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Sustainable energy for Eco-friendly development

S.V.A.R.Sastry[1], V. Ramachandra Murthy[2] and Shyam Shankar[1]

[1]Department of Chemical Engineering, M.V.G.R.College of Engineering, Vizianagaram.

[2]Department of Chemical Engineering, A.U.College of Engineering, Visakapatnam.

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ABSTRACT

It is the provision of energy that meets the demands of the present generation without compromising the ability of the future generations to meet their needs. It includes all renewable energy sources such as hydroelectricity, wind energy, solar energy, wave power, geothermal, bio energy and tidal energy. It also includes technologies that designed to improve energy efficiency. The renewable energy technologies are mainly grouped into three sectors as first, second and third generation technologies. Green energy and energy conservation techniques comes under the category of sustainable energy development. Many European countries employ these techniques in the local level. These techniques are implemented right from energy carriers such as hydrogen and liquid nitrogen carriers. The recent statistic figures show that these green sustainable energies of rapid importance as the planet earth is suffering from global warming. This sustainable energy development has got links with all the sectors of energy such as energy production, conservation, and decrease of pollution and to implement techniques that are eco friendly.

Introduction

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 areparticularly 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

Tele:

E-mail addresses: svarsastry@yahoo.com

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 cook stoves.

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.

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.

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 to ten 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).

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 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.

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 increments7—may be advantageous from acost 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).

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). 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.

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 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 feedstocks to ethanol—would also greatly enhance the net environmental benefits and greenhouse gas reductions achieved by switching from conventional fuels to biofuels.

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 actions 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 cook stoves. 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.

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. 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 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.

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.

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.

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.

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 under developed 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, and 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.

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.

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.

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 technologies (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.

Conclusion(s)

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.

Many sustainable energy technologies are likely to remain more expensive Sustainable energy for developing countries 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).

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