricity

With a strong tradition of recycling and incinerating, Sweden now has too many waste-to-energy incinerators and not enough rubbish to meet demand. While Germany, Belgium and the Netherlands are also importing trash from other countries, with Germany importing the most, Sweden is the leading importer in terms of the share of rubbish burned.

To date, Sweden has imported mainly from Norway. However, as the European Union seeks to reduce the dumping of 150 million tons of rubbish in huge landfills each year, Sweden sees a chance to import more waste from other States of the European Union too.

According to Weine Wiqvist, head of the trade association Swedish Waste Management: "It sounds almost foul to be importing waste, but the import to Sweden is not a problem. The dumping in landfills abroad is a huge problem."

Source: Ringstrom (2012).

Box V.4

Bangladesh: between a coal-based energy system at hand and a promising but distant sustainable energy system

Bangladesh is likely to experience severe negative impacts from climate change and it is preparing for them.[a] The Government has already formulated its National Adaptation Programme of Action and has taken measures to reduce climate change hazards, including community-led coastal afforestation, construction of dual-use flood shelters and programmes to reduce salinity, among others. Bangladesh is also taking important steps towards mitigation. Notably, it has formulated an energy strategy up to 2030, the Power System Master Plan 2010. The Plan, which identifies this strategy as based on a "fuel diversification" scenario considers that it addresses the three main concerns, related to the economy, the environment, and energy security. On the economic front, the Plan aims to eliminate power shortages and to renovate the power infrastructure created during the first phase. In terms of the environment, while the use of coal is central to the Plan, Bangladesh expects to lower carbon emissions by improving the thermal efficiency of coal plants using Japan's clean coal technology. The plan seeks energy security by lowering its current reliance on imported oil.

The power strategy relies on energy generation from coal. Currently, gas is the main source of energy (60-70 per cent) and oil is second in importance (15-30 per cent). The Plan anticipates changing this composition dramatically. The share of coal in power generation will increase from less than 5 per cent in 2012 to about 50 per cent in 2030. Gas will account for 25 per cent and oil for 5 per cent. Nuclear and hydroelectric—domestic and imported, including wind and solar renewables—will account for 20 per cent. The main reason behind the choice of coal as the main source of energy is its comparatively low and stable price and the discovery of high-quality coal deposits in the northern part of the country.

Mondal, Mathur and Denich (2011) argue that a policy package of carbon taxes and regulations placing caps on emissions could have positive sustainability effects. Using a MARKAL model for energy the authors run simulations showing that a policy package of mandated reductions in CO2 emission and carbon taxes directly decreases the use of high-carbon fossil-based technologies in favour of clean renewable energy technologies. A cumulative CO_2 emissions reduction target of 10 and 20 per cent reduces cumulative net energy imports by 39-65 per cent, while a carbon tax of 2,500 taka/ton reduces imports by 37 per cent by 2035. The simulated emissions reduction targets and the carbon tax results suggest that the country can decrease its total primary energy use by 5-22 per cent, relative to the baseline, and do so while satisfying the energy needs of an economy growing at 6.8 per cent per year. Thus, the adoption of low-carbon policies could allow the country to reduce emissions, guarantee energy security, increase efficiency and expand the use of renewables, with the added well-known health benefits.

This quick review invites the following question, which might be relevant not only for Bangladesh but also for many other developing countries: Why not adopt ambitious low-carbon policies? The nature of the answer is, in large part, of course, related to the difficulties of implementing, in the real world, the assumptions made in the modelling realm. Implementation problems need to be overcome in the area of financing of investments in energy generation and infrastructure and, of technology development and adaptation; and political economy-related obstacles need to be overcome in order to implement carbon taxes and regulations on capping emissions, which is known to require complementary policies designed to neutralize or compensate for negative impacts on vulnerable population groups. The adoption of sustainable development paths by developing countries initially depends on effective internaitonal (sp) cooperation, including financial and technical assistance.

