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OPPORTUNITIES FOR SUSTAINABLE ENERGY

ENABLING FRAMEWORKS FOR SUSTAINABLE ENERGY

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INTRODUCTION

Of a current global population of some 6 billion people, 1.5-2 billion do not have access to electricity. Approximately 2 billion depend on collection of resources like wood, dung and other biomass to meet their basic needs for cooking and heating. Women and children are the ones most heavily burdened by the need to collect fuel resources.

The most rapid growth in energy demand takes place in developing countries, where investment resources are scarce and human capacity and inter-sectoral planning processes are often weak. The links between current energy use patterns and environmental problems, such as urban air pollution, indoor air pollution, acidification, and global warming, have all been clearly documented. These problems are certain to be severely aggravated in the future if new technological solutions and new priorities are not brought into the planning process. There is also an undeniable connection between access to high-quality energy services and human, social, and economic development. Inadequate and inequitably available energy services create bottlenecks for employment generation and restrict access to education and health services.

If the energy services are to be available for human, social, and economic development without accelerated environmental degradation and accentuated health impact, a *fundamental change* is required in the manner that energy issues are integrated in national development and the way development assistance is administered. This change involves a move to sustainable energy services, including renewable energy, energy efficiency, and cleaner conventional fuels.

WHAT IS UNISE?

To begin the shift toward a sustainable energy future, UNDP, through its Energy and Atmosphere Programme (EAP), developed the UNDP Initiative for Sustainable Energy (UNISE), which is a strategy to place energy within the United Nations sustainable human development paradigm. UNISE describes how energy relates to UNDP's thematic areas and programme goals (poverty alleviation, improvement of the situation of women, job creation, and environmental protection and regeneration), and outlines how energy programmes and projects can become instrumental in achieving sustainable development. The current challenge is to move beyond advocacy for sustainable energy and to provide operational tools, efficient organisational approaches, and wide information networks for integration of energy concerns into the specific activities within the country programming process. UNISE can be thought of as the continuous thread linking the UNDP programme goals and providing the primary entry point to capacity building at the country level.

BUILDING CAPACITY IN SUSTAINABLE ENERGY AT THE COUNTRY LEVEL

UNDP has a long history of intervention to support energy for development at the country level. Since 1965, UNDP had implemented more than 1,000 energy projects worldwide. Through this experience, UNDP has gained valuable insight into the importance of the supportive conditions necessary to make renewable energy technologies socially and economically viable. Nevertheless, the impact of UNDP's activities during this period has been hard to measure due to lack of an overall strategic approach to energy. This has changed with the adoption by the Executive Committee of UNDP of UNISE as a corporate policy with regard to energy and development, in order to support UNDP country offices in incorporating an energy and development approach into country-level activities.

PURPOSE OF THIS MATERIAL

One of the primary purposes of *"Materials for Decision-Makers"* is to provide UNDP with the capacity for sustainable energy programme and policy development at the country level. Specifically, the goal is to support building of national institutional and human capacity on:

- cross-sectoral approaches to energy issues;
- evaluation of alternatives to deliver energy services to the population; and
- design of sustainable energy policies and programmes.

The materials are intended to examine the normally overlooked aspects of energy and to provide practical models demonstrating how energy could be used as an instrument for sustainable human development. They are expected to equip development analysts with the intellectual tools necessary to address the concrete linkages between energy services and key elements of poverty, including gender, sustainable livelihoods, and the environment, as well as to help identify and develop specific energy interventions in existing programmes as part of a comprehensive agenda for sustainable human development. Hopefully, this capacity building can lead to the design and implementation of more viable and integrated development programmes, thereby improving the possibilities for reaching national development objectives without undue harm being caused to the environment. This stands to positively affect the substantive formulation of country-level sustainable energy activities, enhance the quality of programmes using core resources, and leverage additional cost-sharing to carry out country-level activities. This material is designed to serve as the basis for in-country training activities (UNISE Workshops), which are to be tailored to the particular needs and priorities of the country. The Workshops are meant to strengthen UNDP country offices' capacities for policy and programme development in UNDP's focus areas and assist in mainstreaming UNDP corporate policy at the national level.

A complementary effort that is currently ongoing is the formulation of the World Energy Assessment, by UNDP, the UN Department of Economic and Social Affairs (UNDESA), and the World Energy Council (WEC). This report is meant to help build national capacity by informing the discussion and debate about sustainable energy. The World Energy Assessment intends to provide an evaluation of the social, economic, environmental, and security issues linked to energy, and to examine the compatibility of different energy options with objectives in these areas. Details on the World Energy Assessment process and copies of the report can be found at its website, http://www.undp.org/seed/eap/activities/wea.

SUMMARY OF "MATERIALS FOR DECISION-MAKERS"

"*Materials for Decision-Makers*" presented here are divided into four parts:

- overview of the challenges and opportunities relating to energy and sustainable development;
- special topics concerning energy and development;
- technological prospects for sustainable energy; and
- enabling frameworks for sustainable energy.

The scope of each of the four sections and the specific topics discussed under those sections are briefly summarised below.

Overview

Chapter 1 provides an overview of the various linkages between energy and sustainable development. It focuses on the fact that the level of energy services, rather than the supply of energy, seriously impacts major issues of sustainable human development, such as poverty, gender inequality, food security, population, and environmental degradation. Presently, many of these concerns are linked directly or indirectly to the fact that vast segments of humanity do not have access to clean, affordable, and efficiently derived energy services. In fact, about 2 billion people are entirely reliant on traditional biomass fuels and muscle power to meet their energy needs, while others have access to more efficient energy services that require them to expend far less time, effort and money.

At the same time, there are numerous technological and institutional opportunities to improve the widespread availability of energy services and address major global concerns. On the demand side, some of these opportunities in commercial and residential buildings, industry, and transportation include more efficient household lighting and heating systems, improved industrial motors and processes, and public transportation replacing private vehicles, respectively. Similarly, on the supply side, many opportunities are available to use cleaner fossil fuels like natural gas rather than coal, and to promote the widespread use of renewables, such as biomass, wind, and solar energy. Improved cookstoves and fuels for cooking and heating are also important considerations for addressing a vast set of problems associated with the dependence on traditional biomass by the majority of those living in poverty. Institutional change towards sustainable energy requires the availability of technology, finance, political commitment, and organisational innovation.

Special Topics Relating to Energy and Sustainable Human Development

Among all issues of sustainable development, the most pressing is poverty alleviation. Tackling poverty alleviation requires dealing with the many aspects of such issues as gender, the environment, job creation, and governance. This section deals with two topics of such importance. One is the relation between energy and gender, and the other is the Clean Development Mechanism. The two topics pose complex and challenging issues for development activities and represent important entry points for approaching the goal of poverty alleviation. The Special Topics section is going to be expanded to cover more topics in the future.

Chapter 2 focuses closely on gender's relevance to sustainable energy. Although gender inequality results from culturally-established differences in the roles and status of men and women within particular societies, sustainable energy policies can be used as entry points for promoting greater equity in the allocation of opportunities and resources. This is mainly because women are often the primary users and managers of energy resources, as well as the providers of its services (e.g., collecting, transporting, and using traditional fuels like wood charcoal and dung) who endure energy's adverse social and environmental impacts (e.g., adverse health effects from cooking over smoky indoor fires). By incorporating a gender perspective into energy policies and programmes, women's concerns and experiences, as well as men's, can be included in the design, implementation, monitoring and evaluation.

Chapter 3 examines the opportunities offered by the Clean Development Mechanism (CDM) for developing countries to advance their sustainable development objectives, primarily through energy initiatives, while contributing to reducing greenhouse gas emissions. The underlying premise is that UNDP seeks to identify, finance, and implement programmes and policies that simultaneously stimulate sustainable development and limit greenhouse gasses. The CDM could aid the development prospects of developing countries by stimulating technological "leap-frogging" and generating new investments. While effective guidelines for the setup and operation of the CDM will be required to attract private sector investments to developing countries, ensure equity of access, and provide real, measurable emissions reductions, the CDM has the potential to serve as an effective mechanism for achieving sustainable development objectives.

Opportunities for Sustainable Energy

This section discusses promising opportunities for sustainable energy systems in order to make energy a tool for sustainable development.

In **Chapters 4 and 5**, the prospects for introducing renewable energy and energy efficiency technologies in developing countries are examined in some detail. Decentralised and grid-connected power generation options using biomass, solar, wind and small hydropower have benefited from rapid technology improvements and lessons learned through practical experience, both of which have resulted in vastly lower prices than even a few years ago. In addition to their environmental benefits as compared with conventional alternatives, these technologies can potentially provide opportunities to greatly improve energy services, reduce women's burden, and generate additional income in rural areas. Similarly, the potential for economically feasible energy efficiency improvement in agriculture, industry, transport, and buildings for the next 20 years is estimated at 25-35 percent in most industrialised and developing countries. Implementing the actual improvements on both fronts are going to depend on the status of technology, availability of financing, and institutional considerations.

Enabling Frameworks for Sustainable Energy

Implementation of sustainable energy will require innovative strategies. These include policy reforms, market liberalisation, creation of innovative financial mechanisms, and so forth. Among these issues, Chapters 6 and 7 highlight two particular issues of concern for most decision-makers: policy frameworks and financing issues.

Chapter 6 describes the institutional constraints and challenges to implementing energy reform, as well as present measures to overcome them. Apart from governmental agencies, private businesses, NGOs, and various associations need to play roles in the transformation. Notwithstanding the technological promise of new renewable energy technologies and of advanced methods for energy efficiency, policies to facilitate their market diffusion must be transparent and gradually enforced, with a view to addressing public concerns and learning from field experience.

Chapter 7 highlights the importance of access to credit and affordability of energy services. There are numerous micro-financing options for energy services (i.e., financing at the local level), including direct loans, leasing, and fee-for-service through energy service companies or other financial intermediaries. Implementing any of these options would, in turn, require addressing institutional problems through such measures as removal of market distortions to generate demand, forming strategic partnerships with NGOs, local consumer associations, and financial institutions, reducing transaction costs, and bundling projects together to achieve efficiencies of scale.

1

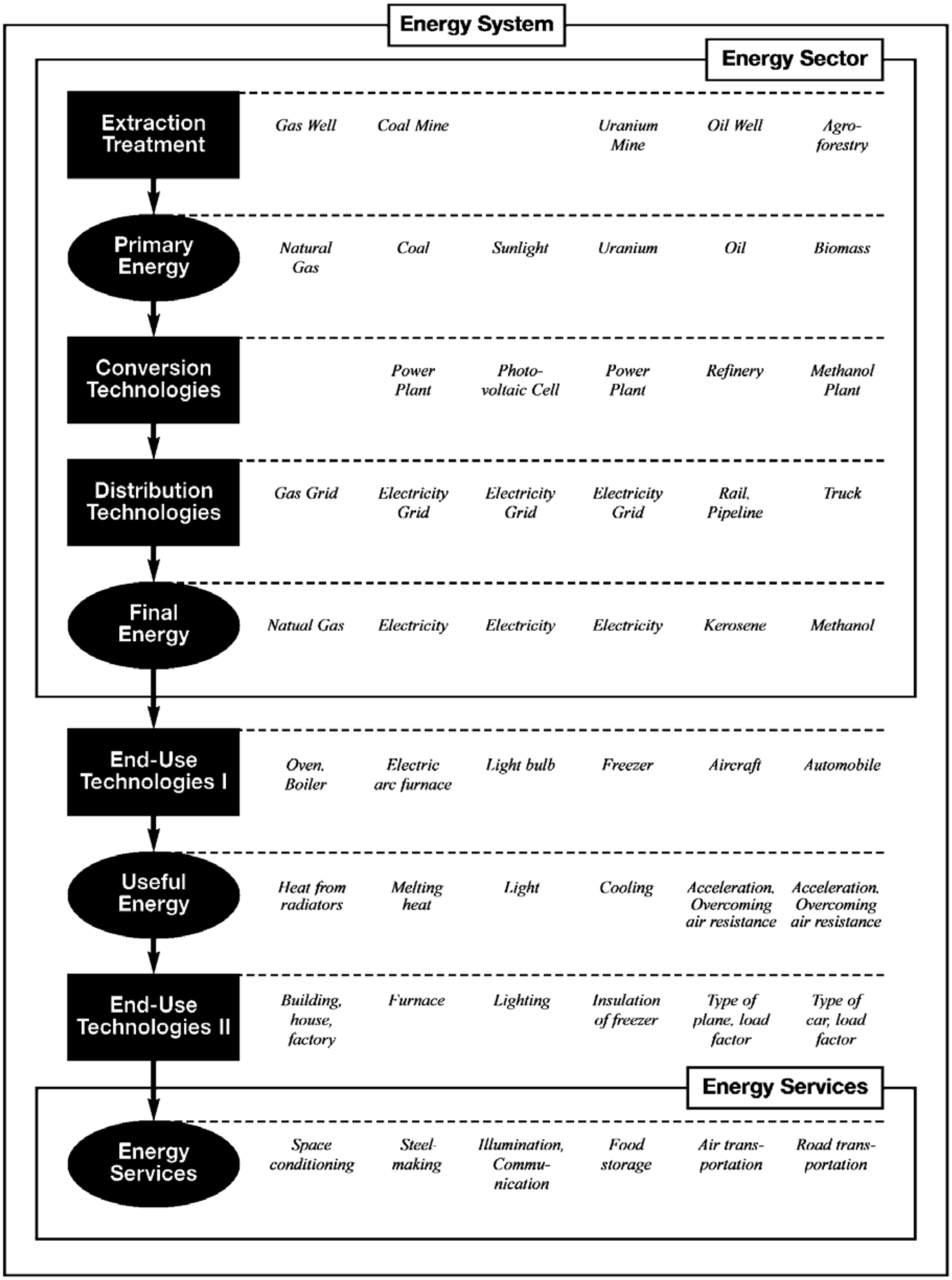
ENERGY AS AN INSTRUMENT FOR SUSTAINABLE HUMAN DEVELOPMENT

1.1. INTRODUCTION

Energy, which is defined as the capacity to do work, is clearly of enormous significance to human existence. At a fundamental level, it could in fact be viewed as being the basis for *all* existence, since physicists construe even matter in terms of energy. Less abstractly, one of the definitions of life concerns the autonomous ability of organisms to convert food into useful energy. But for human societies, energy is typically understood in a far more familiar everyday sense. Energy's importance in our daily lives derives simply from the fact that it provides essential human services, such as lighting, cooking, motive power, space heating and cooling, water pumping, and so on.

