Sustainable energy

for Developing Countries

A report to TWAS,
the academy of sciences for the developing world

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Contents

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Executive Summary

Developing and emerging economies face a two-fold energy challenge in the 21st century: Meeting the needs of billions of people who still lack access to basic, modern energy services while simultaneously participating in a global transition to clean, low-carbon energy systems. Both aspects of this challenge demand urgent attention. The first because access to reliable, affordable and socially acceptable energy services is a pre-requisite to alleviating extreme poverty and meeting other societal development goals. The second because emissions from developing countries are growing rapidly and are contributing to environmental problems, such as climate change and poor air quality, that put the health and prosperity of people around the world—but especially people in poor countries—at grave risk.

Historically, humanity's use of energy has been marked by four broad trends: (1) rising consumption and a transition from traditional sources of energy (e.g., wood, dung, agricultural residues) to commercial forms of energy (e.g., electricity, fossil fuels); (2) steady improvement in the power and efficiency of energy technologies; and (3) a tendency (at least for most of the 20th century) toward fuel diversification and de-carbonization, especially for electricity production; and (4) improved pollution control and lower emissions.

These trends have largely been positive. The problem is that the rate of technology improvement has not been sufficient to keep pace with the negative consequences of rapid growth in demand.

The task, then, is not so much to change course as it is to accelerate progress, especially toward increased energy efficiency and lower-carbon energy sources. This acceleration would have many concurrent benefits for developing countries in terms of reducing pollution and improving public health, making feasible a broad expansion of access to basic energy services and laying the foundation for more competitive industries and future economic growth. Moreover, to the extent that sustainable energy policies promote the development of indigenous renewable-energy industries, they will have the additional benefit of creating new economic opportunities, reducing countries' exposure to volatile world energy markets and conserving resources for internal investment by curbing outlays for imported fuel.

There are several grounds for optimism that indicate developing countries can succeed as sustainable energy leaders, even as they make substantial strides toward closing the gap between energy 'haves' and 'have-nots'. The first is that providing basic energy services to the billions of people who currently lack such services requires at most a modest shift of global resources. It has been estimated that the amount of electricity required to make it possible for people to read at night, pump a minimal amount of drinking water and listen to radio broadcasts amounts to just 50 kWh per person per year. Even multiplied by the 1.6 billion people who currently live without electricity, this increment of consumption would amount to only a tiny fraction (less than one-half of 1 percent) of overall global energy demand. At the same time, the price competitiveness and reliability of renewable energy technologies—many of which are particularly well-suited to small-scale, stand-alone application—has continued to improve, especially in remote rural areas that are not well-connected to electricity grids or transportation networks.

None of this means the tasks facing developing countries will be easy. On the contrary, markets left to their own devices are not likely to choose the cleanest and most efficient technologies most of the time (especially when environmental and other externalities are not reflected in market prices); nor will it always be possible to avoid difficult trade-offs.

This is true of markets everywhere in the world. But the trade-offs can be especially difficult in a developing country context where immediate financial and institutional constraints are likely to be more acute than in most developed countries.

In this context and given the scale of the challenges that must be overcome, concerted policy interventions are essential, not only at the national level, but also at the international, regional, and sub-regional levels. Moreover, the interventions—to be fully successful—must be responsive to the particular needs and constraints of developing countries and must advance, to the greatest extent feasible, multiple societal objectives.

This report outlines several policy priorities for developed and developing countries alike:

- Promote energy efficiency and adopt minimum efficiency standards for buildings, appliances and equipment, and vehicles.
- Reform and re-direct energy subsidies.
- Identify the most promising indigenous renewable energy resources and implement policies to promote their sustainable development.
- Seek developed-country support for the effective transfer of advanced energy technologies, while building the indigenous human and institutional capacity needed to support sustainable energy systems.
- Accelerate the dissemination of clean, efficient, affordable cookstoves.

None of these policy recommendations will be easy to implement. All will eventually require the active engagement of all sectors of society, including individual consumers and local communities, non-governmental organizations, private businesses and industry, the science and technology communities, governments, intergovernmental institutions and donor organizations. Developing countries themselves must take the lead in charting a new energy course. But developed countries must stand ready to provide support, recognizing that they have a vital stake in the outcome.

1. Introduction

Since the dawn of the industrial age, the ability to harness and use different forms of energy has transformed living conditions for billions of people, allowing them to enjoy a level of comfort and mobility unprecedented in human history and freeing them to perform ever more productive tasks. For most of the last 200 years, steady growth in energy consumption has been closely tied to rising levels of prosperity and economic opportunity in much of the world.

Now, however, humanity finds itself confronting an enormous energy challenge. This challenge has at least two critical dimensions. On the one hand, it has become clear that current patterns of energy use are environmentally unsustainable. Overwhelming reliance on fossil fuels, in particular, threatens to alter the Earth's climate to an extent that could have grave consequences for the integrity of vital human and natural systems. At the same time, access to energy continues to divide the 'haves' from the 'have-nots'. Globally, a large fraction of the world's population—more than two billion people, by some estimates—still lacks access to one or several types of basic energy services, including electricity, clean cooking fuels and adequate means of transportation.

The need for a profound transformation of the world's energy-producing and -using infrastructure is, of course, already widely recognized in the context of mounting concern about global climate change. Countless reports have been written on the subject of sustainable energy, but far fewer have approached these issues specifically from a developing country perspective. In nations where a significant portion of the population still lacks access to basic energy services, concerns about long-term environmental sustainability often are overshadowed by more immediate concerns about energy access and affordability.

This report addresses the two-fold energy challenge that confronts developing and emerging economies: expanding access to energy while simultaneously participating in a global transition to clean, low-carbon energy systems.

At a broad level, the policy options recommended here will be familiar—similar prescriptions have been widely advocated in energy policy discussions generally and in a variety of different country contexts. These arguments, however, have often been grounded in experience or evidence from wealthier, industrialized countries. To successfully implement a sustainable energy agenda it will be critical for developing countries to design and implement policies that are both (a) responsive to their particular needs and constraints and (b) advance multiple objectives, including economic and social development objectives as well as environmental ones.

2. Essential Context: Historic Energy Trends

Energy use by human societies has historically been marked by four broad trends:

- Rising overall consumption as societies industrialize, gain wealth and transition from traditional sources of energy (mostly biomass-based fuels such as wood, dung and charcoal) to commercial forms of energy (mostly fossil fuels).
- Steady improvements in both the power and efficiency of energy-producing and energy-using technologies.
- De-carbonization and diversification of fuels used, especially for the production of electricity, throughout most of the 20th century.
- Reduction in conventional pollutants associated with energy use.

Each of these trends has played a major role in shaping our current energy situation. All of them will be important in determining the nature and magnitude of the sustainability challenge humanity confronts in the decades ahead. In particular, much will depend on how the trends described in the last three bullets interact with the first. In other words, the ability of developed and developing countries alike to manage the consequences of rising consumption and increased demand for commercial forms of energy seems likely to depend on whether it will be possible to greatly accelerate historic rates of progress toward increased efficiency, de-carbonization, greater fuel diversity and lower pollutant emissions.

2.1 Rising Consumption and the Transition to Commercial Forms of Energy

Before the industrial revolution, humans relied on natural energy flows and on animal and human power for heat, light and work. Mechanical energy sources were confined to draft animals, wind and water. The only form of energy conversion (from chemical energy to heat and light) came from burning various forms of biomass. Energy use per capita did not exceed 0.5 tons of oil-equivalent (toe) per year.

Between 1850 and 2005, overall energy production and use grew more than 50-fold—from a global total of approximately 0.2 billion toe to 11.4 billion toe (IEA, 2007). Most of this increase occurred in industrialized societies, which had come to rely heavily on the ready availability of energy. On a per capita basis, people in these societies now use more than 100 times the amount of energy that was used by our ancestors before humans had learned to exploit the energy potential of fire (UNDP, 2000, p. 3).

As societies have industrialized, they have not only used more energy but they have used energy in different forms, typically switching—as household incomes rise—from such traditional fuels as wood, crop residues and dung to such commercial forms of energy (*i.e.*, fuels that can be bought and sold) as oil, natural gas, propane and electricity. Reliable estimates for the use of traditional waste and biomass are difficult to obtain, but these fuels are estimated to account for approximately 10 percent of overall primary energy use at present. Much of this use is concentrated in the rural areas of developing countries. More reliable statistics are available for the consumption of commercial energy, which grew rapidly during the second half of the 20th century.[1] Because most commercial forms of energy are derived from fossil fuels (notably, coal, oil and natural gas), consumption of these fuels grew even faster—increasing roughly 20-fold in the 20th century alone. Non-renewable, carbon-emitting fossil fuels now supply approximately 80 percent of the world's primary energy needs (see Figure 1).

Projecting forward from current trends suggests that overall energy use will continue to grow strongly—doubling or even tripling by 2050. More troubling from a sustainability perspective, fossil fuel consumption could grow nearly as strongly as total energy consumption, meaning that fossil fuels would continue to dominate the overall supply mix—again, assuming a continuation of current, business-as-usual trends.

Of course, these are the outcomes that a policy agenda guided by climate concerns and other sustainability considerations would presumably seek to change. Altering the present trajectory, however, will require governments, businesses and individuals around the world to join in a concerted effort to accelerate the other historic trends discussed in the next subsections—trends toward increased efficiency and lower-carbon energy sources, in particular.