Source: UN/DESA, Development Policy and Analysis Division.

a See, for example, World Bank (2010b); and Thurlow, Dorosh and Yu (2011).

in terms of its scope, to focus on a narrow set of energy options, and to ignore trends in other economic and social sectors. Policies will have to specify goals, establish standards for performance, exploit niche markets and adopt a portfolio approach rather than pick a few winning projects or technologies. Policies should be geared towards end users, with specific goals for energy services, markets and the portfolio of technologies to be considered. Given multiple interrelations, the policy focus should be on clusters and should be based on integrated assessments. Examples of integrated approaches to energy policies are the water-energy-food nexus (NEXUS) and the climate-land-energy-water (CLEW) interlinkage. A best-practice energy policy feeding into the national biofuel policy of Mauritius turns out to be inconsistent with respect to future water availability, the cost of extraction and the energy security goals of the country. These inconsistencies were revealed only

Box V.5

Mauritius: coping with climate and land-use, energy and water resources

Land, energy and water are among our most precious resources, but the manner and extent to which they are exploited contributes to climate change. Meanwhile, the systems that provide these resources are themselves highly vulnerable to changes in climate. Efficient resource management is therefore of great importance, for both mitigation and adaptation purposes.

The lack of integration in resource assessments and policymaking leads to inconsistent strategies and inefficient resource utilization, especially at the national level.

In Mauritius, a national biofuel policy that made sense from a best-practice energy, land and water planning point of view was shown to be strongly inconsistent. This was discovered only when the Government and international analysts modelled these systems in an integrated manner. An integrated modelling approach of climate, land-use, energy and water resource systems (CLEW) was particularly useful for assessing the response to climate change-induced reductions in precipitation. The change in rainfall patterns led to increases in water withdrawals, which in turn led to higher demand for the energy needed to drive pumps bringing water from its source to the fields and to power water-desalination plants. The existence of a positive feedback loop means that this will lead to increased demand for cooling of thermal power plants and thus to additional withdrawal of water (unless they are cooled by seawater). If the increase in electricity demand is met with coal-fired power generation, as planned, then the greenhouse gas benefits of the ethanol policy are eroded by increased emissions from the power sector. Higher coal imports also have a negative impact on energy security. The benefits of this policy—aimed at reducing energy import costs and emissions—are thus clearly vulnerable to the impacts of climate change; and the long-term viability of this strategy would be at risk if rainfall were to decrease further and droughts were to continue. In this case, producers would have either to scale back production or resort to expensive water desalination. Both of these options negatively impact the expected climate and energy security benefits of the policy and both would be detrimental to the sugar and ethanol industry.

The water-constrained scenario does, however, also lead to better prospects for renewable electricity generation. Wind and photovoltaic electricity generation is typically much less water-intensive than fossil fuel generation. Furthermore, if power consumption for water desalination facilities were to make up a significant share of total system load, intermittent resources such as wind could be integrated more easily. Since water is cheap and easy to store, it is not important that it be produced at a specific time. It could therefore be treated as an interruptible load and shut down in the event that wind generation was unavailable during times of high system load.

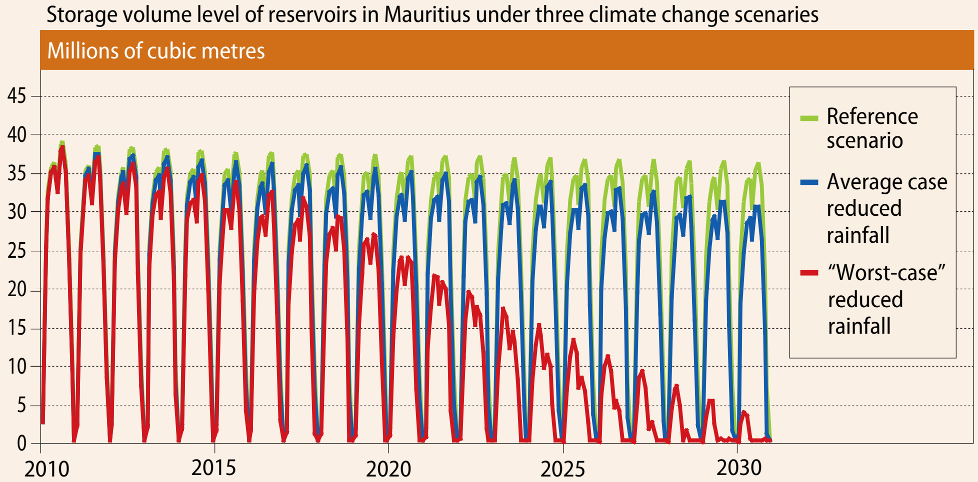
In response to these factors, the Government of Mauritius has appointed a high-level CLEW panel to ensure consistency among its climate, land, energy and water strategies.