For millennia, apart from cooking and space heating dependent on biomass fired in stoves or open fires, energy services have been obtained by and large from devices and systems energised only by the muscle power of humans or draught animals. These resources, in turn, have depended on the biological conversion and storage of food into useful energy to pull carts, grind flour, plough fields, or draw water. Today, in both industrialised and developing countries, there is a variety of fuels to operate more complex systems of energy conversion for cooking, lighting, space heating and cooling, motive power, etc. Nonetheless, vast numbers of people, constituting about a third of humanity, rely entirely on traditional fuels and technologies for most of their energy services. In developing countries, people living in rural areas typically use very low levels of commercial energy and relatively high levels of biomass (e.g., fuelwood, agro-wastes, dung), which is gathered each day mostly by women and children who spend long hours and considerable human energy in the effort. Lack of access to modern energy services for daily uses has serious adverse implications

FIGURE 1. ENERGY SYSTEM EXAMPLES, FROM PRIMARY SOURCES TO ENERGY SERVICES



Source: IPCC (1996).

ENERGY: SOME FUNDAMENTAL ASPECTS

The chain of energy conversions between a primary source and useful energy service constitutes an energy system (see Figure 1). A primary source of energy such as biomass, coal, oil or solar radiation is extracted (or received), converted and distributed into a final energy carrier, such as electricity, kerosene or natural gas, which is expended to power a device or system, like a bulb, stove, or motor vehicle, which ultimately delivers a service such as light, heat for cooking or motive power, respectively. Each conversion process follows the basic laws of thermodynamics. Thus, although total energy is conserved, the useful output energy contained in the service is necessarily lower than the input energy, the balance generally being dissipated through heat or noise. The ratio of the output to input energy defines the efficiency of conversion. The more efficient the device or system delivering the service, therefore, the lower the input energy required to deliver the same level of service.

Energy is measured in terms of joules, kilowatt-hours, barrels of oil equivalent or tonnes of coal equivalent. Figure 2 shows some of the commonly-used units of energy and some examples of energy consumption levels. Between 1988 and 1997, the world's total production of primary energy—petroleum, natural gas, coal, and electric power (hydro, geothermal, solar, and wind)—increased from about 355EJ to 402EJ at an average annual rate of 1.4 percent.[1] There are, however, vast regional disparities in energy consumption; for example, electricity use in developing countries was 815kWh/capita in 1995, whereas industrialised countries consumed nearly 10 times as much per capita (UNDP, 1998).

The leading primary source of energy on Earth is the sun, with much smaller fractions due to radioactive ores and the earth's own stocks of heat energy. Fossil fuels have been formed from the slow decomposition of prehistoric plants and animals that have lived hundreds of millions of years ago. Heat, pressure and bacteria combined to compress and "cook" the organic material under layers of silt to form coal, oil or natural gas, depending on the location and type of geological processes. Solar energy, nevertheless, has been responsible for the growth and sustenance of the original biomass stocks. Solar energy has also been responsible for generating winds and tides. Finally, direct solar radiation can also be used for various purposes, from agricultural drying to electricity generation. Between existing fuel stocks and continuing solar radiation, there is more than adequate energy available to meet the needs of all life on earth for the conceivable future. Solar energy itself is so abundant that unused land area available worldwide could generate up to 117 times global primary energy consumption.[2]

The end uses of energy are roughly equally split among industry, transport, and others, including cooking, space heating and cooling, agriculture, etc. From the standpoint of the end user, what matters most about energy is the level of service it provides, rather than the amount of primary energy that goes into delivering the service. Since conserving a kilowatt-hour (kWh) of electricity or fuel is generally cheaper than producing an additional kWh, the most cost-effective ways to deliver energy services often involve improving the efficiency of energy conversions to final energy or the of end-use devices. It has been estimated that a modest increase in per capita primary energy is sufficient for developing countries to provide energy services equivalent to those enjoyed in Western Europe in the mid-1970s.[3] This would, however, require the widespread adoption of modern energy carriers (electricity and liquid and gaseous fuels) and efficient energy conversion and end-use technologies.

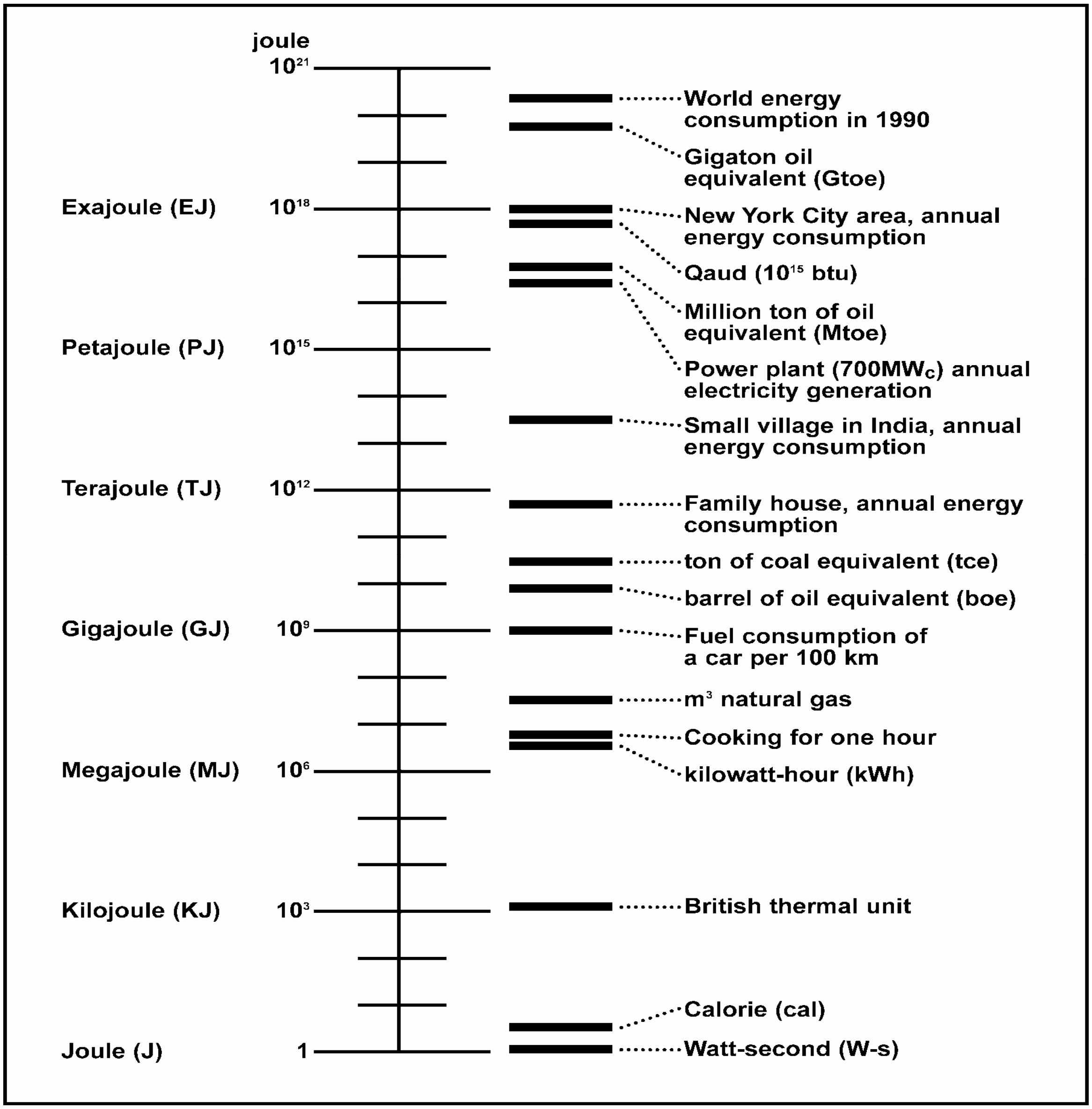
All energy conversion technologies (nuclear, solar, wind, hydro, fossil fuel, geothermal, ocean and biomass based) have direct and indirect environmental and health impacts, at each stage of their full life cycles. The full life cycle for a carrier like electricity includes extraction, refinement, and delivery of the primary resource; manufacture of equipment, construction, and operation of the power supply facility; transmission and distribution of electricity; and eventual decommissioning of power plant. The decision to employ a specific supply or demand-side option to provide energy services within a given context must include all positive and negative impacts and life-cycle costs, and compare these against available alternatives for providing similar levels of service. Life-cycle analysis (LCA) constitutes a valuable set of multi-attribute decision-making tools that provide a framework to compare all relevant qualitative and quantitative measures of impact for choosing among available supply and demand-side options.

for the welfare of the vast numbers of the urban and rural poor, including ill-health, malnutrition, environmental degradation, and worsening conditions of poverty and gender inequality.

The general importance of energy for human development is unmistakable, although we often take its functions for granted. What is even less obvious to many of us, however, is how closely energy production and use are connected with major issues of concern such as poverty, gender inequality, food security, and the environment. In fact, the efficient production and use of energy could provide important means to intervene positively in these vital areas of human concern.

[1] EIA, 1997. *International Energy Annual* 1997, Energy Information Administration, Washington, DC.
[2] IIASA/WEC, 1998. "Global Energy Perspectives," N. Nakicenovic, A. Grubler, A. McDonald (eds). International Institute for Applied Systems Analysis and World Energy Council. Cambridge University Press, Cambridge.
[3] Goldemberg, J., T.B. Johansson, A.K.N. Reddy, and R.H. Williams, 1985: "Basic Needs and Much More with One Kilowatt per Capita". *Ambio,* **14** (4-5), 190-200.

FIGURE 2. ENERGY SCALE WITH EXAMPLES OF CONSUMPTION



Source: IPCC (1996).

A major obstacle to meeting this goal, however, lies in the way energy is generally perceived within the framework of overall socio-economic development. Presently, *energy consumption,* rather than the *level of energy services*, is seen as the indicator of development. By taking energy consumption as the measure of development, energy planners are often simply concerned with increasing fuel and electricity supplies based on existing patterns of energy use, rather than with identifying and sustaining the level of energy services that would be required to satisfy basic human needs. For while energy itself is not a basic human need, it is an essential input for the fulfilment of all basic needs. From the standpoint of sustainable human development, therefore, what is urgently needed is a reorientation of ideas about energy to focus on the manner in which it is presently utilised, its potential for improving people's quality of life, and ways to increase access to its services for the poor.

The training materials for this course are intended to examine these normally overlooked aspects of energy and to provide practical models demonstrating how energy can be used as an instrument for sustainable human development. They are expected to equip development analysts with the intellectual tools necessary to address the concrete linkages between energy services and key elements of poverty, including gender, sustainable livelihoods and the environment, as well as to help identify and develop specific energy interventions in existing programmes as part of a comprehensive agenda for sustainable human development.

1.2. ENERGY AND MAJOR ISSUES OF SUSTAINABLE HUMAN DEVELOPMENT

1.2.1. Energy and Poverty

Poverty can be defined simply in terms of an individual's, or a household's, inability to meet basic human needs for a tolerable life. Such needs include food, clothing, shelter, health, education, and sanitation services. In more quantitative terms, poverty measures relate to a person's actual levels of health, education, body weight, and income or consumption expenditure relative to specified norms that are deemed necessary for a minimum quality of life.

The immense scale of human poverty is reflected in the following statistics:

- about 1.3 billion people in developing countries (30 percent of their total population) consume less than the equivalent of US$1 in goods and services daily.
- 20 percent of people in developing countries do not have access to health services;
- 30 percent lack access to safe water;
- 60 percent lack access to sanitation; and
- 30 percent of children under 5 are underweight (UNDP, 1998).

Although energy is central to the satisfaction of basic nutrition and health needs, and energy services constitute a sizeable share of total household expenditure in developing countries, the poverty-energy nexus has not received serious attention until recently (Goldemberg *et al.,* 1988; UNDP, 1996; UNDP, 1997). The essential relationship of energy with poverty can be stated as follows. About 2 billion people do not have access to modern energy carriers, such as electricity and non-traditional cooking fuels like liquefied petroleum gas, and rely instead on wood, dung, and other biomass. The lack of adequate energy services to these people amounts to a denial of opportunities for a tolerable life and, as such, characterises their poverty starkly.

The poor typically spend a greater fraction of their income on indispensable energy services, such as cooking, than do the rich. At the same time, they frequently forgo (or compromise severely on) services like lighting and space heating that require energy carriers (e.g., electricity) and devices (e.g., fluorescent lights) to which they either don't have access, or whose first costs tend to be unaffordable. In general, people in poverty expend more time and effort to obtain energy services that tend to be of lower quality than the energy services available to the rich. Poor women and children, in particular, bear the burden of having to carry water and firewood across long distances, while the better-off typically enjoy the convenience of having piped water and cooking gas delivered to their homes. Table 1 indicates that there is a striking difference between allocations of time and money for people living in poverty and the wealthy. For example, very low income households in Pakistan devote roughly 100 more hours per year to the collection of biomass than do the rich households. While the rich spend about 30 times more money per year on fuel than do those living in poverty, their expenditure on energy-related activities is, in fact, considerably lower as a proportion of income.