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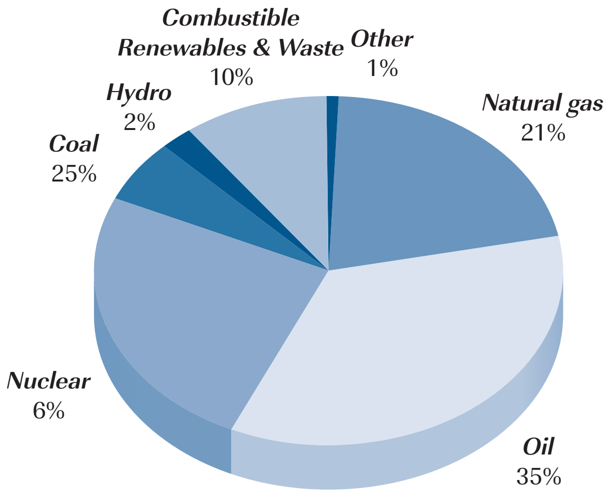
[1] Starting around 1970, global consumption of commercial forms of energy grew by approximately 2 percent per year. Global growth rates moderated somewhat in the 1990s with the economic contraction of a group of countries (primarily in central and eastern Europe and central Asia) that were transitioning from centrally planned to market-based systems. Strong global growth resumed again after 1998. Recently, high energy prices and recessionary pressures caused by a global credit crunch and volatility in several major currencies may again be causing a global slowdown.

Figure 1: Share of World Primary Energy Supply in 2005



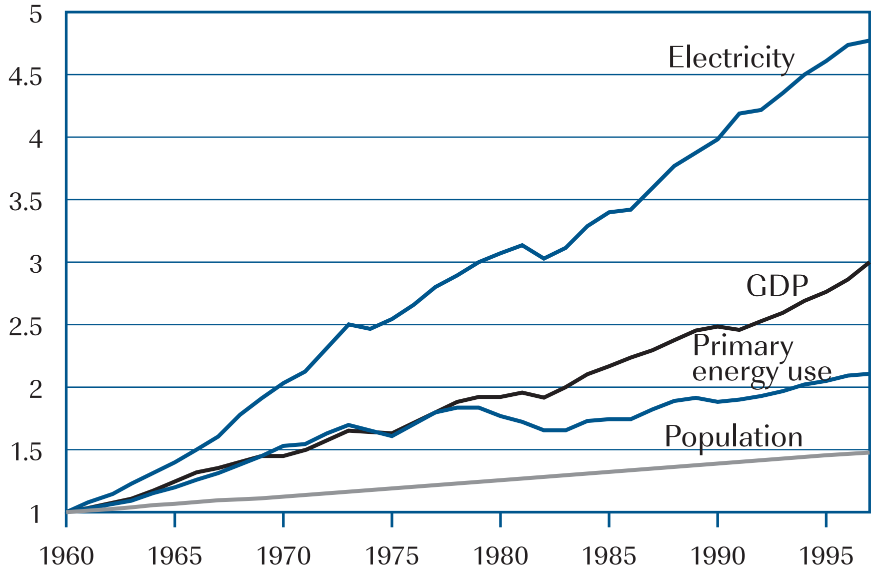
Source: IEA, http://www.iea.org/textbase/nppdf/free/2007/key_stats_2007.pdf, p.6.

2.2 Increasing power and improving efficiency

Harnessing oxen increased the power available to human beings by a factor of ten, the waterwheel increased it by another factor of six, and the steam engine by another factor of ten (UNDP, 2000, p. 3). Cumulatively, these innovations increased the power available to humans by a factor of 600. The development of the steam engine—initially powered by coal—was particularly important. With it, the provision of energy services became site-independent because coal could be transported and stored anywhere. Steam engines fuelled the factory system and the industrial revolution. Used later in locomotives and ships, these engines revolutionized transport as well (Grubler, 1998, p. 249). By the beginning of the 20^{th} century, coal provided almost all of the primary energy needs of the then industrializing countries.

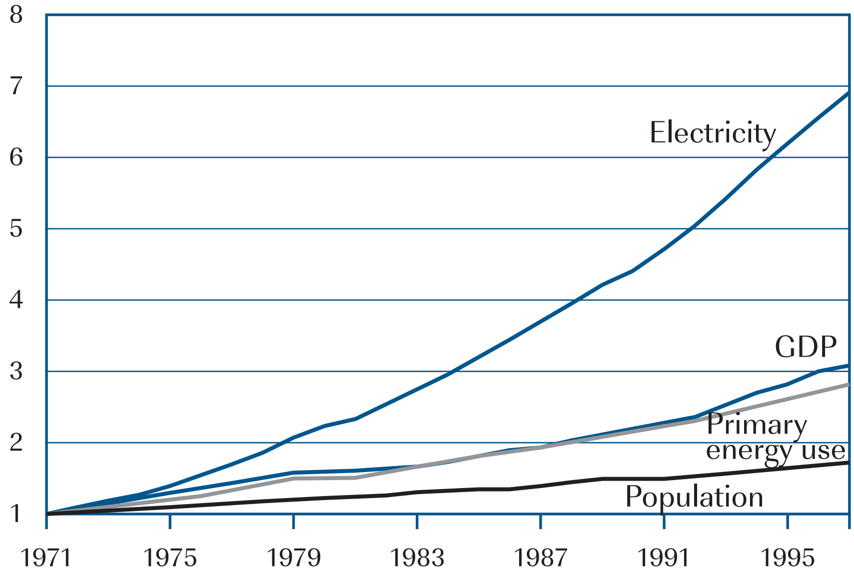
Even as technologies like the steam engine vastly increased the power available to humans, improvements in energy-producing and -using technologies steadily improved the efficiency with which energy could be converted to different forms and be used to deliver goods and services. For example, it is estimated that the thermal efficiency of steam engines has increased by a factor of about 50 since 1700, while the efficiency of lighting devices has improved by a factor of about 500 over the past 150 years (Ausubel and Marchetti, 1996). Large efficiency gains likewise occurred with the development of the internal combustion engine as a replacement for steam engines in many forms of transport (Grubler, 1998, p. 251).

Figure 2: Changes in GDP, population, primary energy use, amd electricity use in OECD countries, 1960-97



Source: UNDP, 2000, Figure 1.1, p. 34.

Figure 3: Changes in GDP, population, primary energy use, amd electricity use in developing countries, 1971-97



Source: UNDP, 2000, Figure C.1 (d), p. 459.

Massive improvements in the efficiency of technologies and devices have allowed for ongoing reductions in the amount of energy required to produce a unit of goods and services in industrialized economies. This phenomenon has resulted in the "decoupling" of economic output from energy consumption—two measures which, until relatively recently, were assumed to grow more or less in lockstep with each other. Figure 2 shows that primary energy use and gross domestic product (GDP) grew at almost the same rate for member countries of the Organisation for Economic Co-operation and Development (OECD)[2] between 1960 and 1978, but began to diverge thereafter, allowing for more output with less energy. The same divergence appears in Figure 3, which presents the same data for developing countries, but it emerges nearly 15 years later (in 1993).

Overall, the energy intensity of the OECD countries—where energy intensity is measured simply as the ratio of GDP to primary energy consumption—has been declining in recent years at an average rate of 1.1 percent per year. Interestingly, energy intensity has been falling even faster in non-OECD countries, presumably because many are in the process of modernizing from a fairly inefficient industrial base. It is worth emphasizing, however, that around the world electricity intensity—that is, the amount of electricity consumed per unit of GDP—has not been declining. In fact, because of its versatility, convenience and lack of emissions at the point of use, electricity use as a share of overall energy use has tended to increase as societies modernize and become wealthier. Consequently, electricity growth has been outpacing the rate of economic growth in all regions in recent years—an observation that is relevant to the discussion of trends in electricity production in the subsection that follows.

2.3 De-carbonization and diversification, especially in the production of electricity

Another historic trend that is likely to be relevant for future energy sustainability involves a change in the carbon content of the fuels used as primary energy sources. The progression from wood and other traditional biomass fuels to a reliance on coal in the first part of the industrial age to, more recently, an energy mix that includes large shares of oil, natural gas and nuclear power in addition to coal, has implied a gradual reduction in the overall carbon intensity

[2] The OECD was established in 1961. Its 30 member countries include the world's major developed economies.

of the world's energy supply.[3] In fact, the ratio of tons of carbon in the primary energy supply to units of energy consumed globally has declined by about 0.3 percent per year since 1860, enough to reduce the overall ratio by 40 percent (Nakicenovic, 1996).

From the standpoint of concern about climate change, the trend toward lower carbon intensity in the second half of the 20th century has been helpful in slowing the rate of increase in atmospheric concentrations of carbon dioxide. (The earlier transition from traditional biomass fuels to fossil fuels, by contrast, has had the opposite effect—despite an associated reduction in carbon intensity—for reasons discussed in footnote 3.) In the three decades before 2000, the carbon intensity of the global economy—in kilograms of carbon (kgC) per U.S. dollar of gross world output (GWP)—declined from 0.35 kgC/$GWP in 1970 to 0.24 kgC/$GWP in 2000. This reduction translates to an average yearly decline in carbon intensity of approximately 1.3 percent per year. More recently, however, the rate of decline in carbon intensity began to slow and even reverse. Globally, carbon intensity per dollar of economic output has increased at a rate of approximately 0.3 percent per year since 2000 (Canadell/PNAS, 2007).

Whether the last few years represent an anomaly and whether global carbon intensity—even absent climate-related policy interventions—will resume the downward trend that was underway before 2000 remains unclear. Global warming concerns notwithstanding, higher prices and longer-term supply concerns for oil and natural gas are likely to prompt increased utilization of coal and unconventional oil resources (*e.g.*, tar sands and oil shale) that could substantially increase the carbon intensity of the global energy supply mix. Indeed this may already be occurring to some extent.