by an integrated assessment of the biofuel policy which included the potential effects of climate-change on water precipitation (box V.5). Increasing the production of biofuels is a natural candidate for the role of addressing energy insecurity and rising greenhouse gas emissions. Burkina Faso, like many other developing countries, would do well to consider expanding the production of biofuels to address energy security concerns and cope with greenhouse gas emissions, even at the cost of accelerating the rapid deforestation that affects the country. However, an integrated assessment recommended the implementation of policies that intensify the use of land for agriculture production (see discussion in chap. III). Even if there are inevitable trade-offs, increasing the intensity of land use leads to net reductions in emissions, contained deforestation and improved energy security (box V.6).

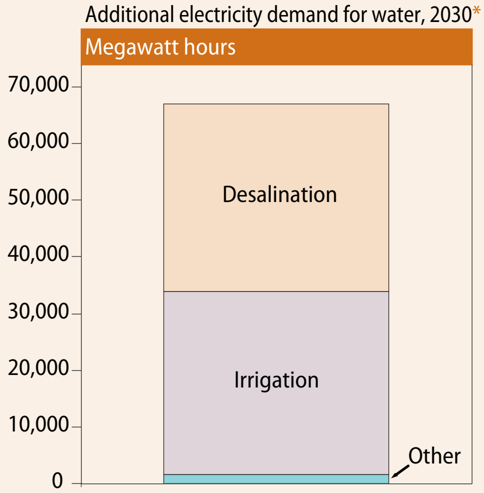
Box V.5 (cont'd)

Predicted impact of climate change on water availability in Mauritius, water-related energy consumption and greenhouse gas emissions, for the year 2030

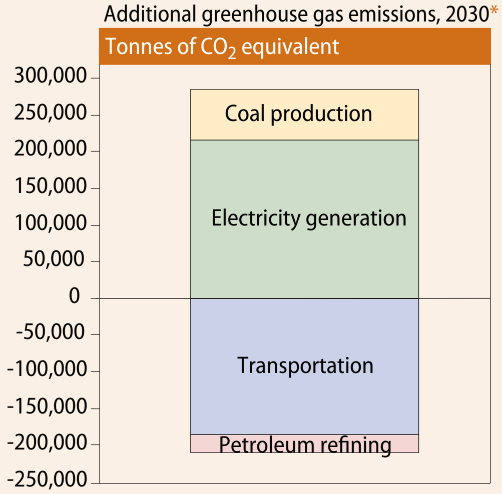
Storage volume level of reservoirs in Mauritius under three climate change scenaries



Additional electricity demand for water, 2030*



Additional greenhouse gas emissions, 2030*



Source: Howells and others (forthcoming).

* Compared with the scenario without climate change impacts, under the worst-case scenario.

Integrated energy assessment and planning constitute a critical tool for the design of sustainable strategies, particularly in developing countries