TABLE 1. HOUSEHOLD FUEL EXPENDITURE BY QUINTILE IN PAKISTAN

	1ST QUINTILE	5TH QUINTILE
Money [1]	**1,348**	**40,132**
Time [2]	**164.5WW**	**61.4W**

1. Money is 1991 Pakistani Rupees per year

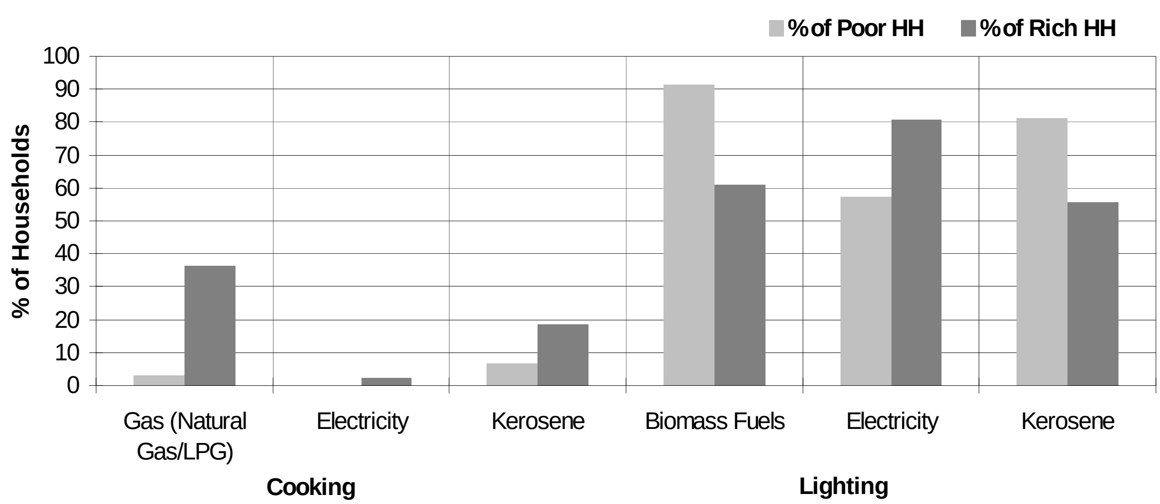
2. Time is the average number of hours per year spent collecting wood or dung.

Source: Pakistan Living Standards Management Study (LSMS), 1991

The fact that the poor spend more time for energy services has a powerful implication. The economic hardship endured by very low-income households is understated when their incomes or consumption expenditures are evaluated in terms of their command over the basket of goods and services typically consumed by households with average incomes or consumption expenditures.

In many countries there is evidence of a so-called "energy ladder" that differentiates income levels in terms of associated patterns of energy usage (UNDP, 1997). For example, wood, dung, and other biomass represent the lowest rung on the energy ladder for cooking, with charcoal, coal, and, when available, kerosene, representing the next rungs up the ladder to the highest rungs, electricity and LPG (see Figure 3). The order of fuels on the energy ladder corresponds to their efficiency (i.e., the fraction of energy released from the carrier that is actually turned into an energy service by the end-use device) and their "cleanliness". For example, the cook-stove efficiencies of firewood, kerosene and gas are roughly 15, 50, and 65 percent respectively. Similarly, moving up the energy ladder results in declining emissions of carbon dioxide, sulphur dioxide, and particulates.

FIGURE 3. HOUSEHOLD ENERGY SOURCE FOR COOKING AND LIGHTING VERSUS POVERTY STATUS IN PAKISTAN.

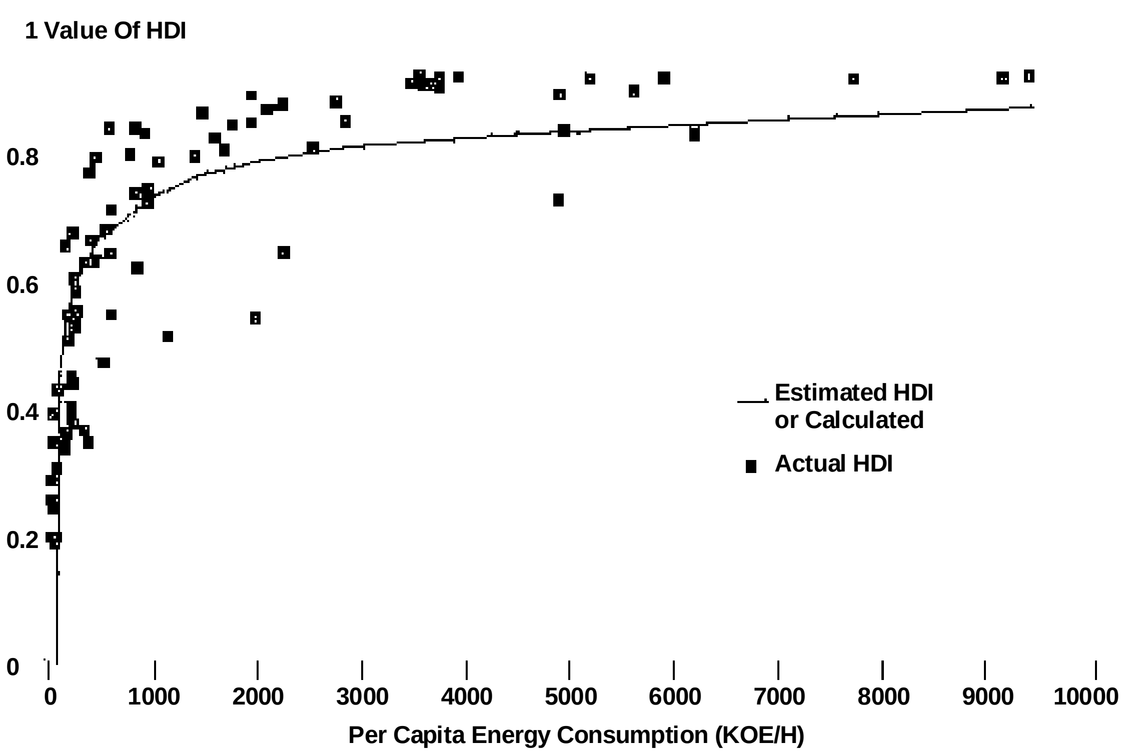


Source: Pakistan LSMS, 1991.

The prevailing patterns of energy consumption among people living in poverty tend to further worsen their misery (Leach, 1992; Dasgupta, 1993). First, because they spend a higher proportion of their income on energy, they are less likely to accumulate the investments necessary to make use of the less costly or higher quality energy sources. Second, the use of traditional fuels has a negative impact on the health of household members, especially when burned indoors without either a proper stove to help control the generation of smoke, or a chimney to vent the smoke outside. Third, continued reliance on biomass in urban areas promotes deforestation, which may increase its future cost, further diminishing the living standards of people living in poverty. As patterns of energy use result in adverse effects on nutrition, health, and productivity, the benefits of economic growth are likely to be absorbed only very slowly by people living in poverty.

The Human Development Index (HDI) developed by UNDP is a composite measure of development based on indicators of longevity, knowledge and standard of living. The components used for calculating HDI are life expectancy, educational level (adult literacy and years of schooling), and per capita gross domestic product (adjusted for purchasing power parity). Figure 4 is based on data from 100 developed and developing countries and shows the relationship between HDI and per capita commercial energy consumption. Note that there is a steep increase in HDI with per capita energy consumption among countries whose per capita energy consumption is very low (less than about 2000 kilograms of oil equivalent). These characterise the vast majority of developing countries. Although this graph does not prove a causal relationship between HDI and energy consumption, it clearly suggests that access to a certain level of energy services is an essential provision in modern societies.

FIGURE 4. RELATIONSHIP BETWEEN PER CAPITA ENERGY CONSUMPTION AND HUMAN DEVELOPMENT INDEX



Note: Data for 100 developed and developing countries.
Source: Suarez (1995)

The decreasing marginal benefits of energy supply on human development parallels the so-called GDP-energy de-coupling that has taken place in various countries during the 20th century. Historical trends of the "energy intensity"—or the ratio of energy consumption to GDP—of several developed economies are remarkably similar. They all show rising energy intensity during early industrialisation, followed by a decline during periods of further industrialisation that is associated with improved energy conversion efficiency, improved processes, and, to a lesser extent, a general shift from manufacturing to service sectors. While this pattern of de-coupling between energy and GDP growth is most pronounced in the examples of the USA, Germany, UK, France and Japan, even a developing country, such as China, and countries in transition like Poland, follow these trends, both having recently passed a "hump" of high energy intensity. Also, since many developing countries are entering periods of industrialisation at a stage when there are already significant opportunities for energy efficiency, it is conceivable that they could "leapfrog" sooner than developed countries to locations on the map with low energy intensity.

The significance of energy for development appears to be greatest in those countries that have the lowest aggregate levels of energy consumption, and where energy use is inefficient. Policies and programmes that directly address the creation of opportunities for people living in poverty (to improve the level and quality of their energy services by making more efficient use of commercial and non-commercial energy, and by shifting to higher quality energy carriers) are going to allow them to enjoy both short-term and self-reinforcing long-term improvements in their standard of living. By contrast, existing strategies for poverty alleviation that are concerned with macro-economic growth, human capital investment and welfare programmes do not focus on the energy-poverty nexus, thereby foregoing many valuable opportunities for intervention in this area.

1.2.2. Energy and Gender Inequality

Energy's relationship to women's work and well-being is evident in women's roles as:

- users of energy resources (both traditional biomass and modern fuels) for household, subsistence and income-earning activities;
- producers of traditional biomass fuels and providers of "human energy" services;
- those most vulnerable to energy scarcity, environmental damages from energy production use, and adverse impacts of technological changes in the energy sector; and
- educators concerning the collection, management and use of fuels, and activists in energy and environmental debates and action.

Women not only bear the brunt of poverty's afflictions, they are also the main users of household energy and are primarily beset by problems of access to energy services. Globally, 70 percent of people living in poverty are women, in part, because while women typically work longer hours than men do, with roughly two-thirds of this time is spent on unpaid work. More than 50 percent of the world's households use wood, crop residues, and untreated coal as fuel for cooking, an activity carried out almost entirely by women. Poor rural women and children may spend four to six hours travelling seven to ten kilometres and collect only enough firewood for one day's cooking and heating needs for a household of four to five persons (UNDP, 1997).

Women also have significant roles as producers of traditional biomass fuels and providers of "human energy" services. Women and children are the primary collectors of fuelwood, other household fuels, and other forest products for household consumption, as well as for sale to urban markets. For example, 48 percent of women in Fazoum Province, Egypt, work in minor forest industries, and some 250,000 women are employed in collecting forest products in Manipur, India. Women fuelwood carriers surveyed in Gujarat, India use most of their income for buying food.[4] The management and conservation of these depletable forest resources are critically important to women, who are the chief repositories of knowledge concerning the use and management of trees and other forest products.

Prevailing patterns of energy production and use give rise to distinct occupational hazards for

[4] *FAO (Food and Agriculture Organisation), 1992:* Protect and Produce: putting the pieces together. *FAO, Rome.*

women and carry with them high social and economic costs. Exposure to indoor air pollution due to conventional cooking and heating is linked to acute respiratory infections, chronic obstructive lung diseases, low birth weights, lung cancer, and eye problems (Smith, 1987). Similarly, women fuelwood carriers suffer frequent falls, bone fractures, eye problems, headaches, rheumatism, anaemia, chest, back and internal disorders, and miscarriages, from carrying loads often weighing 40-50 kg—nearly as much as their own body weights.[5] The production of palm and other oils in women's informal sector enterprises is extremely arduous, requiring lifting and moving heavy containers of hot liquids and hence exposure to burns and smoke. Women's nutritional status is often worsened because, for cultural reasons, they eat last and least, but tend to expend more energy in work than men. Finally, women are often vulnerable to adverse impacts of technological changes, including energy-related technological changes, even when such changes appear to be "gender-neutral".

A classic example is the displacement of landless women in rice hulling in South and Southeast Asia. In Indonesia, on governmental initiative, mechanised rice hullers replaced 90 percent of hand rice hulling between 1970 and 1978, with estimated resulting job losses as high as 1.2 million in Java alone and 7.7 million in all of Indonesia. Losses in earnings to women hand-pounders arising from the use of hullers were an estimated US$50 million annually in Java, representing 125 million women-days of labour.[6]

At the same time, there are several aspects to women as educators and activists in energy and environmental debates and action. Women are educators of young people in the collection, management and use of fuels and other natural resources, which has implications on how energy-use patterns are replicated over time and passed on to future generations. They are often the primary educators of children concerning sanitation, consumption habits, waste disposal, use of natural resources, and interaction with the environment in general. When convinced of the utility and practicality of an energy technology or forestry scheme, women or women's groups have been effective in persuading households and communities to invest the resources necessary to make the scheme work. The Vietnam Women's Union, for instance, is at the forefront of a revolving credit project to install the first household and community photovoltaic systems in that country. When convinced of the negative effects and costs to their livelihoods, on the other hand, women have been equally forceful in blocking changes advanced as "improvements". The Chipko movement to protect forests on which women's livelihoods depend in northern India is a well-known example. More subtle but no less effective was Sahelian women's rejection in the 1970s of so-called improved stoves designed without their consultation and whose laboratory savings were not borne out in actual use (Baldwin, 1986).

The principal role played by women in environment and resource issues is an accepted fact. What is less well known is that many of women's environmental roles and concerns are closely linked to the use, supply and management of energy resources. Strengthening the role of energy in advancing sustainable development will require paying specific attention to women's participation in energy activities.[7]

1.2.3. Energy and the Environment

The production and use of energy have environmental consequences at local, regional, and global levels. These impacts extend throughout the fuel cycle of an energy system—the entire chain of activities from extraction of energy sources through processing to transport,

[5] *Haile, F., 1991:* Women Fuelwood Carriers in Addis Ababa and the Peri-Urban Forest. *International Labour Organisation (ILO), Geneva.*

[6] *UNIFEM (United Nations Development Fund for Women), 1988:* Cereal Processing—Food Technology Source Book. *(UNIFEM), New York.*

[7] *Cecelski, E., 1995: "From Rio to Beijing: Engendering the Energy Debate".* Energy Policy*, **23** (6), July.*

storage, final conversion, and end use. They could also manifest themselves over short, medium or long time-scales, or have cascading effects by combining with other environmental problems.