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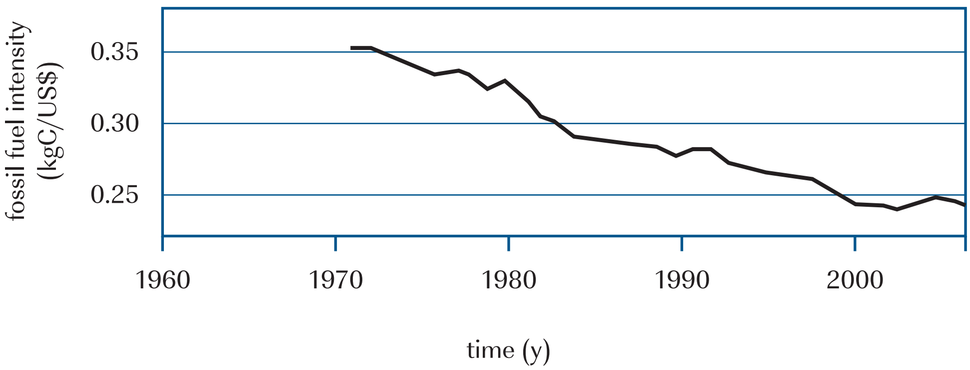
[3] The ratio of hydrogen atoms to carbon atoms in wood is effectively one to ten; in coal it is between one to two and one to one; in oil it is two to one; and in natural gas it is four to one. It bears noting, however, that from a climate change perspective not all sources of carbon are equal. Provided that biomass feedstocks are being managed sustainably, carbon dioxide released by the combustion of biomass fuels is offset by an equivalent uptake of carbon dioxide from the atmosphere to support the growth of new biomass. As a result there is, in equilibrium, no net change in atmospheric carbon dioxide concentrations. The combustion of coal and other fossil fuels, by contrast, puts carbon in the atmosphere that has been stored—and thus kept out of circulation—for millennia. It therefore produces a net increase in atmospheric concentrations. Together, human activities—primarily fossil fuel combustion and land use changes—are believed to be responsible for an increase in atmospheric carbon dioxide concentrations of approximately 40 percent since pre-industrial times (from roughly 270 parts per million around 1750 to 380 parts per million in 2005) (IPCC, 2007, Fourth Assessment Report, Summary for Policymakers, p. 5).

Figure 4: Xxxxxxxxxxxxxx

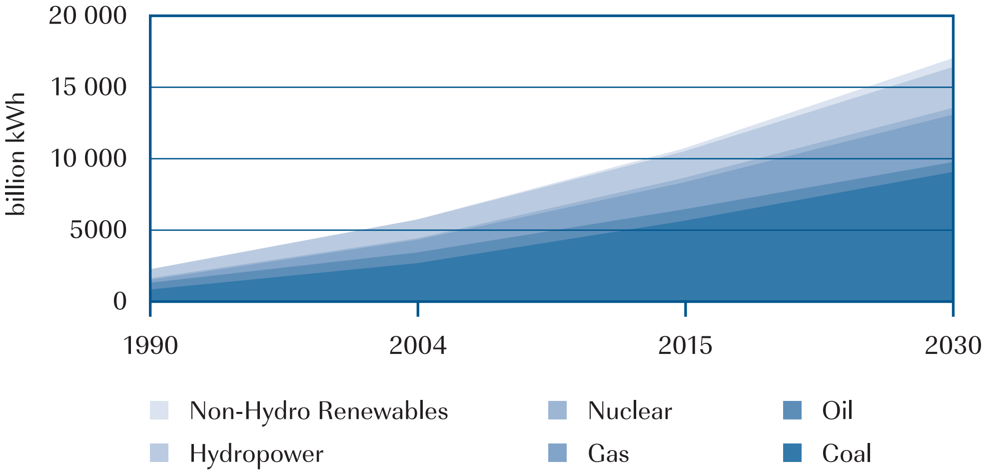


Source: Canadell, Josep G., etc., in PNAS, 2007, p. 18868.

Longer term, many experts believe that climate change and other concerns will necessitate a transition—via natural gas—to a hydrogen economy dependent on the introduction of non-carbon energy sources and the sustainable use of biomass (Ausubel, 1996, p. 4). Based on the historic rate of energy de-carbonization, this process could take 80 years to unfold in the absence of further policy interventions. The process could possibly be longer if rising prices and supply constraints for oil and natural gas, coupled with a lack of cost-competitive non-fossil-fuel alternatives, create countervailing pressures to move toward more carbon-intensive fuels like coal.

A second distinct trend, one that has clear linkages to the gradual process of de-carbonization described above, began in the early 20th century and continues today. It is characterized by a proliferation of end-use technologies that rely on diversity of fuels to generate electricity. Figure 5 shows current and projected electricity production by fuel for developing countries, based on the International Energy Agency's (IEA) 2005 reference scenario forecast. The figure suggests that total electricity production by developing countries will nearly triple over the next 25 years. Non-hydropower renewables are expected to increase their share of the total electric sector supply mix from roughly 1 percent to 4 percent over that timeframe. Overall, however, coal continues to dominate—accounting for roughly half of total developing-country production in 2030. Of course, the IEA projections do not account for the effect of new policies that could be introduced to address climate change and other concerns in the decades ahead. Such policies could further expand the contribution from non-fossil primary energy sources in the world's electricity supply mix over the next several decades.

Figure 5: Electricity Generation in Developing Countries: 2006 IEA Reference Case Forecast



Source: IEA, World Energy Outlook 2006, p. 513.

An effective response to the threat of climate change will require a significant acceleration of the historic trends toward de-carbonization and fuel diversification. This acceleration will need to take place on a global scale. It cannot be restricted to the developed countries but must be pursued with equal or even greater vigor in developing countries.

2.4 Reduction in conventional pollutants associated with energy use

The archetypal symbol of the industrial age was the smokestack, and in many developing countries large energy facilities continue to represent modernity and economic opportunity. With increasing affluence and better understanding of the adverse environmental and human health impacts associated with most conventional air pollutants, however, the public's willingness to accept dirty technologies has decreased, especially in the last 30 years. The result has been a clear link between rising incomes and increased emphasis on environmental performance in many countries. Over time, both energy end-use technologies (*e.g.*, cooking stoves, automobiles) and energy conversion technologies (*e.g.*, power plants) have become progressively cleaner, at least with respect to visible, local and immediately harmful pollutants.

In fact, the energy technology with the most immediate potential to improve human health and well-being in many developing countries is relatively simple: improved cooking stoves. Use of such traditional fuels as wood and dung for cooking is inefficient and generates extremely high levels of indoor pollution. Accelerating the transition to more expensive, but far cleaner kerosene, liquefied petroleum gas (LPG), or electric stoves, would dramatically reduce exposure to unhealthy levels of particulate pollution, especially among women and children, in many developing countries. Other sectors that offer large opportunities for reducing conventional air pollutant emissions and improving public health are transport and electricity production. More stringent pollution control requirements for automobiles, heavy-duty vehicles and equipment and power plants, in particular, could substantially improve air quality.

In some cases, technology improvements that reduce emissions of conventional air pollutants (such as sulfur dioxide, nitrogen oxides, hydrocarbons and particulate matter) can be expected to also reduce emissions of greenhouse gases. A good example is the use of natural gas for electricity production, which became increasingly common in the United States in the 1990s, in part because the avoided cost of pollution controls made natural gas competitive with coal for capacity additions. Some conventional pollutants, such as black carbon, directly contribute to warming. In those cases, conventional emission controls can provide automatic climate co-benefits. In other cases, the relationship is more complicated: Sulfur particles, for example, actually have a cooling effect in the atmosphere. In general, most post-combustion conventional-pollutant control technologies do not reduce emissions of carbon dioxide, the chief greenhouse gas. Moreover, agreements to reduce or control emissions that could disrupt global climate systems have proved much more difficult to negotiate.

Devising effective policy responses to a problem that is truly global and multi-generational in scale presents a challenge that is unprecedented in the history of environmental regulation and daunting for developed and developing countries alike. For developing countries, that challenge is greatly complicated by the simultaneous need to expand access to essential energy services and to provide low-cost energy for economic development.

3. Promoting Sustainable Energy in Developing Countries

Global consumption of commercial forms of energy has increased steadily over the last four decades, recently marked by especially dramatic growth rates in many developing countries. Yet, stark inequalities persist in the worldwide distribution of access to modern energy services. Between 1970 and 1988, developing countries' share of global primary energy consumption increased from approximately 13 percent to about 30 percent. In 2005, the non-OECD countries accounted for just over half (52 percent) of global primary energy consumption. This increase in energy consumption has not, however, resulted in more equitable access to energy services on a per capita basis. In 2005, average per capita energy consumption in the OECD countries was more than four times average per capita energy consumption across all non-OECD countries, and nearly seven times the average per capita energy consumption in Africa (IEA, Key Energy Statistics 2007, p. 48).

Overall, at least one-fourth of the world's 6.6 billion people are unable to take advantage of the basic amenities and opportunities made possible by modern forms of energy. Inequities in per capita electricity use are even larger than the inequities in per capita primary energy use. In 2005, the average citizen in the OECD countries used 8,365 kwh of electricity. By contrast, the average citizen in China used 1,802 kwh, the average citizen elsewhere in Asia used 646 kwh, the average citizen in Latin America used 1,695 kwh and the average citizen in Africa used 563 kwh.