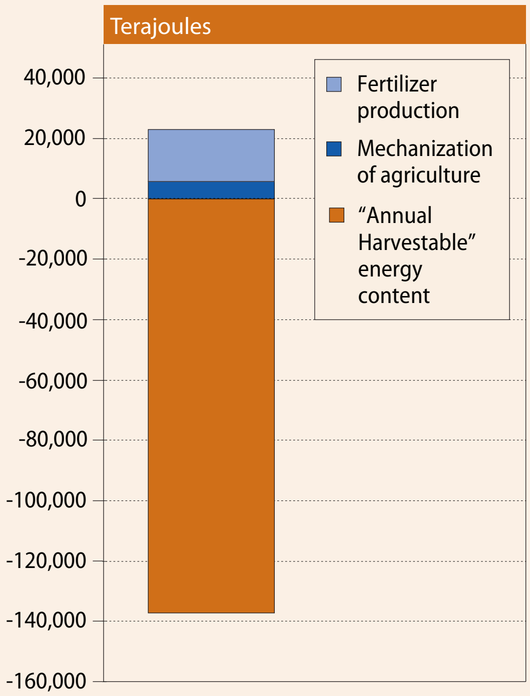
Integrated energy assessment and planning constitute a critical tool for the design of sustainable strategies, particularly in developing countries—and even more so in those countries that are likely to be affected by climate variability. However, these countries rarely have the capacities needed to undertake such analysis. Widespread access to integrated energy assessment and planning tools should be part of the international co-operation framework for sustainable development. It is important to harness the expertise on energy systems acquired by a number of research institutions throughout the world to assist developing countries in the task of building sustainable energy systems. It will thus be important to establish a network of independent centres for energy systems analysis with a mandate to assist the design and implementation of sustainable energy plans in developing and least developed countries.

Box V.6

Burkina Faso adds energy in order to reduce emissions

Policies to reduce emissions have to take into consideration the fact that the economic-environment system is complex, specific and interlinked. In Burkina Faso, a country with rapid deforestation, growing energy insecurity and greenhouse gas emissions, an integrated approach finds that a measure with damaging direct effects on each of these factors has disproportionately positive knock-on effects. This phenomenon is uncovered by an integrated modeling of the system, allowing for appropriate national development actions.

Changes in the energy balance in Burkina Faso, 2030



Source: Hermann and others, 2012.

In summary, agriculture is expanding rapidly, eating into forest, a natural "carbon sink". Forest supplies vital fuel wood used for cooking and heating. As forest is displaced, people are forced, for energy needs, to use oil, which is imported and expensive. Emissions are increasing as the carbon sink is disappearing and oil use is increasing. Energy security is reduced as more oil is imported, and energy poverty is increased as the price of the new energy source (oil) is relatively expensive.

However, agriculture in Burkina Faso is not intensive. The land requirements for similar outputs can be significantly reduced by changing practices. Those changes would include higher application of fertilizer and mechanization. To fully grasp these linkages it is useful to recall that conventional production and application are highly greenhouse gas-intensive and increased mechanization requires higher volumes of oil use in tractors and other equipment.

More broadly, significant investments will be needed in technological innovation and adaptation, supported by efficient technology transfers and cooperation at the regional and international levels (United Nations, 2011b). The design of sustainable energy systems as part of national development strategies calls for capacities and skills that are not abundant in many countries of the world. Building such capacities will enable countries to undertake transformative energy plans that would otherwise be considered completely out of reach.

It will be important to establish a network of independent centres for energy systems analysis to assist in the design and implementation of sustainable energy plans in developing and least developed countries

Sustainable energy systems in a global development agenda

The transformation of the energy system should be a core element in a post-2015 development agenda. The four dimensions integrated in the UN-System view of the post-2015 development agenda provide a useful reference for framing the transformation of the energy system (United Nations System Task Team on the Post-2015 UN Development Agenda, 2012). Each of the four dimensions can be mapped to further detail for relevant energy transformative policies. For example, the environmental sustainability dimension can be directly linked to the promotion of renewables and energy efficiency, as well as linked with integrated energy policies (figure V.9). The inclusive economic development dimension can relate to policies for reducing dependence on traditional biomass energy and policies aimed at providing universal access to electricity, among others. The inclusive social development dimension can be mapped to integrated policies for ensuring access to modern energy and food security, and to strategies for integrating access to water and provisioning energy, for example. The dimension of peace and security can be related to policies designed to lessen dependence on energy imports or policies for diversifying sources of energy. Member States currently working to define the main threads of the post-2015 development agenda might wish to take note of the importance of explicitly incorporating energy goals.

Member States currently working on defining the main threads of the post-2015 development agenda might take note of the importance of explicitly incorporating energy goals