1.2.3.1. Local Impacts

The local impacts of energy production can be very harmful to human health. Many stages of the major world fuel cycles have important direct environmental health implications. Broadly these can be categorised as follows:

- human exposures to chemical or radioactive pollution from routine operations;
- accidents and diseases in work related to the fuel-cycle;
- shifts in disease-vector distributions from hydropower development; and
- physical injury or pollutant contamination from major accidents.

Indoor air pollution due to traditional cookstove use is linked with chronic lung disease among women in developing countries (Smith, 1987). Gathering heavy loads of firewood across large distances causes chronic health problems to women and children. Thermal power plants generate air pollution in the form of particulates, oxides of sulphur and nitrogen, and various air toxics, apart from causing land and groundwater pollution during disposal of sludge and fly-ash. By themselves and through photochemical reactions to produce ozone, the air pollutants are well-characterised as causes of respiratory disease and severe crop damage. Polycyclic organics, heavy metals and radionucleides that contaminate soil and groundwater or are released through power plant stacks are associated with increased birth defects and cancer among populations in surrounding areas. Among fossil fuels, natural gas and oil generate fewer local impacts than coal during generation, but extraction and transport of these fuels can have comparable environmental consequences.

The process of generating hydropower does not produce wastes or other harmful byproducts. At the same time, the accumulation of a large, almost stationary body of water sets in motion a chain of events, particularly in tropical areas, that may enhance the spread of infection and disease, including filariasis and schistosomiasis. Shallow waters associated with the shores of reservoirs can provide suitable breeding places for mosquito vectors of malaria. Dams also create new and favourable habitats for various kinds of vegetation, which in turn may render sizeable areas more attractive to disease vectors. In addition, dissolved minerals, silt, and organic matter brought by in-flowing rivers may alter the aquatic ecosystems and possibly cause algae blooms, and foster growth of snails, midges, and mosquito larvae. Dams also pose accident risks when sited upstream from large populations. Important indirect health effects can be created in populations forced to leave their lands because of large hydropower development (IPCC, 1996).

Small or mini-hydropower generation is a much more environmentally safe option than large hydroelectric plants. Similarly, other renewable energy technologies, such as wind and solar power, have relatively minor environmental impacts associated with them. Wind farms cause some noise pollution and also present a potential hazard to breeding birds. Solar panels using batteries have adverse environmental effects associated with the disposal of lead and battery acid, but these can be reduced considerably with proper environmental management of waste and good housekeeping practices. The environmental risks from the use of nuclear energy to produce electricity are also well-known, especially after the disasters at Three Mile Island and Chernobyl. But apart from the ill-famed consequences of a “melt-down”, there are less dramatic but almost as serious—and far more frequently encountered—environmental hazards associated with handling and disposal of radioactive materials during the fuel cycle of uranium or plutonium.

The use of energy also has adverse local impacts. Energy conversion to generate steam or process heating in industry typically involves a combustion

TABLE 2. AIR POLLUTION
IN MEGACITIES OF THE WORLD

CITY	SO_2	SPM	Pb	CO	NO_2	O_3
Bangkok	◎	●	⊙	◎	◎	◎
Beijing	●	●	◎	○	◎	⊙
Bombay	◎	●	◎	◎	◎	○
Buenos Aires	○	⊙	◎	●	●	●
Cairo	○	●	●	⊙	○	○
Calcutta	◎	●	◎	○	◎	○
Delhi	◎	●	◎	◎	◎	○
Jakarta	◎	●	⊙	⊙	◎	⊙
Karachi	◎	●	●	○	○	○
London	◎	◎	◎	⊙	◎	◎
Los Angeles	◎	⊙	◎	⊙	⊙	●
Manila	◎	●	⊙	○	○	○
Mexico City	●	●	⊙	●	⊙	●
Moscow	○	⊙	◎	⊙	⊙	○
New York	◎	◎	◎	⊙	◎	⊙
Rio de Janeiro	⊙	⊙	◎	◎	○	○
Sao Pãulo	◎	⊙	◎	⊙	⊙	●
Seoul	●	●	◎	◎	◎	◎
Shanghai	⊙	●	○	○	○	○
Tokyo	◎	○	○	◎	◎	●

● **Serious problem; WHO guidelines exceeded by more than a factor of two**

⊙ **Moderate to heavy pollution; WHO guidelines exceeded by up to a factor of two (short-term guidelines exceeded on a regular basis at certain locations)**

◎ **Low pollution; WHO guidelines are normally met**

○ **No Data Available**

Source: UNEP/WHO, 1992

process in which coal, oil, biomass or natural gas is burned, thereby generating harmful air pollutants to varying degrees. Industrial energy use, like centralised power production, also has harmful environmental consequences for local water bodies and the soil. Urban transportation is associated with some of the most serious problems of air pollution (see Table 2). Finally, energy use through combustion is also associated with accident hazard through fires, explosions, etc.

With centralised, large-scale operations, both production and use of energy can cause local resource depletion, either because of excessive extraction or contamination of land, water, and forests through pollution, or habitat destruction. Thus, large thermal power plants, whether they use renewables or fossil fuels, could have adverse local resource impacts related to excessive water consumption, soil and ground-water pollution, or deforestation. Large industries or agricultural or transport operations that operate at high intensity can have similar adverse local resource impacts.

1.2.3.2. Regional Impacts

The regional environment can be characterised as the scale of thousands of square kilometres over which environmental impacts can be felt. The impacts could be due to remote activities taking place within a much smaller area, or due to a range of activities covering the entire region. In both cases, though, the regional transport and fate of pollutants across air, soil, water, and biota is significant.

Acid deposition, which is one of the most important regional environmental problems in the world today, is directly related to energy production. Acid deposition is caused by emissions of sulphur and nitrogen oxides, both entirely products of combustion. Acidification of lakes, soils and streams in North America and Europe has caused severe ecosystem damage and substantial losses in forest cover. Coal-fired power plants have been implicated as the single major contributor of acidifying compounds, which has led to stringent legislation limiting the emissions of sulphur and nitrogen oxides in many countries in these regions. In developing countries, acid rain legislation is still in its incipient stages, even though the risk is dangerously high in some regions.

Other well-known regional impacts of energy production are oil spills due to off-shore drilling and transport, habitat destruction, and large-scale displacement of people due to the construction and operation of large hydro projects and trans-boundary problems of radiation due to nuclear power plant accidents. The worst regional environmental disasters in recent memory are the Exxon-Valdez oil spill off the coast of Alaska and the Chernobyl nuclear disaster in the former Soviet Union.

The large-scale use of energy for groundwater pumping in agriculture causes widespread resource loss of water and soil. Excessive water pumping in countries like the United States, India and China has lowered the water table considerably and also increased the risk of soil salinity due to repeated irrigation and water-logging. In the state of Tamil Nadu, in India, for instance, ground water levels reportedly fell between 25 and 30 meters over a decade due to over-pumping.[8]

1.2.3.3. Global Impacts

One of the most serious global environmental problems today is the steady and long-term increase in atmospheric concentrations of so-called greenhouse gases such as carbon dioxide, methane, nitrogen dioxide, and chlorofluoro-carbons (IPCC, 1996). Long-term stability in the concentrations of these gases is vital because they absorb outgoing radiation from the Earth's surface and effectively trap heat in the atmo-sphere, raising its average temperature to a level that makes life on earth possible. Substantial increases or decreases in greenhouse gases are likely to induce climate change within a matter of decades, with possibly devastating consequences for several countries.

The world energy system is responsible for more than half the anthropogenic greenhouse gas emissions, of which the predominant gas is carbon dioxide (CO_2). Again, the majority of these emissions is due to fossil fuel use, which represents about 75 percent of total energy use. This combustion leads to about three-fourths of the annual human-related emissions of CO_2. These annual emissions accumulate, increasing the greenhouse gas concentrations in the atmosphere. The Inter-governmental Panel on Climate Change (IPCC) has estimated that business-as-usual activities are likely to increase carbon emissions by a factor of three by 2100, whereas emissions have to fall far below the present level in order to stabilise the atmospheric concentration of CO_2.

Apart from climate change, there are some other, less severe though significant, global environmental impacts associated with energy production and its use. These include loss of biodiversity due to fossil fuel exploration and drilling in remote regions with rare species of flora and fauna, land degradation, desertification, and biodiversity loss associated with excessive biomass consumption in some developing countries, as well as ozone layer depletion due to refrigeration systems using chlorofluorocarbons.

1.2.4. Energy and Population

The conventional view of the relationship between energy and population is simply that population growth puts additional pressure on energy use. But it is just as valid to view energy use patterns as influencing population growth by creating social and economic pre-conditions that affect family decisions on the desired number of births and their timing. For instance, measures of improved human welfare, such as reduced child mortality, improvement of the living environment (drinking water, sanitation, housing, etc.), education of women, diversion of children from household-survival tasks and employment to schooling, and so on, are associated with fertility decline.[9] As emphasised earlier, improving energy services to the poor in general and to women in particular can have a positive impact on each of these indicators of development. The implication of this dimension of the energy-population nexus is that one important challenge for the energy system is to

[8] *WWI, 1998:* State of the World 1998*, Worldwatch Institute, Washington, DC.*

[9] *UNO, 1995.* The World's Women 1995 Trends and Statistics, *New York.*

ENERGY AND MAJOR UN CONFERENCES

Agenda 21 programme areas, activities and objectives from the Rio Conference describe numerous links between sustainable development and energy issues. These are reflected in the chapters on Promoting Sustainable Human Settlement Development, Health, Integrating Environment and Development in Decision-Making, Protection of the Atmosphere, Combating Deforestation, Combating Desertification and Drought, Sustainable Mountain Development, and Promoting Sustainable Agriculture and Rural Development. Chapter 34 on Environmentally Sound Technology, Cooperation and Capacity Building is particularly relevant to energy and modern clean energy technology.

The Programme of Action adopted at the United Nations Conference on Population and Development at Cairo emphasises the need to integrate population concerns into all aspects of economic and social activity. Chapter 3 addresses the interrelationships between population, sustained economic growth, and comprehensive sustainable development, particularly for the implementation of effective population policies and meeting basic human needs. The Cairo Conference recognised poverty as a major obstacle to solving population problems.

The Global Conference on Sustainable Development in Small Island Developing States (SIDS) produced a Plan of Action which deals with energy resources in Chapter 7. It concludes that SIDS "are currently heavily dependent on imported petroleum products, largely for transport and electricity generation, energy often accounting for more than 12 percent of imports. They are heavily dependent on indigenous biomass fuels for cooking and crop drying". The absence of energy alternatives is a clear factor in unsustainable development patterns in SIDS. Thus, "increased efficiency through appropriate technology and national energy policies and management measures will reap both financial and environmental benefits for small island developing states".

The Social Summit Programme of Action represents a global effort to address issues related to social development and the negative impacts of underdevelopment and poverty. Global consensus has been reached on the need to create an enabling economic environment aimed at promoting more equitable access to sustainable development and the goal of eradicating poverty. Chapter 2 recognises that improving the availability and accessibility of transportation, communication, power and energy services at the local and community level is a way of improving the access to productive resources and infrastructure necessary for poverty eradication, especially for isolated, remote and marginalised communities.

The implementation and follow-up of recommendations from Cairo and Copenhagen related to health, education, safe food, potable water and sanitation, transportation, employment and poverty eradication, as well as the needs of special groups such as the ageing, handicapped, victims of natural disasters, children, refugees and displaced, will all require a substantial increase in energy services.

The Beijing Conference Platform for Action, Objective K "Women and the environment" refers to women's numerous roles in the management and use of natural resources, as providers of sustenance for their families and communities, as well as women's needs and requirements as users, consumers, managers, and decision-makers. It stresses the need to integrate gender concerns and perspectives in all programmes for sustainable development.

The United Nations Conference on Human Settlements HABITAT II statement "Sustainable Human Settlements Development in an Urbanising World" explicitly deals with sustainable energy use. Chapter 4 states that the use of energy is essential in urban centres for transportation, industrial production, household, and office activities. "Current dependence in most urban centres on non-renewable energy sources can lead to climate change, air pollution, and consequent environmental and human health problems, and may represent a serious threat to sustainable development. Sustainable energy production and use can be enhanced by encouraging energy efficiency, by such means as pricing policies, fuel switching, alternative energy, mass transit and public awareness. Human settlements and energy policies should be actively co-ordinated". The promotion of efficient and sustainable energy use and actions for Governments, the private sector, non-governmental organisations, community-based organisations, and consumer groups to solve many of the crucial social and economic requirements of sustainable development are recommended.

The World Summit on Food Security in its Declaration noted that "unless governments and the international community address the multifaceted causes underlying food security, the number of hungry and malnourished people will remain very high in developing countries, particularly Africa south of the Sahara and sustainable food security will not be achieved". The importance of energy in agricultural production, food preparation and consumption is clear.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change is concerned predominantly with the sustainable production and use of energy. In Article 2, it affirms that "Each Party included in Annex I (primarily, developed countries), in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development", shall implement policies and measures, including the "enhancement of energy efficiency in relevant sectors of the national economy" and "research on, and promotion, development, and increased use of, new and renewable forms of energy". Article 12 creates a new Clean Development Mechanism to give a new stimulus for technology transfer to developing countries. Among its other features, "(a) Parties not included in Annex I will benefit from project activities resulting in certified emission reductions; and (b) Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments."

accelerate the demographic transition in which the population moves from a configuration of high mortality and high fertility to one of low mortality and low fertility.