These regionally or nationally aggregated figures mask even starker within-country disparities, since the energy consumption patterns of elites in many developing countries are similar to those of the general population in developed countries. In fact, though it is estimated that developing countries were spending as much as $40 to $60 billion annually on electricity systems by the end of the 20th century (G8, RETF, 2001), approximately 40 percent of the population in these countries remained without access to electricity. This means that the number of people without access to electricity worldwide has hardly changed in absolute terms since 1970 (UNDP, 2000, p. 374). Not surprisingly, the rural poor in developing countries account for the vast majority (nearly 90 percent) of households without access to electricity worldwide.

In this context, the most immediate energy priority for many developing countries is to expand access. In fact, providing safe, clean, reliable and affordable energy to those who currently have no access is widely viewed as critical for advancing other development objectives. While there was no specific chapter on energy in Agenda 21 (1992) and no specific United Nations Millennium Development Goal (2000) on energy, access to basic energy services is directly linked to most of the social and economic development targets outlined in the Millennium Declaration (WEHAB Working Group, 2002).

If access is the priority, the immediate obstacle for many poor households and governments in developing countries is a lack of financial resources. Moreover, where access to energy is lacking, other urgent human and societal needs are often unmet too, meaning that energy needs must compete with other priorities. Fortunately, people need only a relatively modest amount of electricity to be able to read at night, pump a minimal amount of drinking water and listen to radio broadcasts (G8-RETF, 2001). It is possible, in other words, to greatly improve the quality of life for many poor households at a level of energy consumption far below that of the average citizen in an industrialized country.

To pay for even basic services, however, households need income-generating opportunities, which also require energy. Table 1 below shows typical electric service requirements for off-grid households in developing countries, assuming an average size of five persons per household. It has been estimated that basic household services, along with commercial and community activities (*e.g.*, rural clinics and schools), could be provided for, on average, just 50 kilowatt-hours (kWh) per person per year (note that this figure includes only basic electricity needs; energy requirements for cooking and transportation are not included).

Table 1: Typical Electricity Requirements for Off-Grid Populations in Developing Countries

Energy service/Development need	Typical energy services	Electricity demand kWh/ month per household
Lighting	5 hours/day @ 20 W/household	2.0-6.0
Radio/music	5 hours/day @ 5 W/household	
Communications	2 hours/day @ 10 W/household	
Portable water	Community electric pump providing 5 liters/day/capita	
Basic medical services	2.5 kWh/day for 100 households	0.5-1.0
education	2.5 kWh/day for 100 households	0.5-1.0
Income generating productive uses	5 kWh/day for 100 households	0.0-20.0
TOTAL	--	**3.0-30.0**

Source: Adapted from Table 1, (G8 RETF, 2001, p. 23).

An estimated 1.6 billion people worldwide lack access to electricity. Providing basic electricity services to these people at an average annual consumption level of 50 kWh per person would imply an increase in global end-use electricity demand of roughly 80 billion kWh per year. This figure represents less than one-half of 1 percent of global annual electricity production (estimated at 18,235 billion kWh in 2004) and less than one-fifth of the expected year-to-year increase in global electricity production projected for the next two decades, according to the IEA's 2006 reference case forecast for 2004–2030.

Besides expanding access, many developing countries face at least two other immediate energy-related challenges. The first and most pressing issue for many oil-importing countries is economic: a rapid rise in world oil prices has led to a steep and, for some countries, increasingly unmanageable escalation in their import bill for energy commodities. For example, India's oil import bill increased more than 20 percent in a single year, from $33 billion in 2006 to an estimated $40 billion in 2007.[4] According to the Economic Research Service of the U.S. Department of Agriculture: "For oil-importing developing countries, the $137-billion increase in the energy import bill in 2005 far exceeded the $84 billion of official development assistance they received."[5] Moreover, oil prices have continued to rise substantially since 2005, adding further to this financial burden.

For many smaller and poorer countries, the combination of rapidly rising energy prices and a recent, similarly precipitous escalation of world food prices is generating concerns about internal economic and political stability. For these countries, diversifying their domestic energy resource base and reducing their demand for imported fuels would carry a host of benefits, not only by freeing scarce resources for domestic investment but also by reducing their long-term exposure to the financial and humanitarian crises that now loom in many parts of the world.

A second, important energy-related challenge is environmental. As noted in a previous section, energy use is a significant and immediate cause of high levels of air pollution and other forms of environmental degradation in many developing countries. Energy-related emissions from power plants, automobiles, heavy equipment and industrial facilities are largely responsible for levels of ambient air pollution—especially in major cities—that routinely exceed, sometimes by an order of magnitude, the health thresholds set by the World Health Organization. And in urban and rural areas alike, indoor air pollution attributable to the use of traditional fuels for cooking and space heating exposes billions

[4] Source: http://www.upiasiaonline.com/Economics/2007/12/11/india_and_china_lose_with_high_oil_prices/6010/

[5] Source: http://www.ers.usda.gov/AmberWaves/February08/Features/RisingFood.htm

of people, especially women and children, to significant cardiovascular and respiratory health risks on a daily basis. In many cases, adverse environmental impacts begin well upstream of the point of energy end-use: the extraction of commercial fuels like coal and oil is often highly damaging to local ecosystems and an immediate cause of land and water pollution. Meanwhile, reliance on traditional fuels such as wood can produce its own adverse impacts.

Longer-term, climate change caused by energy-related emissions of greenhouse gases can be expected to pose many risks for developing countries. Even though developed-country emissions are overwhelmingly responsible for current levels of heat-trapping gases in the atmosphere, numerous analyses predict that the myriad burdens of global warming are likely to fall disproportionately on developing countries. That is because developing countries are likely to be more sensitive to such adverse impacts as the effects on water resources and agricultural productivity. They are also more likely to lack the financial and institutional means to implement effective adaptation measures.

Given that developing countries are expected to account for a large and growing share of overall greenhouse gas emissions in the future, active participation in efforts to de-carbonize the world's energy systems is essential as a matter of self-interest and in the interests of averting a global environmental catastrophe.

To a significant extent, fortunately, the goal of reducing greenhouse gas emissions may be aligned with the pursuit of other energy-related objectives, such as developing indigenous renewable resources and reducing local forms of pollution. In the near term, however, there will be tensions. This is particularly likely if policies to discourage the use of carbon-intensive conventional fuels, many of which would implicitly or explicitly have the effect of raising energy prices, are seen as conflicting with either (or both) the goal of expanding access to essential energy services for the poor or promoting economic development. Pursuing a sustainable energy agenda for developing countries thus requires leveraging positive synergies with respect to other societal and economic objectives while minimizing potential conflicts between different public goals.

How this may be accomplished through well-designed policies is discussed in a later section of this report. First, however, it is useful to review some of the technology options available to developing countries in seeking to meet their growing energy needs in a global context marked by increasingly intractable environmental and resource constraints.

4. Sustainable Energy Technologies

The different energy supply technologies that will likely play a role in a carbon-constrained future have been extensively reviewed elsewhere. The usual list includes renewable energy technologies (*e.g.,* wind, solar and biomass), nuclear technology and advanced fossil-fuel systems with carbon capture and sequestration. Natural gas systems are widely viewed as a crucial 'bridge' technology. In addition, energy efficiency is often cited as a critically important and an often lower-cost complement to improvements on the supply side.

In principle, the same supply- and demand-side options are available to all countries. Nevertheless, some options—especially technologies that are in the very early stages of commercialization, or that require very large, upfront capital investments or substantial outside expertise to operate—are likely to face additional deployment hurdles in developing countries.

For purposes of this report, we focus on renewable energy technologies because they can be particularly attractive in dispersed, 'off-grid' applications and therefore represent an important option for rural areas that lack electricity transmission and distribution infrastructure. Other low-carbon supply technologies are reviewed briefly (at the end of this section), while energy efficiency is covered as part of the policy discussion in the section that follows.

A number of renewable energy technologies have improved to the point where they can now provide electricity at lower cost than other supply options wherever grid extension is prohibitively expensive or uneconomic. There are six broad categories of renewable energy technologies—biomass, wind, solar, hydro, geothermal and marine. They can be tapped using a variety of conversion technologies or processes to produce a range of energy services, including electricity, heat (or cooling), fuels, mechanical power and illumination. The competitiveness of different renewable technologies in different settings depends on their cost and performance, as well as on the local cost and availability of fossil-based energy. Both factors still vary widely and depend strongly on local conditions.

For example, many renewable energy sources are inherently intermittent. Thus their integration into a unified electricity grid can pose challenges, especially on a large scale, and may make them less competitive with conventional generating systems.[6] In dispersed, off-grid applications, by contrast, intermittency may pose less of a problem and renewable technologies may be more cost-effective than the next available conventional option. In addition, their modularity—that is, the fact that many renewable energy technologies can be deployed in relatively small unit increments[7]—may be advantageous from a cost and risk standpoint in many developing countries.

In general, costs for most forms of renewable energy have declined substantially in recent decades. In the early 1990s, only hydropower was competitive with conventional power plants for on-grid applications. Since then, expanding markets and experience-driven cost reductions have made wind and geothermal power competitive or nearly competitive with other, conventional sources. Solar photovoltaic technology remains more expensive but can compete in some off-grid niche market applications. These comparisons are, of course, based on narrow criteria of strict cash flow and ignore other advantages, such as environmental benefits, that renewable technologies can confer (G8 RETF, 2001, p.16-17).

Table 2 shows current and projected future costs for selected renewable technologies. The figures are somewhat dated, but they indicate how much further costs might be expected to fall with additional experience, larger-scale deployment and continued technology improvement. Prospects for continued cost reductions are promising given recent rapid growth in renewable energy markets. Over the past several years, the global rate of increase in installed wind and photovoltaic capacity has averaged as much as 30 percent per year, making these some of the most rapidly expanding energy technology markets in the world.