1.2.5. Energy and Food Security

According to the Food and Agriculture Organisation (FAO), about 800 million people, approximately 15 percent of the population in developing countries, were undernourished in 1990. The elimination of chronic undernutrition will require at least: *(i)* elimination of poverty through job creation and thereby better distribution of income, and *(ii)* increased food production.[10] FAO estimates that a 35 percent increase of recent food production in developing countries is required by the year 2010. This could be achieved by increasing crop yields, by a greater intensity of cropping, and, perhaps, also by bringing new land into agricultural production. Moreover, gastro-intestinal parasites can undermine nutritional status by consuming, perhaps as much as 10-15 percent of the food intake, often termed the "leaky bucket" syndrome. This problem has to be tackled by health care and the provision of safe water and a clean living environment.

Most factors that effect food security are energy-dependent. It is impossible to envisage an effective food production system, or an efficient food processing and distribution system, without the necessary energy inputs that make them operate. There is a close correlation between the quality and quantity of food produced, transformed, and consumed and the quality and quantity of energy used to "turn the wheels" of food security. In many cases, it is precisely the low quality and the meagre amounts of energy available for the food system which are at the base of unattainable food security.

Many areas of developing countries are characterised by a lack of sufficient energy inputs to satisfy the minimum requirements to reach the potential food security level. Agricultural practices, to a large extent, remain based on human and animal power; little, if any, indirect energy inputs, such as for irrigation or fertilisation, are at hand. Food losses are very high due to the lack of energy for processing or storing, or for transportation to markets. The use of locally-available energy sources, such as solar, wind, biomass, or hydropower is minimal, as is the access to conventional energy sources, such as hydrocarbons or electricity.

[10] *FAO (Food and Agriculture Organisation), 1995*: World Agriculture: Towards 2010. *An FAO Study. N. Alexandratos (ed.). John Wiley, Chicester, UK.*

Apart from efforts to increase the production and supply of food in developing countries, many related measures are warranted to enhance food security, such as: *i)* raising incomes through employment generation; *ii)* providing healthy environments; *iii)* implementing programmes of supplementary nutrition for vulnerable groups; and *iv)* increasing supplies of cooking fuel and/or efficient stoves and of domestic water. Several of these measures are strongly energy-related, and, therefore, if energy is to contribute to the solution of undernutrition, the energy components of these measures must be reflected in energy strategies. Such considerations, however, have been incorporated into conventional energy strategies only rarely.

1.2.6. Energy and the Economy

Expenditure on increasing energy supply represents a major economic cost to all countries. In the developing world, the financial and opportunity cost of capital, foreign exchange constraints, and the cost of energy subsidies combine to create severe economic constraints to supply-driven models for expanding energy. The present level of worldwide investment in the energy supply sector, \$450 billion per year, is projected to increase to perhaps \$750 billion per year by 2020, about half of which would be for the power sector. Such investment levels cannot be sustained by traditional sources of energy financing.

For developing countries, there are widely differing estimates of capital investment needs in the energy sector. But even the lowest of these estimates is challenging, particularly in the electricity sector where annual investment requirements are projected to increase from US\$65 billion per year, in 1990-1995, to US\$170 billion per year, in 2015-2020 (WEC, 1995). A significant part of the capital problem is due to widespread subsidies that distort energy prices. On average, electricity and natural gas prices would have to be raised 60 and 25 percent, respectively, for electric and gas utilities to generate enough revenues to cover costs in developing countries.[11] The financial

[11] *World Bank, 1994:* World Development Report 1994. *The World Bank, Washington DC. 121-122.*

burden of under-priced electricity in developing countries has been estimated to be US$90 billion per year. Under-pricing weakens market power in capital markets, leads to new capacity requirements in excess of true needs, and makes it difficult to make the system more efficient. A number of developing countries and transitional economies recognise the problems posed by under-pricing energy and are moving away from heavy subsidies to a system where pricing is more reflective of costs. However, few steps have been taken to reflect all costs including externalities such as adverse environmental and other societal impacts.

The dependence on fossil fuels has created a variety of problems for non-oil producing developing countries, as well as for some industrialised countries and economies in transition. In over 30 countries, energy imports exceed 10 percent of the value of all exports, a heavy burden on their balance of trade often leading to debt problems. In about 20 developing countries, payments for oil imports exceed payments for external debt servicing. This is an important aspect of the energy-debt nexus.

1.3. OPPORTUNITIES FOR SUSTAINABLE ENERGY

Based on the discussion in the previous sections, it is clear that prevailing trends in the energy sector hinder sustainable human development. In fact, energy's links with poverty and gender issues, environmental degradation, macroeconomic, and security concerns indicate that the diverse problems faced by developing countries could only intensify if they were to follow the patterns of energy consumption that developed countries have exemplified thus far.

Unfortunately, for a variety of reasons, such patterns have become entrenched in the energy policies and programmes of many developing countries. Much of energy discourse is dominated by a supply-oriented paradigm that links GDP growth directly with energy use. Cross-country experience has shown, however, that national energy demand is proportional to GDP *if and only if* the structure of the economy and the energy intensities are constant. Many countries, including China, Japan, Poland, UK, and USA display trends where energy intensity has reduced due to efficiency improvements, process changes, or product changes (UNDP, 1997). In addition, a widely-held belief among policy-makers is that the only energy carriers of significance are coal, petroleum-derived liquid fuels, natural gas for industry and transport, and electricity for almost all other services. Linked with this is the often-mistaken idea that the investment costs of harnessing energy from renewable sources would be much higher than from fossil fuels.

These factors have often caused developing countries to follow policies emphasising only growth in energy supply as a means for ensuring economic growth. Such policies are typically implemented at the expense of promoting measures to provide energy services in the most efficient manner possible, through an optimal combination of supply and demand-side options. In addition, many countries tend to invest heavily in an energy supply infrastructure based entirely on conventional fuels, which frequently requires huge (and often hidden) government subsidies to support their centralised, fossil-fuel dependent, and supply-driven energy economies. This, in turn, has caused some countries to experience being "locked" into the unsustainable energy pathways that were carved out during early years of modernisation.

In spite of these constraints, most developing countries are still at a juncture in their economies where they can exploit several available leap-frogging technologies and institutional opportunities to steer themselves towards sustainable modes of development. There are several indications that the judicious development of energy services could bring in new prospects for meeting these countries' sustainable development goals. These opportunities exist on the demand and supply sides of the energy sector, as illustrated below.

1.3.1. New Opportunities on the Demand Side

In developing countries, the potential for energy efficiency improvement is often much greater than in industrialised countries, for several reasons. First, energy-intensive activities are growing rapidly in developing countries, so that a larger fraction of the opportunities for making improvements in energy efficiency is associated with new installations (rather than retrofits of existing installations), compared to the already industrialised countries. Second, energy prices are typically subsidised and low in many developing countries, so that the market has not encouraged the use of efficient technologies. The creation of a level playing field for energy services stands to vastly improve the opportunities for energy efficiency. Third, many commercial technologies for improving energy efficiency have not been readily available in developing countries. Fourth, while capital markets throughout the world generally tend to discriminate against investments in energy efficiency (UNDP, 1997), the difficulty of financing such investments is compounded in developing countries, where domestic capital markets are not yet as well-established as in industrialised countries.

In addition, developing countries are characterised by: 1) the high cost of capital; 2) higher perceived risk (both political and financial) on the part of foreign investors, which pushes up the rates of return necessary to attract foreign direct investment; and 3) exchange rate risk, which can prevent enterprises or municipalities (not to mention households) from obtaining fixed-rate hard-currency loans and hinder the import of foreign energy-efficient technologies. Overcoming these barriers will pave the way for harnessing the significant potential for energy efficiency improvement in developing countries.

1.3.1.1. Commercial and Residential Buildings

The opportunities for improving energy efficiency for buildings are usually far greater with new investments than with retrofitting existing equipment. These are especially important considerations for developing countries, because most investments in infrastructure and equipment aimed at economic growth are yet to be made. Nevertheless, net savings are also possible for existing buildings, equipment, and installations if older devices and systems are replaced with more efficient counterparts that provide the same or better services. In many instances, it is cost effective to replace incandescent light bulbs with compact fluorescent light bulbs, electrical or biomass-fired water-heaters with solar water heaters, or inefficient motors, air-conditioners and refrigerators with efficient systems. Typically, the replacement costs for the new technology will be recovered within a short period (from a few months to about 3 years) through savings in energy costs. Figure 5 shows how improvements in refrigerators can result in energy and cost savings that are significant.

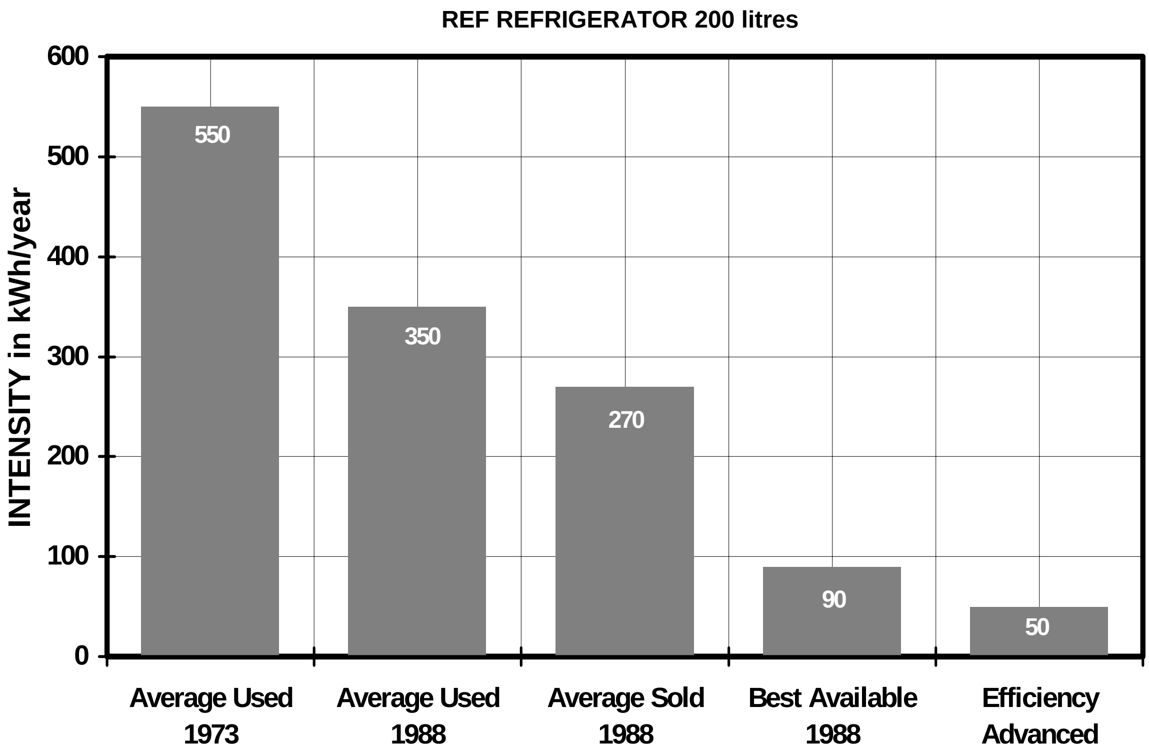
Energy services to poor households can also be delivered in a manner that results in net savings to the users, provided the appropriate infrastructure is made available for using more efficient carriers. The switch from kerosene wick-lamps to fluorescent tubelights that took place in Pura village in South India provides an illustrative example. In this case, the energy input decreased to one-ninth compared to the kerosene originally used and the household expenditure for lighting was cut in half, but illumination rose most significantly by a factor of about 19.[12]

The most important energy service in many developing countries is cooking (see Section 3.2.3), where traditional fuels—fuelwood, crop residues and dung—are the main fuels used in rural areas. In many urban areas, charcoal and coal

[12] *Rajabapaiah, P., S. Jayakumar, and A.K.N. Reddy, 1993: "Biogas electricity—the Pura Village case study". In:* Renewable Energy: Sources for Fuels and Electricity. *Johansson, T.B., H. Kelly, A.K.N. Reddy, and R.H. Williams (eds.), Island Press, Washington, DC, 787-815.*

are also used. There can be a substantial reduction in both operating costs and energy use in going from traditional stoves using fuelwood to improved biomass, gas, or kerosene stoves. There are also opportunities to substitute high-performance biomass stoves for traditional ones, or to substitute liquid or gas (fossil or biomass-based) stoves for biomass stoves. Local variations in stove and fuel costs, availability, convenience and other attributes, and in consumer perceptions of stove performance, should then determine consumer choice (Karekezi, 1992; Barnes et al., 1994; Kammen, 1995).

FIGURE 5. ENERGY EFFICIENCY OF REFRIGERATORS (KWH/PER UNIT/PER YEAR)



Note: Stock average performance improves as newer, more efficient models penetrate. Opportunities exist to speed up the process of technology development and penetration in the capital stock. See also Dutt (1995).

Source: Nörgård (1991)

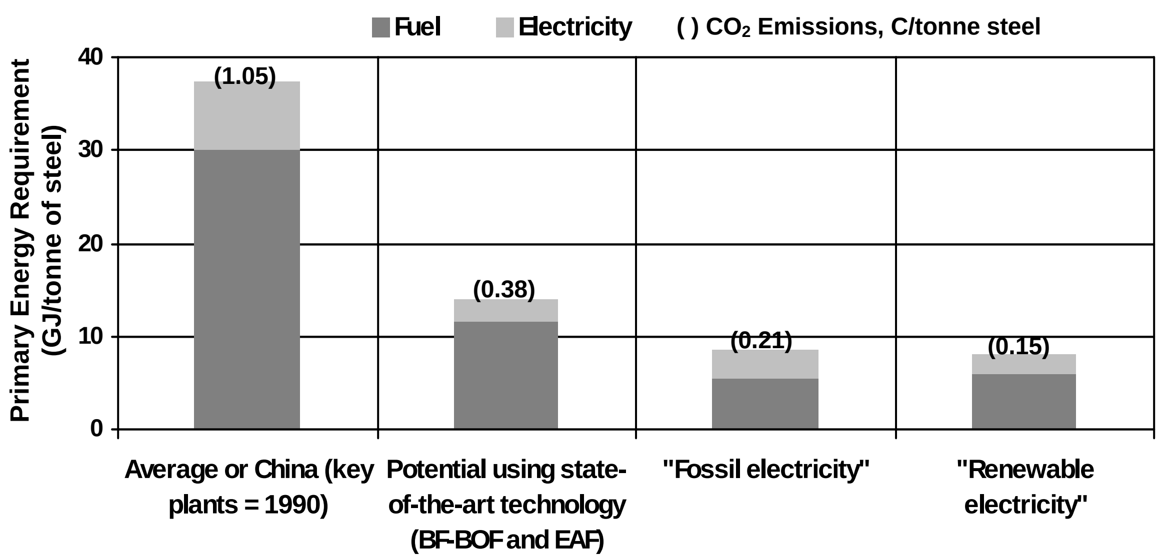
1.3.1.2. Industry

Although there is significant potential for improving energy efficiency in all industries, the greatest opportunities for savings are in the energy-intensive industries. Significantly, the five major industries—iron and steel, chemicals, petroleum refining, pulp and paper, and cement—together account for roughly 45 percent of global industrial energy consumption, or about 15 percent of all commercial energy use (IPCC, 1996).