[6] Longer term, the development of cost-effective storage systems can overcome this drawback of renewable technologies like wind and solar.

[7] Most if not all technologies have a range of sizes over which they are most economical or cost-effective to use. For a long time, the industry benchmark for power generation was a 500 MW centralized pulverized coal plant costing $500 million (or $1000/kW of installed capacity). Given their higher efficiency, industrial gas turbines now produce electricity at half the cost achieved by large-scale coal plants. The range of sizes for these turbines, however, is of the order of 5 to 50 MW. This is now the industry standard to beat for energy costs. It is possible that micro-turbines, in the 100-kW range, with one moving part, could produce power at a rate lower than even gas turbines. Fuel cells represent another, potentially promising “micro-power” option for the future.

Table 2: Current and Projected Future Costs of Renewable Energy Technologies:

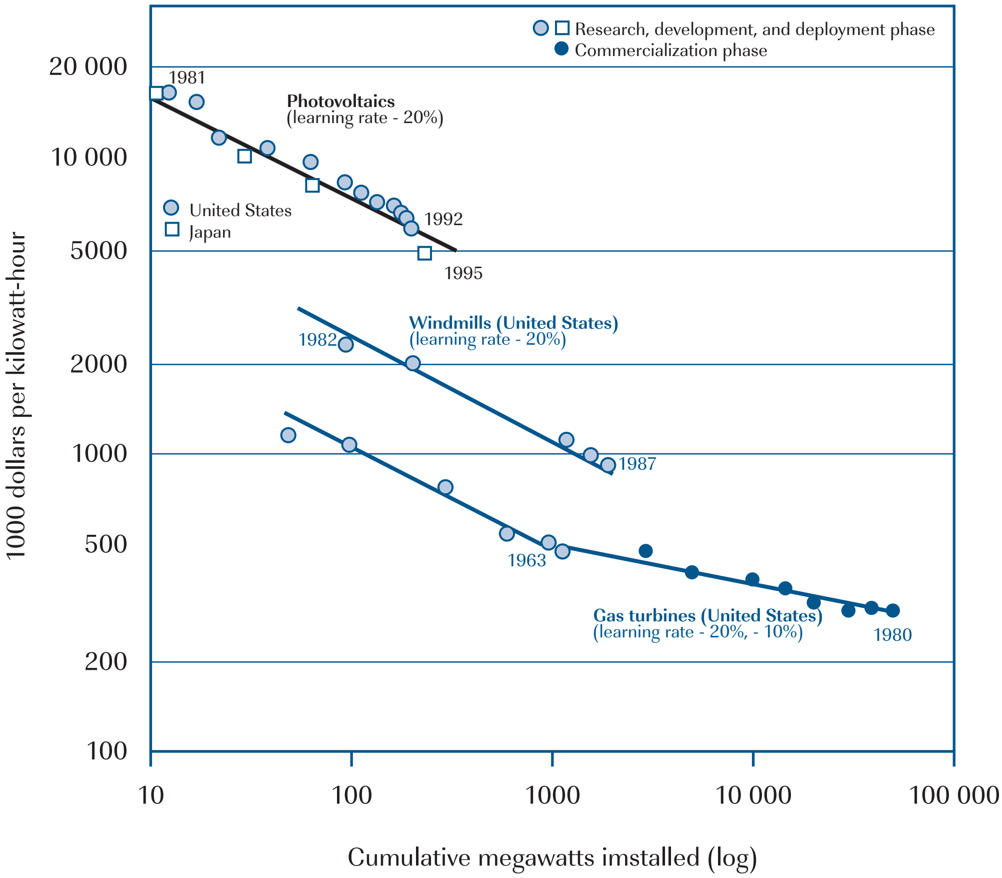
		Current Energy Costs		Potential Future Energy Costs	
Source	Units	Low	High	Low	High
Biomass/Ethanol	$/GJ	8	25	6	10
Bio-diesel	$/GJ	15	25	10	15
Geothermal-Heat	c/kWh	0.5	5	0.5	5
Biomass-heat	c/kWh	1	6	1	5
Geothermal-Electricity	c/kWh	2	10	1	8
Large Hydro	c/kWh	2	10	2	10
Small Hydro	c/kWh	2	12	2	10
Solar low temperature heat	c/kWh	2	25	2	10
Wind Electricity	c/kWh	4	8	3	10
Biomass-Electricity	c/kWh	3	12	4	10
Marine-current	c/kWh	10	25	4	10
Solar Thermal Electricity	c/kWh	12	34	4	20
Marine Wave	c/kWh	10	30	5	10
Solar PW Electricity	c/kWh	25	160	5	25
Marine-ocean thermal	c/kWh	15	40	7	20
Marine-tidal	c/kWh	8	15	8	15

For comparison, in recent years typical (wholesale) electricity production costs in many developed countries have been on the order of 2–4 c/kWh; retail prices have been on the order of 8 c/kWh; prices in off-grid niche markets have been on the order of 14 c/kWh and peak power prices have typically ranged from 15–25 c/kWh (G8, RETF, 2001).
Source: (adapted from UNDP, 2004, Table 7, p. 50).

Expectations of declining costs with greater field experience and larger-scale deployment are not unique to renewable energy technologies. They would apply as well to other relatively new, low-carbon technology options (such as carbon capture and sequestration). Figure 6 compares the decline in unit costs for wind and photovoltaic technology in the United States and Japan with the historic decline in the prices of gas turbines. The figure shows that for gas turbines the declines were more rapid at first but tapered off as the technology matured. This feature is typical of maturing technologies.

All renewable energy sources can be converted to electricity (in principle, energy can always be converted from one form to another). In actual practice, however, there will be some routes that will be preferred due to cost-effectiveness. Table 3 suggests some specific near-, medium-, and long-term options for supplying basic energy needs in rural areas using low-carbon technologies. The mix of options likely to be optimal in different settings will depend on cost, scale, location, timing and availability of local resources and expertise and a host of other factors. In general, a greater diversity of supply options will help to reduce exposure to resource and technology risks. On the other hand, there are also trade-offs to be considered—some standardization can help to reduce deployment costs and make it easier to develop the local expertise needed to operate and maintain new technologies and systems.

Figure 6: Experience curves for photovoltaics, windmills, and gas turbines in Japan and the United States



Technology performance and costs improve with experience, and there is a pattern to such improvementscommon to many technologies. The specific shape depends on the technology, but the persistent characteristic of diminishing costs is termed the 'learning' or 'experience' curve. The curveis likely to fall more sharply as technologies first seek a market niche, then full commercialization, because lower costs become increasingly important for wider success. *Source: Nakicenovic, Grübler, and McDonald, 1998.*
Source: UNDP, 2000, Figure 12.1, p. 436.

Table 3: Technological Options for Rural Energy

Energy source/ service	Present Options	Near Term Options	Medium Term Options	Long Term Options
Electricity	Grid-based or no electricity	Natural gas combined cycles, biomass gasifiers coupled to internal combustion engines, wind, photo-voltaics, small hydro for remote applications.	Biomass gasifiers coupled to micro-turbines; mini grids with combinations of photovoltaics, wind, small hydro, batteries.	Grid-connected photovoltaics and solar thermal, biomass gasifiers coupled to fuel cells and fuel cell/turbine hybrids.
Fuel	Wood, charcoal, crop residues, animal dung	Natural gas, liquid petroleum gas, producer gas, biogas.	Syngas, dimethyl ether.	Dimethyl ether from biomass with electricity as a co-product.
Cogeneration	--	Internal combustion engines, turbines.	Micro-turbines with integrated combined cycles.	Fuel cells, fuel cell/ turbine hybrids
Cooking	Woodstoves	Improved woodstoves, liquid petroleum gas, biogas.	Producer gas, natural gas, dimethyl ether.	Electric stoves, catalytic burners.
Lighting	Oil and kerosene lamps	Electric lights	Fluorescent and compact fluorescent lamps	Improved fluorescent lamps, compact fluorescent lamps
Motive power	Human and animal power	IC engines, electric motors	Bio-fueled prime movers, improved motors	Fuel cells
Process heat	Wood, biomass	Electric furnaces, cogeneration, producer gas, natural gas/solar thermal furnaces.	Induction furnaces, biomass/solar thermal furnaces.	Solar thermal furnaces with heat storage.

Source: Adapted from table 10.3, UNDP. 2000, p. 380.

Along with the need to extend basic electricity services to rural areas, many developing countries face rising demand for grid-connected power to meet industrial and manufacturing energy needs and to provide electricity in fast-growing urban areas. In countries with access to substantial coal supplies, conventional coal-fired steam-electric power plants are often the cheapest near-term option for adding large-scale, grid-connected generating capacity. But such investments run the risk of locking in decades of high carbon emissions and—unless modern pollution controls are included—substantial quantities of conventional air pollutant emissions. These economy/environment trade-offs are difficult to navigate, especially for poorer countries with urgent near-term needs for low-cost power. In those instances, assistance from developed countries to offset the additional costs and technology demands of more expensive but cleaner and lower-carbon technologies will be essential.

Nearer-term, commercialized alternatives to high-emitting conventional coal plants include, among renewable technologies, primarily wind and biomass;[8] higher-efficiency conventional coal plants (*e.g.*, super-critical and fluidized bed systems); nuclear power; and—where natural gas is available—integrated, combined-cycle gas turbines. Longer-term, advanced coal technologies—such as integrated, combined-cycle gasification systems—coupled with carbon capture and sequestration must be successfully commercialized to make continued reliance on coal resources compatible with global carbon constraints.

Of the major non-renewable, low-carbon generating options, modern natural gas systems are relatively clean and efficient and can be cost-competitive where ample supplies of natural gas are available. They can also be deployed relatively quickly and in small (<100 MW) increments. Nuclear technology, by contrast, is far more demanding. China and India are poised to make substantial commitments to nuclear power in the next few decades. But for smaller developing countries this technology—because of the operational and waste management challenges it presents, and its high upfront capital costs—is unlikely to be attractive in the near- to mid-term. Advanced coal systems with carbon capture and sequestration are at an even earlier stage in the research, development and deployment trajectory. Given their high capital cost and the relatively unproved nature of the technology, most analysts believe that developed countries will need to take the lead in demonstrating and commercializing this option.

As noted in an earlier section, the mix of technologies and fuels used to meet electricity needs has become more diverse over time. In contrast, the transportation sector has remained—with few exceptions—overwhelmingly dependent on petroleum fuels. This is problematic both from an environmental standpoint (transportation accounts for roughly one-quarter of global energy-related carbon dioxide emissions) and an energy and economic security standpoint given recent trends in world oil markets. Rapid growth in vehicle ownership and overall travel are significant issues for many developing countries that are contending with already high levels of air pollution in urban centers and seeing a sharp rise in expenditures for imported oil.

In the near- to medium-term, developing and developed countries alike have two primary options for advancing sustainability objectives in the transportation sector: (1) improving vehicle performance through improved efficiency and emissions controls and (2) promoting sustainable, low-carbon biofuels as an alternative to petroleum-based fuels. Both options have drawn increased

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[8] In addition, concentrating solar-thermal technology for electricity production has recently attracted renewed attention, with demonstration projects planned or underway in several countries.

attention in recent years. A number of countries with large vehicle markets, including China and India, have adopted more stringent emissions standards and are considering automobile fuel-economy standards. At the same time, global interest in biofuels development has intensified markedly, in part because of the adoption of aggressive fuel mandates in developed countries like the United States. Brazil is already a world leader in this area, having successfully nurtured a major domestic sugarcane ethanol industry that is economically competitive with conventional gasoline.

The current worldwide boom in biofuels is proving a mixed blessing at best, however, especially in many developing countries where it is being blamed for contributing to accelerated rates of deforestation, habitat destruction and high food prices. These are significant issues and they should be addressed expeditiously through a thoughtful re-examination and reform of current biofuels policies—not only in the developing world but also in the developed countries that are driving much of the recent push to expand global production.

In the long run, the viability of biofuels as an alternative to oil—and the ability to manage or minimize tensions with food production and habitat preservation—will depend on the successful commercialization of improved feedstocks and conversion technologies. In general, such improvements—an example would be the ability to cost-effectively convert ligno-cellulosic feed-stocks to ethanol—would also greatly enhance the net environmental benefits and greenhouse gas reductions achieved by switching from conventional fuels to biofuels.

5. Diffusing Sustainable Energy Technologies

The energy challenges confronting developing countries are significant and growing greater in time. Moreover, it is clear that developing countries will not be able to avoid potentially large adverse consequences without the concerted policy interventions by developing and developed countries alike.

This section focuses on a relatively short, concrete list of policy actions that would help shift developing countries to a more sustainable energy trajectory. None will be easy to implement. All will require the active engagement of all sectors of society, including individual consumers and local communities, non-governmental organizations, private businesses and industry, the science and technology research community, governments, intergovernmental institutions and donor organizations. Developing countries must take the lead in charting a new energy course for themselves, but developed countries must stand ready to provide support, recognizing that they have a vital stake in the outcome. These policy action include:

- Promote energy efficiency and adopt minimum efficiency standards for buildings, appliances and equipment, and vehicles.
- Reform and re-direct energy subsidies.
- Identify the most promising indigenous renewable energy resources and implement policies to promote their sustainable development.
- Seek developed-country support for the effective transfer of advanced energy technologies, while building the indigenous human and institutional capacity needed to support sustainable energy technologies.
- Accelerate the dissemination of clean, efficient, affordable cookstoves.

Before proceeding to a more detailed discussion of these policy recommendations, it is worth underscoring a broader point concerning the need for harmonized policies and holistic approaches. First, as noted in the introduction, sustainable energy policies are more likely to succeed if they also contribute toward other societal and economic development objectives. Second, governments should look across policies to maximize positive synergies where they exist and avoid creating cost-cutting incentives. Too often, governments—in responding to different pressure groups at different times—adopt conflicting policies that at least partially undermine each other. For example, government efforts to promote energy efficiency can be undercut by simultaneous subsidies that tend to promote increased energy consumption.

Harmonization will not always be possible for political and other reasons, and it may not be possible to pursue a comprehensive set of policies all at once. Nevertheless, governments should recognize that maximum benefits can be achieved through an approach that remains mindful of the interaction of different policies, leverages multiple opportunities wherever possible and responds to the specific needs and constraints of individual countries.

5.1 Energy efficiency

Assessments of climate-change mitigation costs consistently find that energy efficiency improvements offer the largest and least costly emissions-reduction potential, while also providing important ancillary benefits such as energy cost savings, reductions in conventional pollutant emissions, reduced dependence on imported fuels and improved economic competitiveness. Energy efficiency can be especially important in rapidly industrializing countries as a way to manage rapid demand growth, improve system reliability, ease supply constraints and allow energy production and distribution infrastructure to 'catch up.'

As discussed in an earlier section, historic trends show steady progress toward improved energy efficiency and reduced energy intensity (where intensity is measured by the amount of energy required to deliver a unit of goods or services).

This historic rate of improvement can be expected to continue. Yet, absent policy intervention, such improvement is unlikely to keep pace with continued growth in demand—especially in countries that are still in the early stages of industrialization. Moreover, experience shows that market forces by themselves often fail to capture all cost-effective opportunities to improve energy efficiency.[9]

Countries like the United States have significant untapped energy efficiency potential. The U.S. economy, as is often pointed out, is only half as efficient as the Japanese economy (that is, the United States consumes twice as much energy per dollar of GDP). But the opportunities are also large in some

[9] A recent report by the McKinsey Global Institute finds that half of all global growth in emissions could be avoided at a negative net cost using energy efficiency measures. Specifically, the report finds that a global investment of US$170 billion per year in energy efficiency would yield US$900 billion in benefits annually by 2020, providing an average internal rate of return on investment of 17 percent per year. See: http://www.mckinsey.com/mgi/publications/Curbing_Global_Energy/index.asp

rapidly industrializing economies. China, for example, consumes nine times as much energy per dollar of GDP as compared to Japan. Overall, a recent assessment of global efficiency opportunities by the McKinsey Global Institute (2007) finds that the average annual rate of decline in global energy intensity could be boosted in a cost-effective way to 2.5 percent per year—essentially doubling the recent global rate of decline, which has been averaging approximately 1.25 percent per year. This is a significant finding as it confirms that even relatively small changes in year-to-year improvement can produce a wide divergence of outcomes over time.

At first blush, it might seem grossly insensitive to recommend energy conservation to countries that consume so little by global standards. But the historic record indicates that small, incremental and cumulative improvements in efficiency over long periods can deliver enormous benefits by making economies less wasteful, more productive and more competitive. The potential benefits of such improvements are particularly large in countries with rapidly expanding demand for new infrastructure, buildings, appliances and equipment. It is typically much easier and more cost-effective to build in a high level of efficiency from the outset than to improve efficiency at a later point in time. Moreover, policies that ride the waves of grand transitions are less likely to encounter friction than those that run counter to them. In most situations and in all countries, programmes to promote more efficient use of energy are essential and represent a no-regret option for reducing demand for all types of energy (G-8 RETF, 2001, p. 5).

Governments have an important role to play in promoting energy efficiency and conservation. Efficiency standards for appliances, equipment and automobiles, for example, have proved extremely cost-effective in many developed countries and are often relatively easy to implement compared to other policies—especially if countries can harmonize their standards with the standards manufacturers face in other large markets. Efficiency standards or codes for buildings, especially commercial buildings, are extremely important given the long life-span of most structures. To be effective, however, countries will need to educate architects and builders and develop the capacity to monitor and enforce compliance. By setting a floor or baseline for energy efficiency, minimum standards can deliver substantial energy savings in the future with a high degree of confidence.

To secure additional benefits and ensure that manufacturers keep innovating, other policies and incentives are needed to generate demand for products that perform above the minimum baseline. For example, governments can adopt labeling requirements and pro-active public procurement policies. Likewise, intergovernmental and non-governmental organizations and donors can encourage or insist on the use of more efficient equipment.

In some countries, utility companies have been successfully enlisted in efforts to promote efficiency among end-use customers. There is a substantial track record of such programmes in the United States. But examples can also be found in other countries (the textbox describes one utility-led initiative in India). Energy-efficiency or 'demand-side management' programmes can provide a number of benefits in developing countries, including reducing costs to customers, easing electricity supply problems, enhancing system reliability and moderating rapid demand growth.

5.2 Subsidy reform

Although energy subsidies have been declining in many parts of the world over the last decade, subsidies for fossil fuels still amount to several tens of billions of U.S. dollars in developing countries. Cumulatively, these subsidies total less than overall taxes imposed on such fossil fuels as petrol (G-8 RETF, 2001). But they have several effects that undermine, rather than advance, sustainable energy objectives. First, by artificially reducing the price of certain fuels, they distort the market and encourage inefficient levels of consumption (that is, consumption above the level that would be efficient for society based on their real costs). Second, fossil fuel subsidies make it more difficult for energy efficiency and cleaner sources of energy to compete.