Energy purchases represent such a large fraction of production costs in these industries that new technologies for making basic materials have been generally more energy-efficient than the technologies they have replaced, a trend that is likely to persist (Goldemberg *et al,* 1988). Developing countries are experiencing the fastest growth in demand for basic materials like steel, cement, and chemicals and also have the greatest potential for energy-efficiency improvements. The opportunities for technological "leapfrogging" in these countries are therefore quite significant and are illustrated in Figure 6, which shows how a particular set of advanced technologies can reduce energy requirements, while improving the economic and environmental attributes of steel making.

Advanced technologies can make it possible to improve substantially the well-being of the majority of the world's population without straining resource bases and with much lower environmental impacts than with existing technologies. Policies aimed at promoting innovation to improve technological, economic and environmental performance in basic industries would also be effective in improving energy efficiency.

FIGURE 6. ENERGY REQUIREMENTS FOR PRODUCING STEEL WITH ALTERNATIVE TECHNOLOGIES, COMPARED TO THE CURRENT AVERAGE STEEL-MAKING TECHNOLOGY IN CHINA



Note: BF=Blast Furnace; BOF=Basic Oxygen Furnace; EAF=Electric Arc Furnace.
Source: Worrell (1995).

Industrial ecology provides a relatively new set of approaches to improve the overall efficiency of industrial processes by examining the environmental problems that occur at each step in production and consumption.[13] Its general aim is to harness opportunities for increasing the efficiency of materials use, often by locating complementary industries together so that waste streams of one industry could be used as process inputs for another.

Ideally, industrial practices should be oriented towards ensuring management of full material chains, taking into account environmental, energy, and other concerns at each point in the product cycle. Currently, policies in most countries are not designed to do this. Instead, to the extent that materials management policies have been enacted, they are typically limited to single aspects of the product life cycle (e.g., mining or waste management). Providing consumers with information to encourage demand for environmentally benign products (e.g., via eco-labelling) is a step towards more sustainable production that has been taken in some countries. Some governmental and corporate procurement programs have also established "market pull"

[13] *Socolow, R., C. Andrews, F. Berkhout, and V. Thomas (eds.), 1994:* Industrial Ecology and Global Change. *Cambridge University Press, Cambridge; Ayres, R.U., and U.E. Simonis (eds.), 1994:* Industrial Metabolism: Restructuring for Sustainable Development. *United Nations University Press, Tokyo, Japan.*

instruments, although these are not yet used widely. There are, however, legislative proposals in several countries aimed at increasing the producer's responsibility for managing the total life cycle of the product—proposals requiring involvement of producers in waste management and recycling activities and encourage design and development of products compatible with sustainable development objectives.

1.3.1.3. Transportation

Transport is one of the fastest-growing sectors of energy use, with road transport being the major sub-sector. During the period 1971 to 1992, the rate of growth in transport energy consumption for developing countries was much more rapid (4.7 percent per year) than in the industrialised countries and economies in transition (2.1 and 2.0 percent per year, respectively) (WEC, 1995). Still, industrialised countries dominate transport energy use, accounting for nearly two-thirds (39 EJ) of total world consumption in 1992 (WEC, 1995).

Transport energy use can be reduced by: *i*) shifting to less energy-intensive transport modes to achieve the same or similar transport service; *ii*) changing the mix of transportation fuels; *iii*) improving the transportation infrastructure (roads, railways); *iv*) improving the efficiency of transportation technology; and *v*) introducing land-use changes and other incentives to reduce the intensity of travel demand. Significant reductions in energy use can be achieved by encouraging shifts to less energy-intensive modes of transport, since strong variations in intensities exist for various modes. For example, shifting commuting from passenger cars to buses can reduce the energy intensity of travel (in MJ/pass-km) by 60 to 75 percent, depending on world region, although increasing the load factor of cars via carpooling would have a similar effect.[14]

Shifting fuels can, sometimes, lead to energy savings, but these may be offset by higher environmental risks that must be evaluated carefully. When fuel cell cars become available, fuel choice are going to have a large effect on automotive fuel economy. Initially, fuel cell cars probably stand to be fuelled by gasoline or diesel that can be provided through the existing fuel infrastructure (UNDP, 1997).

Planners are beginning to examine methods to make better use of existing infrastructures or to improve infrastructures to reduce energy demand by transport vehicles. Policies that encourage large shifts to public transit systems in urban areas like Singapore, Curitiba, and Manila have been shown to reduce overall energy demand. In Curitiba, Brazil, the city's bus line accounts for 70 percent of total transport and, partly as a result, Curitiba's per capita energy use is 30 percent lower than in otherwise comparable Brazilian cities.[15] In all these instances, integrated approaches to transportation and land use planning have been crucial for encouraging shifts to mass transit.[16]

Advanced automotive technologies provide valuable options for dealing with urban air pollution, while some may also improve transport energy efficiency. For example, battery-powered electric buses and battery-assisted bicycles are being introduced in Beijing. In Bangkok, prototype battery-powered electric buses will be introduced by 1998, and prototypes of battery-powered "tuk-tuks" (three-wheeled vehicles used as taxis and for urban cargo hauling) are being tested as prospective alternatives to conventional LPG-fuelled tuk-tuks. Although not commercially available yet, in mass production, fuel-celled vehicles can potentially compete with the petroleum-fuelled internal combustion engine in automotive applications, while providing transport services at a two-to-three-fold higher energy

[14] *Worrell, E., M. Levine, L. Price, N. Martin, R. van den Broek, and K. Blok, 1997:* Potentials and Policy Implications of Energy and Material Efficiency Improvement. *A Report of the United Nations, New York.*

[15] *Rabinovitch, J. and J.Leitmann, 1993: "Environmental Innovation and Management in Curitiba, Brazil." United Nations Development Programme/World Bank/Habitat, Urban Management Programme, Working Paper Series No. 1, New York.*

[16] *Birk, M. and C. Zegras, 1993:* Moving Toward Integrated Transport Planning: Energy, Environment, and Mobility in Four Asian Cities. *International Institute for Energy Conservation, Washington, DC.*

efficiency and emitting zero or near-zero local air pollution without the use of emission control technology (UNDP, 1997).

Regardless of the sector considered, end-use energy efficiency improvement reduces global warming, air pollution (acid precipitation, smog in the urban and industrial environment), waste production (ash, slag), water consumption, and thermal pollution. At the same time, end-use efficiency improvement is a cheap energy "source", and, in many cases, is far cheaper than new supply. Other economic benefits are reduced costs of energy transformation and generation, reduced fuel imports, and increased energy security. Technology developments have neither reached their limits in the provision of continuing improvements to energy efficiency, nor are they going to in the foreseeable future.

1.3.2. New Opportunities on the Supply Side

Energy supply options that increase efficiency (the energy efficiency of making energy carriers from primary energy sources), reduce pollutant emissions, and reduce emissions of greenhouse gases can contribute to sustainable development objectives.

1.3.2.1. Advanced Technologies for Electric Power Generation

In fuel-based electric power generation, there are good prospects for routinely achieving efficiencies of over 60-70 percent or more in the longer term, compared to the present 30 percent world average. Large efficiency gains can also be achieved by replacing the separate production of heat and power with combined heat and power (CHP) technologies. Moreover, rapid progress is being made in the use of renewable energy in power generation.

Thermal Power Generation: The natural gas-fired gas turbine/steam turbine combined cycle has become the thermal power technology of choice in regions having ready access to natural gas, because of its low unit capital cost, high thermodynamic efficiency, and low pollutant emissions. Because of increasingly competitive conditions in the electric power industry, turnkey combined cycle plant costs have fallen sharply. Since the feasibility of firing combined cycle power plants with coal via the use of closely coupled coal gasifiers has been successfully demonstrated in the late 1980s, there has been much progress in commercialising the coal-integrated gasifier/combined cycle (CIG/CC). This technology makes it possible to adapt the continuing advances in gas turbine technology to coal, with pollutant emissions as low as for natural gas combined cycles, and would be well suited to countries like India and China, which have large coal resources.[17]

In 1994, a 41 percent-efficient 250 MWe CIG/CC plant began operation in The Netherlands, and in late 1995, a 262 MWe CIG/CC plant began operating in the United States in Indiana. Other projects are underway in the USA and Australia. With advanced gas turbines, it is expected that CIG/CC efficiencies will be able to reach 50 percent (UNDP, 1997).

Fuel Cells: Fuel cells, devices that convert fuel directly into electricity without first burning it to produce heat, are now beginning to enter CHP markets. Fuel cells were first used for practical applications as a source of onboard electric power in spacecraft in the 1960s. They are now beginning to enter electric generation markets on earth, where they offer strong inherent advantages in electricity markets, characterised by increasing competition and environmental regulations.

Fuel cells offer high thermodynamic efficiency, low maintenance, quiet operation, and zero or very low air pollutant emissions without exhaust-gas control technologies. Fuel cells could prove to be economically viable even in small-scale (100 kW_e or less) CHP sited unobtrusively close to end-users, e.g., in residential and commercial buildings. Such siting of fuel cells as "distributed

[17] *Tavoulareas, S. and J. Charpentier, 1995: "Clean Coal Technologies for Developing Countries," World Bank Technical Paper No. 286, Energy Series, E. July.*

power sources" makes CHP designs economically attractive and offers the potential of reducing capital outlays for electricity transmission and distribution equipment (Hoff *et al.,* 1995). There are exciting prospects to use this technology in grid-connected rural applications that use biomass fuels and meet rural, as well as urban, loads. Such uses of fuel cells could generate rural employment and also facilitate rural electrification (Kartha *et al.,* 1997).

Hydro Power: Hydroelectric power is a well established renewable electricity supply, providing 2,100 TWh, nearly 20 percent of the global electricity generation supply (11,300 TWh/year) in 1990. The theoretical potential, determined by annual water runoff (47,000 km^3), is 36,000 to 44,000 TWh/year worldwide. The estimated technically usable potential is 14,000 TWh/year, while the estimated long-term economic potential is 6,000 to 9,000 TWh/year.[18]

Because of growing environmental and social concerns, some of the economic potential for hydroelectric development might not be fully realised, but hydroelectric power will continue to be developed wherever these concerns can be dealt with effectively. However, even in regions where there are no new hydroelectric projects, there can be significant new roles for hydro-electric power in modulating irregular electricity supplies from intermittent renewable supplies (wind, PV, and solar thermal-electric).

Wind Power: The cost of electricity from new wind farms has fallen sharply since the mid-1980s. While deployed initially in industrialised countries, wind power is now growing rapidly in some developing countries. By the end of 1998, global wind capacity has reached about 9800 MW from 1730 MW in 1989, of which China, India, and Germany have 224 MW, 968 MW, and 2874 MW, respectively.[19] China has especially good wind energy resources, though these are mainly concentrated in areas remote from electricity demand centres. Nonetheless, it has been estimated that electricity from large wind farms in these remote regions could be brought to the major electricity markets using long-distance transmission lines—at costs potentially competitive with coal electricity in northern China.[20]

Biomass: The electrical loads of rural villages of the developing world are typically in the range 5-200 kWe. Producer gas-engine generator sets based on the use of biomass gasifiers coupled to small reciprocating engines are well-matched to these loads. Until recently, several biomass-producer gas-engine projects have failed, largely because of excessive tar formation in the gasifier and maintenance problems posed by tars. However, most of these problems have been solved. Field demonstrations have been carried out successfully, and the technology is ready for commercial applications. These generators often use diesel fuel, but biomass-derived producer gas could replace 75-95 percent of this diesel fuel. Small rural loads, such as water pumping, can be served best through this technology, and at costs that are lower than would be possible through grid extension, to provide power from centralised power plants.[21]

Biomass is used as fuel for steam turbine-based CHP generation in the forest product and agricultural industries of several countries. The biomass used as fuel consists mainly of the residues of the primary products of these industries. There is also a growing trend to co-firing coal-fired power plants with supplemental biomass inputs. In developing countries, there

[18] *Moreira, J.R, and Poole, A.D., 1993: "Hydropower and its constraints". In*: Renewable Energy-Sources for Fuel and Electricity*, Johansson, T.B., Kelly, H., Reddy, A.K.N., and Williams, R.H. (eds.), Island Press, Washington DC, 73-119.*

[19] *WPM, 1999:* Wind Power Monthly, *Vol.15, No.4, April; WWI, 1997:* Vital Signs, *World Watch Institute, Washington, DC.*

[20] *Lew, D.J., R.H. Williams, S. Xie, and S. Zhang, 1996:* Industrial-Scale Wind Power for China. *Report prepared for the Working Group on Energy Strategies and Technologies of the China Council for International Cooperation on Environment and Development, Beijing, China, August.*

[21] *Ravindranath, N.H. and D.O. Hall, 1995:* Biomass Energy and Environment: A Developing Country Perspective from India. *Oxford University Press, Oxford, UK; Mukunda, H., Dasappa, S., Srinivasa, U. 1993. "Open-top wood gasifiers". In:* Renewable Energy—Sources for Fuel and Electricity.*Johansson, T.B., H. Kelly, A.K.N. Reddy, and R.H. Williams (eds.), Island Press, Washington, DC, 699-728.*

is large potential for efficiency improvements in the use of biomass for energy in industry and growing interest in introducing modern steam-turbine CHP technology (e.g., in the cane sugar industry). An advanced technology that could make it possible for electricity derived from plantation biomass to compete with coal in power generation is the biomass integrated gasifier/combined cycle (BIG/CC). In addition to plantation biomass, which must address potential conflicts with food production, less costly biomass residues can be used.