The justification usually offered for subsidies is that they help the needy. In fact, many developing-country governments rely on subsidies largely because they lack other reliable mechanisms for making transfer payments to the poor. Even as a mechanism for poverty alleviation, however, subsidies are highly flawed. Because it is often difficult or impossible to restrict their use to the neediest households, the bulk of the benefit typically goes to wealthier households that can afford a higher level of consumption.

Of course, fossil fuel subsidies are not peculiar to developing countries. They exist in many countries. They are also addictive and those who benefit from them are usually unwilling to give them up. Thus it is easy for analysts to write that subsidies should be eliminated or phased out. But this step is notoriously difficult to take for politicians who have to renew their mandates periodically.

Reforming and re-directing energy subsidies—if necessary over time rather than all at once—may thus be a more realistic strategy for developing countries than attempting to abolish subsidies all at once. For example, a gradual reduction in subsidies for conventional fossil fuels could be used to provide new subsidies for more sustainable forms of energy or more efficient technologies. Alternatively, the public resources conserved by reducing subsidies could be directed toward other societal needs.

Box 5.2 A Utility-led Efficient Lighting Program in Bangalore, India

The Bangalore Electric Supply Company (BESCOM), a distribution company serving the Bangalore metropolitan area in the state of Karnataka, recently partnered with the International Institute for Energy Conservation to implement a programme to replace inefficient incandescent light bulbs with compact fluorescent lights (CFLs).

The programme was motivated in part by the need to address peak power shortages.

The BESCOM Efficient Lighting Program (BELP) was innovative in the developing world for several reasons: The programme was piloted on a substantial scale so that distribution utilities everywhere could witness its implementation and impacts.

- *Over nine months, BESCOM's monitoring and verification programme showed that 100,000 customers bought an average of two CFLs. Estimated programme benefits included a 300-percent increase in CFL sales, reductions in peak-power demand of 12 megawatts, energy savings of 10 megawatt-hours and carbon dioxide reductions totaling 100 tonnes.*
- *The utility and industry formed a novel and replicable partnership, wherein BESCOM used their billing and collection system to pass energy savings to customers and CFL vendors agreed to meet international product specifications and provide improved warranties.*
- *Except for the programme design, which was funded by the U.S. Agency for International Development, all marketing costs were borne by BESCOM, demonstrating that subsidies are not always necessary.*

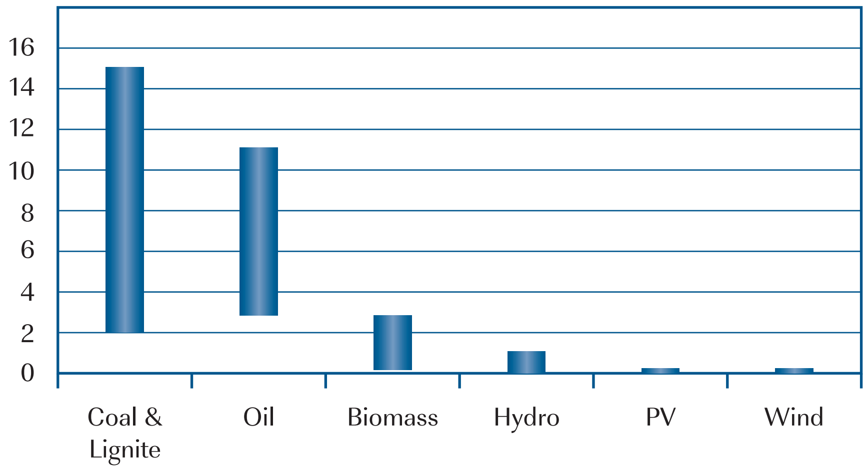
The BELP programme was widely viewed as a success and subsequently served as a model for lighting programmes sponsored by other companies. In addition, the Ministry of Power's Bureau of Energy Efficiency (BEE), which implements the Energy Conservation Act of 2001, recently announced a bulk purchase programme to further reduce the price of CFLs and invited distribution utilities in India to participate. Several vendors have agreed to reduce their prices through an across-the-board carbon financing mechanism, and BESCOM has continued to scale-up its programme.

Where there is concern that poor households will not be able to access basic energy services if they have to pay the full market price, it might be feasible to provide subsidies only up to a certain level of consumption. This is more likely to be practicable in the case of electricity (where, for example, low-income households might be offered reduced rates for the first increment of consumption) than in the case of portable fuels like petrol or kerosene. In sum, creative policy approaches are needed to navigate the tensions between expanding energy access and promoting sustainable energy outcomes. The research community and non-governmental organizations (NGOs) should take up this challenge and begin to explore possible solutions, including new mechanisms for transferring aid to poor households so that they can meet their basic needs.

In the longer-run, of course, energy prices for fossil fuels should not only be subsidized, but also increased to reflect environmental and public health externalities that are currently unrecognized by the marketplace. In principle, monetizing positive and negative externalities and making sure they are included in energy prices is an elegant way to address many issues of sustainability. Absent this step, the market will tend to over-allocate resources where there are negative externalities (such as pollution) and under-allocate resources where there are positive externalities (such as improved energy security).

The difficulties associated with internalizing externalities are essentially parallel to those associated with removing subsidies, with the added complication that it is often difficult to place a precise monetary value on certain impacts. Figure 7 illustrates the results of one attempt by the European Commission to quantify the external costs of global warming, public health, occupational health and material damage associated with different ways of generating electricity. The figure shows that the ignored costs associated with coal, lignite and oil are often much greater than the current cost differential with many renewable technologies. There is, however, considerable uncertainty about what specific number for external costs should be assigned to any one technology.

Figure 7: External costs for electricity production in the EU in Eurocent/kWh.



Data from the European Commission-ENERGIE Programme (European Union 5th Research and Technological Development Framework Programme)

Source: G-8 RETF, 2001, Figure 5, p. 19.

These difficulties are not insurmountable. Governments are continually faced with making decisions based on reasonable judgments, negotiated through the political process, in the face of uncertainty. In practice, the greater difficulty is likely to be political. Raising energy prices is almost always deeply unpopular with business leaders and the public. Objections are likely to be voiced on the basis that higher energy prices could harm consumers and the economy, with especially large effects on competitive industries and low-income households. As with reducing or removing subsidies, any effort to internalize externalities must navigate the apparent tension between raising prices for many conventional forms of energy and expanding access for the poor. (Note that this general point applies whether government seeks to internalize externalities through a tax or through environmental regulation.) Because of these parallels, some of the approaches noted in connection with subsidy reform may be helpful, including using a gradual approach and offsetting impacts on poor households through other forms of assistance. If the mechanism used to internalize externalities is an emissions tax, for example, the additional public revenues can be used to provide increased support for social services or other (non-energy) necessities or to subsidize other forms of consumption that primarily benefit the poor.

5.3 Developing indigenous sustainable resources

Many developing countries have abundant renewable energy potential and could benefit from the positive economic spillovers generated by renewable energy development, especially in currently underserved rural areas where decentralized, small-scale renewable energy technologies are likely to be most cost-competitive with conventional alternatives.

In most cases, however, government policies and public support will be necessary to capture these opportunities. The World Bank has concluded that incentives will usually be required to motivate the private sector to invest in providing services to the often remote and underdeveloped areas where the poor reside. In these areas, there is a case for providing intelligently designed incentives and/or subsidies for the development and use of appropriate technologies, preferably in ways that are targeted, simple, competitive and time-limited (G8 RETF, 2001).

Incentives or subsidies by themselves will not always be adequate to overcome market barriers, especially for risky projects in less accessible areas of developing countries. In those cases, direct financial support from the government or from outside groups or institutions may be necessary to implement renewable energy projects. There is ample precedent for such interventions: international aid organizations and other entities have invested millions of dollars in sustainable energy projects in developing countries. The track record for such investments, however, is decidedly mixed. Many projects have failed over time as a result of inadequate attention to practical problems, local conditions and the need for ongoing maintenance and operational expertise.

Given the scale of the challenge in relation to the scale of available resources, it is vital that future efforts improve on the record of the past. This can partly be accomplished by taking greater care in the design and implementation of projects and by ensuring that the skills and financial resources needed to sustain new energy installations are in place. For its part, the research community should put greater emphasis on developing renewable energy technologies that are robust and well-adapted to the specific conditions found in developing countries. In addition, researchers and advocates alike must avoid the tendency to understate costs, or belittle potential problems with the technologies they bring forward. Other aspects of this challenge are discussed in subsequent sections, which address the importance of expanding and improving international technology transfer initiatives and the need to build institutional and human capacity.

Box 5.3 Using Rural Cooperatives for PV electricity in Bangladesh

The Grameen Bank of Bangladesh, a world-renowned micro-lending agency, established a non-profit subsidiary, Grameen Shakti, in 1996 to administer loans for photovoltaic solar home systems to serve those without access to electricity. Initially, Grameen Shakti found that long distances, poor transport infrastructure, periodically flooded and impassable roads, low literacy rates, lack of technical skills and transactions based on barters all contributed to high transaction costs and difficulty in building consumer confidence in their product. In 1998, a Global Environment Facility (GEF) grant enabled Grameen Shakti to offer improved credit terms to its customers and install thousands of systems. They also found that a critical mass of installations in an area (of the order of 100 systems) built consumer confidence, making it easier and less time consuming to expand the customer base (G8, RETF, 2001). Grameen Shakti now expects to be able to draw additional financing for scale-up activities from commercial banks.

Government support for sustainable energy technologies clearly has a role to play in the demonstration and initial deployment stages described above. But government involvement is even more crucial in the earlier stages of research and development (R&D). Not surprisingly, developed countries have historically taken the lead in energy R&D spending because they have had the resources to do so. This is likely to continue to be the case. But it does not mean that there is no role for developing countries. Some of the larger developing countries have sufficient resources to make their own substantial technology investments. Others can participate by targeting investments and/or by working cooperatively with other countries or institutions to ensure that broader R&D efforts address the specific opportunities and constraints that apply in a developing country context. Investment in energy R&D can also be seen as a way to build indigenous human capital in science and engineering. Brazil, for example, has nurtured a viable domestic biofuels industry through all stages of technology development, deployment and commercialization (see text box below).

Box 5.4 National Alcohol Program in Brazil

When concerns about gasoline (petrol) shortages emerged in the first half of the 20th century (1896–1943), many European nations experimented with programmes to blend gasoline with alcohol. As supply concerns faded, however, so did these programmes. Brazil's earliest attempts to introduce blended automotive fuels date back to 1903. But a full-scale biofuels effort did not begin until 75 years later when the National Alcohol Program (Pro-Alcool) was launched in 1975 in response to an dramatic rise in international oil prices and the adverse balance of payments that this increase created.

At various times, Brazil's Pro-Alcool programme has favored the use of neat hydrated alcohol (96 percent ethanol, 4 percent water) and gasohol (74 to 78 percent gasoline and 22 to 26 percent anhydrous ethanol), both produced from sugar cane. Brazil now has the largest programme of commercial biomass utilization in the world (UNDP, 2000, p. 229). Although automobiles that run on hydrated alcohol are no longer being produced in Brazil, those running on blends sustain an annual production of 200,000 barrels of ethanol per day. From 1975 to 1989, the value of the avoided import oil bill associated with this level of production was about US$12.5 billion whereas the investments in the program during the same period did not exceed US$7 billion (Rosa and Ribeiro, 1998, p. 466). The avoided oil import bill reached US$40 billion for the first 25 years of the program's operation.

Brazil's programme has had many social, economic, and environmental benefits. It has created significant number of skilled and semi-skilled jobs, played a significant role in developing a strong agro-industrial base, reduced urban environmental pollution by reducing carbon monoxide emissions and improved the global environment by curbing carbon dioxide emissions. Subsidies for this programme were phased out and fully eliminated in 1999. Not surprisingly, the programme seems to flourish most whenever international oil prices are high and international sugar prices are low.

Governmental support for energy R&D, however, is currently declining in all countries (UNDP, 2000, p. 448). Given the challenges at hand, this trend will need to be reversed because only governments take a long enough view (on the order of decades) to support the long-term investments in energy R&D that are needed to fully commercialize new technologies.

5.4 Promoting technology transfer and developing human and institutional capacity

Substantial efforts to facilitate technology transfer from developed to developing countries are clearly essential to achieving global sustainability objectives. This need is widely acknowledged and was affirmed most recently at the December 2007 UN Conference on Climate Change in Bali. At that conference, developing-country negotiators called for language explicitly linking mitigation action by developing countries to "measurable, reportable and verifiable" support for technology, finance and capacity-building.

Accordingly, Decision 1(d) of the Bali Action Plan10 calls for enhanced action on technology development and transfer to support action on mitigation and adaptation, including consideration of:

- Effective mechanisms and enhanced means for the removal of obstacles to, and provision of financial and other incentives for, scaling up of the development and transfer of technology to developing countries to promote access to environmentally sound technologies.
- Ways to accelerate deployment, diffusion and transfer of affordable environmentally sound technologies.
- Cooperation on R&D of current, new and innovative technology.
- Development of effective mechanisms and tools for technology cooperation in specific sectors.

While the current situation clearly demands that more technology transfer be done, it also demands that technology transfer be done better. In the past, too many well-intended projects have failed to live up to their promise. To ensure that rural areas of developing countries do not become graveyards for sustainable energy technologies, sustained attention must be paid—by host and donor nations alike—to the human and institutional capacities needed to support these technologies on a long-term basis (UNDP, 2000, p. 441).

Research shows that technology transfer is more successful and more likely to produce innovation when the host institution has requisite technical and managerial skills. Thus there is an urgent need to develop skills to produce, market, install, operate and maintain sustainable energy technologies in developing countries. Ensuring that as much of this capacity-building as possible occurs in local communities and companies based in the host country has the potential to provide additional benefits, not only in terms of local job creation and economic development, but also because project developers and operators are likely to be more effective when they have close ties to the population that will be using the technology.

One potentially promising approach to capacity building involves the development of regional institutes that can provide training in basic technology skills to local organizations and individuals drawn from the local population. Such institutes could also help provide independent assessments of alternative technologies and policy choices, and explore practical strategies for overcoming real-world barriers to the expanded deployment of sustainable energy technolo-

[10] Source: http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_action.pdf

gies (UNDP, 2000, p. 441; Martinot, et al., 2002). The Consultative Group on International Agricultural Research (CGIAR) has successfully used this approach to propagate technological and scientific advances in agriculture to developing countries. This may provide a promising model for the energy field.

In sum, successful technology transfer and a worldwide expansion of the human and institutional capacities needed to implement sustainable technologies are critical elements of an effective global response to the energy challenges we confront.

To meet these challenges, developed countries will need to follow through on current commitments and work closely with developing countries to make the most effective use of scarce resources. Developing countries, for their part, must not be passive bystanders in that process. They have everything to gain from leveraging future investments to build their indigenous human and institutional capacities and from taking the lead in adapting and improving sustainable energy technologies to suit their particular needs.

5.5 Clean, efficient cookstoves

The rationale for immediate policy action to accelerate the transition from traditional cooking methods to the use of clean, efficient cookstoves is grounded in public health and welfare concerns. This recommendation therefore stands somewhat apart from the others discussed here, which tend to be motivated by broader environmental and energy security concerns.

Box 5.5 Ceramic Charcoal Stoves in Kenya

The Kenya Ceramic Stove (jiko) is one of the most successful cookstove initiatives in Africa (UNDP, 2000, p. 198). Between the mid-1980s and the mid-1990s, more than 780,000 of these stoves were disseminated. Today, some 16 percent of rural households in Kenya also use these more efficient jiko stoves.

The programme promotes a stove made of local ceramic and metal components made by the same artisans who make the traditional stoves. The new stoves are not radically different from the traditional all-metal stoves, except that their energy efficiency is now close to 30 percent. The remarkable feature of this programme is that from the beginning it has received no government subsidies. This lack of subsidies has forced private entrepreneurs to ensure self-sustained production, marketing and commercialization and prices Kenya's low-income households can afford. The project has now been successfully replicated in Malawi, Rwanda, Senegal, Sudan, Tanzania and Uganda (UNDP, 2000, p. 198).

However, the stove still requires charcoal, which needs to be produced and transported. Charcoal production has been historically very inefficient and will also need attention if the programme is to reach its full environmental potential.

Improved cookstoves are worth singling out, however, because they offer enormous public health and welfare benefits at relatively low cost. Globally, it has been estimated that exposure to indoor pollution from the use of fuels like wood and dung for cooking and space heating causes as many as 1.6 million deaths annually, primarily among women and young children (WHO, 2002). In addition, the need to gather fuel can cause local environmental degradation and take up large amounts of time, for women and girls especially, that would otherwise be available for more productive activities. A shift away from traditional fuels for cooking could marginally increase demand for commercial fuels like propane, natural gas or electricity. The change would be quite small in the context of overall energy requirements but more than justified from a social welfare perspective. Various programmes have been deployed to disseminate improved cookstoves among poor households in rural areas. One of them is described in the text box below.

6. Conclusion

For the past 10 to 15 years, the energy sectors in most countries have been in turmoil. Many developing countries have been attempting to restructure their energy sectors but are finding it difficult to implement reforms for a host of reasons, including the multiplicity of actors involved, changing perceptions of the relative roles of the market and governments, and the baggage of accumulated policies of the past few decades—many of which may have made sense when they were proposed but now impose unsustainable burdens. Meanwhile, a sharp run-up in world energy prices over the last two years and growing supply concerns related to conventional petroleum (and, in some parts of the world, natural gas), combined with projections of continued strong demand growth at the global level and greater awareness of the threats posed by climate change, have brought a heightened sense of urgency to national and international energy policy debates.

The current energy outlook is challenging to say the least. Whether governments are chiefly concerned with economic growth, environmental protection or energy security, it is clear that a simple continuation of current energy trends would have many undesirable consequences at best, and risk grave, global threats to human well-being at worst.

The situation for developing countries is in many ways more difficult than for developed countries. Not only are there obvious resource constraints but access to basic energy services may be lacking for a significant part of their population.

Yet, developing countries also have some advantages: they can learn from past experience, avoid some of the policy missteps of the last half century and have the opportunity to "leapfrog" directly to cleaner and more efficient technologies. Fortunately many essential elements of a sustainable energy transition can be expected to mesh well with other critical development objectives such as improving public health, broadening employment opportunities, nurturing domestic industries, expanding reliance on indigenous resources and improving a country's balance of trade.

This does not mean that cleaner, more efficient technologies will usually be the first choice or that difficult trade-offs can always be avoided. In the near term, many sustainable energy technologies are likely to remain more expensive than their conventional counterparts—and even when they are cost-effective, as is already the case for many efficiency technologies, powerful market failures and barriers often stand in the way. Changing the incentives and overcoming those barriers is for now more a question of political will and coordination than it is one of adequate resources (at least at the global level).

That doesn't make the task any easier—quite the contrary. Surveying the current landscape, ample justifications could be found for a profoundly pessimistic view—or an equally optimistic one. Which outlook proves more accurate will depend to a large extent on how quickly developed and developing countries not only recognize, but also begin to act upon, their shared stake in achieving positive outcomes that can be managed only by working together.

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