Although BIG/CC technology is not as advanced as coal integrated gasifier/combined cycle (CIG/CC) technology, several demonstration projects are underway. Catching up may not take long, because: 1) much of what has been learned in developing the CIG/CC is readily transferable to BIG/CC technology; 2) biomass is in some ways a more promising feedstock than coal for gasification (e.g., it contains very little sulphur and is much more reactive than coal); and 3) BIG/CC would facilitate decentralised rural electrification and industrialisation, thereby promoting rural development (a potentially powerful market driver). Moreover, the modest scale of BIG/CC power plants relative to conventional fossil fuel and nuclear plants facilitate financing and cost-cutting as a result of "learning-by-doing". For power applications, hybrid BIG/FC/GT systems offer the potential for achieving biomass-to-electricity conversion efficiencies in excess of 40 percent—or more than twice the efficiency of producer gas-engine generator sets—and prospectively cost-competitive power at power plant scales of hundreds of kilowatts (Kartha *et al.,* 1997).

PV Power: Worldwide sales of photovoltaic (PV) modules have increased from 35 peak megawatts/year (35 MWp/year) in 1988, to 134.8 MWp/year in 1998.[22] Between the mid-1970s and the present, the price of PV modules has fallen 10-fold, as the technology has moved along its experience curve, with the cumulative volume of production increasing about 1000-fold (see Figure 7). So far, most applications have been for a variety of consumer electronic and other niche markets, but both stand-alone and grid-connected electric power applications are becoming increasingly important applications of PV technology.

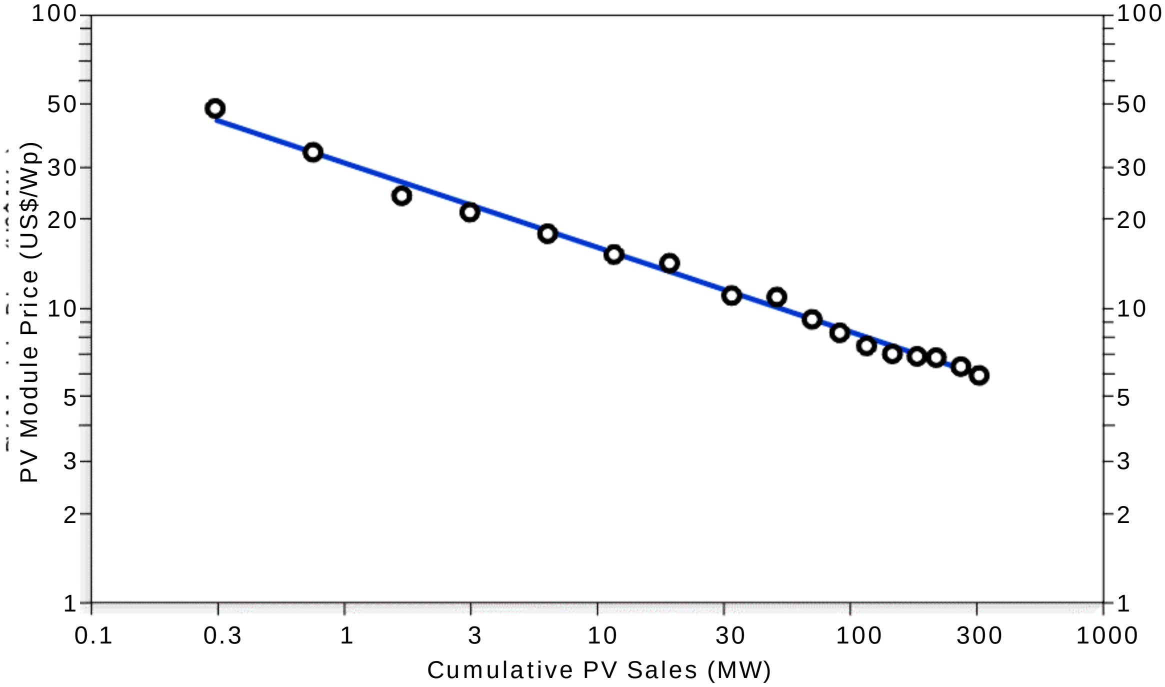
PV technology is being successfully deployed in small-scale, stand-alone power applications remote from utility grids. Decentralised rural electric applications, largely for domestic lighting, refrigeration and educational purposes, make it possible to serve modest household lighting and other rural electric needs, while avoiding the economic inefficiencies of bringing centralised power supplies to these customers in remote areas. On a life-cycle basis, solar household systems are typically less expensive than grid extension for remote rural areas currently unserved by the grid. However, stand-alone PV systems have to compete in biomass-rich regions with biomass-based community-scale electricity generation serving households.

PV technology is now also cost-effective in some high-value, grid-connected applications where PV units are sited near users. Central station PV power plants, which offer opportunities for bringing costs down quickly, are currently being planned in Hawaii and India.

Solar Thermal Electric Power: High-temperature solar thermal-electric technologies use mirrors or lenses to concentrate the sun's rays onto a receiver, where the solar heat is transferred to a working fluid that drives a conventional electric power-conversion system. Three major solar collector/receiver designs have been developed: *i*) the parabolic trough system, which concentrates solar energy onto a receiver pipe located along the line focus of a parabolic mirror trough collector; *ii*) a central-receiver system, which uses sun-tracking mirrors called heliostats to reflect solar energy onto a receiver located on top of a tower; and *iii*) a parabolic-dish system, which uses a tracking parabolic dish reflector to concentrate sunlight onto a receiver mounted at the focal point of the dish. Applications for solar thermal-electric systems range from central station power plants to modular, remote power systems.

[22] *Oswald, G.J., 1999:* The role of the private sector in increased rural access, *Paper presented at the World Bank Energy Week, 1999, April.*

FIGURE 7. LOG-LOG PLOT OF THE SELLING PRICE OF PV MODULES



In the period 1976-1992, the world-average PV module selling price declined 18.4 percent for each cumulative doubling of PV module production. Module sales data and prices are from Strategies Unlimited, Mountain View, CA.

Source: UNDP (1997).

1.3.2.2. Power Systems

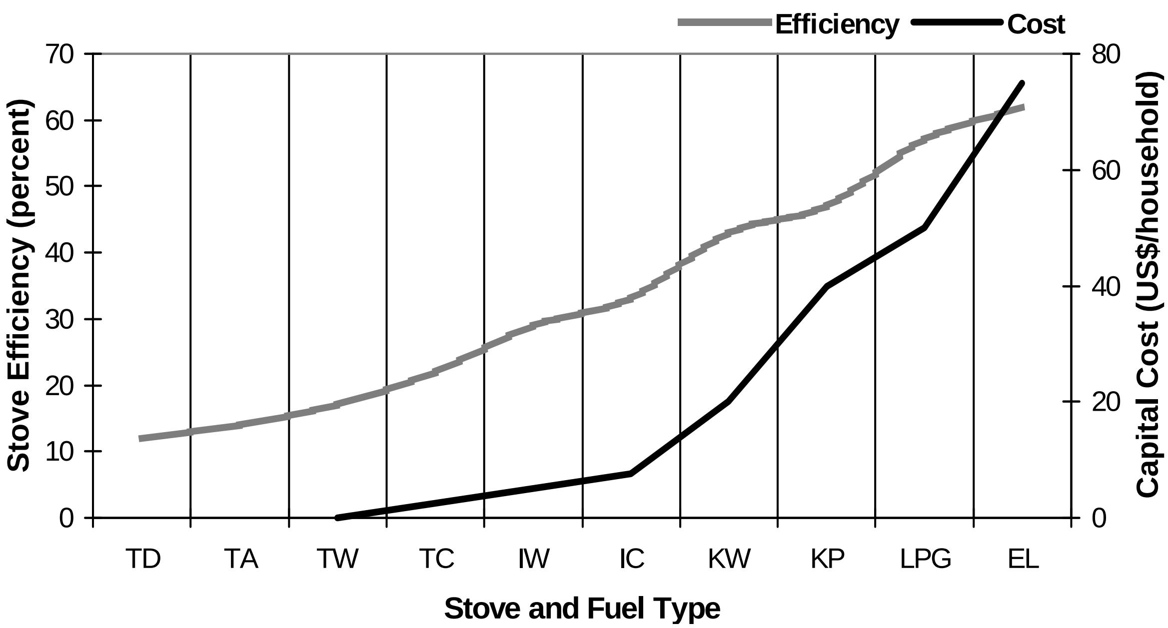
Large-scale adoption of renewable electric technologies will require that they be connected to electric utility grids. Managing grid-connected renewable electric technologies poses new challenges for utilities. Since costs are relatively insensitive to scale, renewable energy sources will be used to produce electricity from plants that are much smaller than those in today's power systems. Scales range from 1 kW_e for some PV systems to 25-300 MW_e for BIG/GT systems. Many of the smaller-scale technologies will be sited at or near customers' premises rather than in central-station plants. Some PV and fuel-cell systems can be operated unattended and even installed at individual houses. Electricity produced from such "distributed power systems" is worth more to the utility than central station power whenever the electrical output is highly correlated with the utility peak demand, largely because such siting makes it possible to defer transmission/distribution investments (Hoff *et al.,* 1995).

Intermittent supplies from wind or grid-connected PV systems can be managed by a combination of load-management techniques (e.g., using a time-varying electricity price to induce load shifting), backing up the intermittents with an appropriate mix of dispatchable generating capacity, using interconnecting grid systems for transferring electricity over large distances to cope with some of the daily variations of wind and solar energy, and energy storage (mechanical, electrochemical, thermal, or other).

1.3.2.3. Cooking Fuels/Stoves

Since cooking using traditional biomass fuels is both the dominant energy activity and the source of undue hardship to the poor in developing countries, the dissemination of more efficient cookstoves using traditional or modern fuels is an essential sustainable energy intervention. Depending on relative fuel and stove prices, substantial reductions in both operating costs and energy use can be obtained from switching from traditional stoves, using commercially purchased fuelwood to improved biomass, gas, or kerosene stoves (see Figure 8). There may be opportunities to substitute high-performance biomass stoves for traditional ones, or to substitute liquid or gas (fossil or biomass-based, for instance, natural gas, liquified petroleum gas, kerosene) stoves for biomass stoves.

FIGURE 8. REPRESENTATIVE CONVERSION EFFICIENCIES AND CAPITAL COSTS FOR VARIOUS STOVES



TD-Traditional Stove using Dung; TA- Traditional Stove using Agricultural Residues; TW- Traditional Stove using Wood; TC- Traditional Stove using Charcoal; IW- Improved Wood Stove; IC- Improved Charcoal Stove; KW- Kerosene Wick Stove; KP- Kerosene Pressure Stove; LPG- LPG Stove; EL- Electrical Resistance Stove.

Source: UNDP (1997).

Over three decades, there have been numerous cookstove research and dissemination projects covering a wide range of stove designs and adopting a variety of mechanisms to transfer the technology to the eventual users of cookstoves, who are primarily women (World Bank, 1992a; Smith *et al.,* 1993). Several important lessons have been learned from these programmes, particularly relating to cookstove design, development, dissemination, adoption, and the interaction between project implementers and end-user groups. Cookstove design has since been geared to combustion of fuel, radiative heat transfer from the fire to the pot, convection from the fire to the pot, conduction to the pot and, most importantly, user satisfaction by making the stoves convenient to use (with local fuels, cooking pots, and utensils) and able to easily prepare local dishes well (Kammen, 1995). Apart from remaining fuel-efficient under diverse cooking conditions, stoves must be easy to use and perform robustly in real-world environments.

Early cookstove projects often have failed for both technical and social reasons; that is, their designs have not been based on sound scientific research to meet the technical criteria given above or have been expensive and difficult to use and have degraded rapidly with use (Baldwin, 1986). The end users have not been involved in initial discussions, feedback, or training programmes; these have been inappropriately targeted to men or to extension workers who rarely cook food themselves. Significantly, many of these projects have involved dissemination of designs imposed, rather than locally determined. One way to avoid such a top-down approach to dissemination is to create local cookstove training centres in which various stove designs and different approaches to managing community workshops are discussed with community leaders, who then select and refine the methods they consider best suited for their particular local conditions (Kammen, 1995).

One example of a successful programme has been in Ethiopia, where a British NGO (Energy for Sustainable Development) has developed and commercialised two types of improved biomass cookstoves through an iterative approach of needs assessment, design, product trials, redesign, and performance monitoring. The team works with households, stove producers, installers, merchants, and pays attention to promotion, technical assistance, quality control, the provision of business, management, and marketing skills to producers. Over 600,000 stoves of one type, and 54,000 of a second type, introduced a few years later and using about half the fuel of conventional stoves, have been disseminated, with volumes expected to increase substantially in subsequent years (EC/UNDP, 1999).

In the long term (assuming income growth and the ability to finance imports), the transition to high quality liquid and gas fuels for cooking is inevitable. With this transition, substantial amounts of labour now expended to gather biomass fuels in rural areas could be freed and the time and attention needed to cook when using crude biomass fuels may be reduced substantially.Furthermore, household, local, and regional air pollution from smoky biomass (or coal) fires may be largely eliminated. On the other hand, high-quality fuels are likely to increase monetary costs to the individual consumer. Moreover, if fuels or stove equipment are imported, this situation can have significant impacts on national trade balances and foreign exchange holdings. The use of commercial liquid fuels from biomass, advanced gasification designs for stoves, and other options may be particularly important here. To realise any of these advanced biomass-based systems, however, substantial further research and development effort is required.

1.3.3. Scenarios

Numerous models to predict scenarios of sustainable energy futures have been developed based on consumption, production assumptions, and technology pathways that are feasible given international commitment to sustainable development. Two such global scenarios, the Ecologically-Driven Scenarios, developed in a joint World Energy Council/International Institute for Advanced Systems Analysis report (WEC/IIASA, 1995), and the energy-efficient variants of the Low CO_2-Emitting Energy Systems (LESS), developed in the Second Assessment Report of Working Group II of the IPCC (IPCC, 1996), indicate how the global energy economy may evolve over the period 1990-2100 if energy options generally supportive of sustainable development objectives are emphasised.

These options include the more efficient use of energy, innovative technologies for reducing environmental impacts of fossil fuel use, and renewable energy sources. Both sets of scenarios also include nuclear-intensive variants (in which the nuclear power industry is revived and nuclear capacity expands approximately 10-fold, 1990-2100) and variants in which nuclear power does not grow. Both scenarios assume public policies that promote the efficient use of energy, environmental values in the energy system, and energy innovation (by supporting research and development and by providing commercialisation incentives to help launch new technologies in the market). Both also emphasise international cooperation and a high rate of technology transfer to, and energy innovation in, developing countries. Both assume that existing petroleum resources are to be fully exploited.

The single most important attribute of these energy futures is efficient energy use, although technical limits for energy efficiency improvement are not approached. By 2020-2025, per capita commercial energy use rates for developing countries are only 1.4 to 1.5 times 1990 values; the corresponding ratio for industrialised countries and economies in transition is 0.8. Improved energy efficiency can lead to lower costs for energy services, reduced environmental impacts from energy supplies, reduced dependence on foreign exchange requirements for energy imports, and flexibility in choosing energy supplies.

1.4. BUILDING THE ENABLING FRAMEWORK FOR SUSTAINABLE ENERGY

The vast opportunities for increasing the efficiency of energy production and use, as well as the obvious advantages of their implementation over conven-tional strategies, suggest that sustainable energy initiatives can be carried out readily by governments and yield results almost spontaneously. As stated earlier, however, prevailing notions about energy are deeply supply-biased and growth-oriented, so that wide-ranging policy innovation is, in fact, needed in order to realise the objective of using energy as an instrument of sustainable human development. Moreover, the transition to sustainable energy is necessarily affected by numerous institutional impediments and shaped by current trends sweeping the world. The latter include globalisation, marketisation, popular participation in decision-making, the changing roles of government, restructuring (and corporatisation) of energy utilities, and the changing magnitude and mix of sources of external funding.

A few guiding principles can be drawn into a broad framework for sustainable energy reform (UNDP, 1997):

- emphasise energy services rather than fuel or electricity supply, thus establishing and maintaining a level playing field among alternative supply and end-use technologies in providing energy services;
- promote universal access to modern energy services;
- include external social costs in energy market decisions;
- accelerate the development and market penetration of sustainable energy technologies;
- promote indigenous capacity building; and
- encourage broad participation of stakeholders in energy decision-making.

Advancing sustainable energy within this framework requires significant institutional changes, including those that lead to easier access to capital and advanced technology than is presently available for developing countries. While there is no panacea for bringing about such changes, the following are some policy approaches that appear to be significant catalysts for reform.

1.4.1. Creating Favourable Legal, Institutional, and Regulatory Climates

An important way for countries to exploit the numerous supply and demand side opportunities for leapfrogging energy technologies is to establish special incentives that make their adoption attractive for producers, consumers, and manufacturers of energy services. For instance, the United States has introduced legislation in 1978 (Public Utilities Regulatory Policy Act) specifying that utilities must buy electricity generated by qualifying independent power producers (IPPs), including producers of electricity from small-scale renewable energy sources, at price levels equal to their avoided costs (the costs the utilities could avoid by not having to produce the electricity themselves). This law proves influential in establishing cogeneration and renewable electricity generation capacity in this country, because it secures access to the market and assures fair, predictable prices. Eventually, it has also demonstrated that, given a level playing field, renewable energy producers can frequently generate electricity at a lower cost than traditional electricity utilities. Moreover, it has provided important institutional lessons for the IPP industry, namely, the need to secure long-term purchase price contracts for electric power to obtain financing and manage their risk, and the development of standardised contracts providing guidelines for terms and conditions of capacity and energy sales to utilities.

Similarly, in India, the Indian Renewable Energy Development Authority (IREDA), a government-established public bank, has been implementing a US$430 million programme to develop India's renewable energy resources. Supported by US$255 million in multilateral and bilateral loans and grants, the programme provides soft loans to developers of renewable energy projects for up to 75 percent of project costs. The majority of loans have gone to wind power development, resulting in the installation of nearly 900 megawatts (MW) of wind power by 1998, up from 200 MW in early 1995. The loan programme has helped provide the initial impetus for market development. Loans are also provided to other areas, such as biomass, solar thermal, and photovoltaic applications.

Technological leapfrogging through such policy innovation provides developing countries the opportunity to employ the most technologically advanced energy systems available on the world market to meet their energy demands, if not to actually consider deploying new, emerging technologies and systems which are not yet in wide use. Nevertheless, it is important that these technologies be chosen wisely, to ensure their appropriateness to conditions of cheap labour markets, natural resource availability, and the satisfaction of basic needs.

1.4.2. Accessing Private Capital for Sustainable Development

Although utilities generally raise most of their investment capital for new energy projects from savings, in most developing countries retained earnings are virtually non-existent, because of tariffs that are below marginal cost, consumer subsidies, poor collection, or fraud. Moreover, these problems themselves lead to lower credit ratings for these utilities, making it difficult for them to raise capital in commercial capital markets. Even governments are increasingly unable to provide investment funds to utilities because of fiscal constraints.

Fiscal constraints also limit the availability of financial assistance from ODA—Official Development Assistance—sources. Although sustainable development strategies generally require less total energy investment, and thus are easier to finance, capital market reforms are needed even to meet even these reduced capital requirements. A major potential new source of capital for energy-sector investments in developing countries is foreign private capital, flows of which have increased considerably in recent years.

Prospective private investors must, of course, be convinced that the financial risks are acceptable and that the projected returns on investment are at least comparable to those available on alternative investment opportunities. More than these conditions of commercial viability, however, it seems to be crucial that countries have well-defined and consistently enforced laws and regulations, including a dependable property rights regime, in order to attract long-term private capital for energy sector investments.

1.4.2.1. Concessions

Several renewable energy technologies are compact and modular, thus benefiting from economies of scale in production. Nonetheless, when the initial markets are small or dispersed, individual manufacturers are often reluctant to invest in large-scale production. One way to overcome this barrier is for governments to offer concessions for renewable energy development, where a single supplier is provided exclusive market development rights in a delineated region over a specified period of time, following a competitive bidding process.

While concessions have been applied very effectively in the mineral extraction industries (e.g. petroleum, natural gas, metals), this idea has been proposed recently as a very effective mechanism for wind resource development (Brennand, 1996). Here, the concession can be used as an effective instrument for harnessing large, high-quality wind energy resources that are concentrated in regions remote from major electricity markets, as are the cases of the United States and China. In a delineated region of high-quality wind resources, the government can offer concessions to companies for the exploration and development of wind energy in the region over a specified period of time. Apart from issuing the concessions via some competitive process, the government is going to issue and enforce the rules and regulations that define and guide concessions (including the payment of royalties and specifications for technology transfer) and the relationships among the electricity producers, transmitters, and buyers, including long-term electricity purchase agreements.

The government stands to gain, at very little risk, greater control over the rate and scale of wind energy development, since all front-end risks are borne by the wind energy developers. Concessions issued via competitive bidding processes can help to reassure the government's authority that it is getting a fair deal, and the negotiating process enables the authority to gain experience of how much the "market" can bear. Moreover, the issuance of concessions for gigawatt-scale wind projects is bound to attract a new generation of larger companies organised as international joint ventures and other collaborations that can bring together the needed financial and technical resources for such large wind energy development projects. The institutional establishment of the concession, together with the emergence of this new generation of wind energy developers, stands to lead to lower costs through the scale economies of wind turbine production and large wind-farm development, and to make it possible to speed up the timetable on which wind energy is able to make substantial contributions to overall electricity supplies.

For prospective wind energy developers, the concession offers the opportunity to participate in far larger wind energy projects than has heretofore been possible. The concession also has the potential to attract a wider range of potential developers than has been typical for wind energy development. Furthermore, the concession, with its detailed rules and regulations, stands to add a great deal of transparency to the negotiating process relative to present-day private power market development negotiations in many developing countries. This transparency is bound to encourage competition and reduce the financial risks for would-be developers.

In Argentina, concessions are being applied for rural electrification (UNDP, 1997). In an alternative to the conventional approach of extending the existing electricity grid to remote areas, private purchasers of the concessions are to provide electricity to dispersed rural residences and public facilities (e.g., schools, medical centres, drinking water services, etc.) through a range of energy technologies determined by what the concessionaire considers to be is the least costly. Solar photovoltaic panels, small wind mills, hydraulic micro-turbines, and diesel-driven generators are to compete on the basis of the lowest cost of provided energy.

1.4.3. Innovative Credit and Purchase Arrangements

Innovative financing mechanisms for first cost-sensitive investors can be designed to convert the capital cost into an operating cost, so that payments are aligned with the stream of benefits received. "Microfinancing" (i.e., financial intermediation at the local level) is an effective mechanism for institutions to use in providing households and small businesses with access to capital via loans for small-scale investments under flexible, and often non-traditional, lending conditions, so as to expand the market for sustainable energy systems. If a loan is for a more energy-efficient piece of equipment that produces a stream of monetary savings greater than the stream of loan payments, the borrower realises lower costs. Sometimes, an added benefit is a higher level of energy services obtained from more efficient equipment, leading to more energy services provided with less energy consumption.

To illustrate the importance of such loans, consider, as an example, microfinancing for photovoltaic (PV) systems for lighting and other household activities in rural areas that don't have access to electric utility grids. A World Bank study has shown that, in many instances, PV systems, though capital-intensive, are less costly on a life cycle cost basis than current technologies for providing lighting in many developing countries, when the same levels of services are compared. For example, a 100 Watt PV system providing 12 hours of area lighting each day, 14 hours of task lighting, plus 0.15 kWh of electricity for other loads in rural Indonesia, would have a total levelised cost over a 25-year period of approximately US$14 per month—about one-third less than the currently favoured technology, consisting of 2 kerosene wick lamps, 2 kerosene mantle lamps, and 2 automotive batteries for providing the same level of services. This assessment assumes a 12 percent discount rate, present PV technology, but a mature, two-step distribution system (i.e., manufacturer-to-dealer and dealer-to-customer), with manufacturer and dealer sales of 5,000 and 200 systems per year, respectively (Cabraal *et al.*, 1996).[23] If financing is available to the consumer via a 5-year loan at 12 percent interest and a 30 percent downpayment, the monthly loan repayment rate during this period stands to be less than 10 percent more than what the consumer currently pays for lighting with the conventional technology. Over the remaining 20 years of the life cycle, the cost is likelt to be zero.

An institutional alternative to micro-financing to deal with the capital allocation problem for small-scale investments is to aggregate many small investments under the umbrella of an energy service company (ESCO). For example, investments in energy end-use efficiency may be financed not by energy suppliers or consumers but rather by third-party ESCOs, which already operate in some countries. In return for providing the capital for the equipment investment, the ESCO collects an agreed-upon fraction of energy savings that arise from the investment.

Although many smaller-scale users are willing to pay market prices for sustainable energy technologies, there remains a critical need to set up financing mechanisms that are suited to the small scales of the capital-intensive equipment they seek to purchase. Once appropriate financing mechanisms are set up to support such energy alternatives, users become capable of paying the full costs of their purchases.

1.4.4. Developing Productive Uses (e.g., Creating an Additional Income Stream) for Energy Services

Promoting the development of productive uses (e.g., creating an additional income stream) for energy services can include developing strategies to fully utilise natural resources in order to create additional economic benefits and possibly the establishment of new industries (e.g. food processing and industrial residues for ethanol). New urban industries can create value-added energy generation activities. Such measures may persuade development aid agencies, governments and entrepreneurs to perceive the direct value in promoting sustainable energy policies. In addition, well-designed demonstration projects may also encourage governments to revise obsolete laws and regulations that hinder the development of renewable energy or energy-efficient technologies.

23 *Cabraal, A., M. Cosgrove-Davies, and L. Schaeffer, 1996:* Best Practices for Photovoltaic Household Electrification Programmes—Lessons from Experiences in Selected Countries*, World Bank Technical Paper No. 324, Asia Technical Department Series, World Bank, Washington, DC.*

INSTITUTIONS AND INSTITUTIONAL CHANGE

In recent years, there has been much interest in examining how institutions can affect the pace and direction of economic development (North, 1991; World Bank, 1997). These considerations constitute a new intellectual effort to widen the existing framework of neo-classical economics, which assumes that the state and organisations of civil society are exogenous factors and that "getting the prices right" is the sole factor for economic development. New Institutional Economics (NIE), on the other hand, emphasises the role of governance structures, prevailing norms, learned practices, etc., in shaping economic transactions and their outcomes.

NIE defines institutions as the rules of the game; that is to say, as the humanly devised constraints that structure human interaction. Institutions consist of formal rules, informal constraints, and their enforcement characteristics. Institutions are formed to reduce uncertainty in human exchange. Together with the technology employed, they determine the costs of transacting (and producing). Organisations, by contrast, are the players, the groups of individuals bound by a common purpose and comprising political, economic, social, and educational bodies such, as parties, firms, churches, and schools, respectively. Competition continually forces organisations to invest in skills and knowledge to survive. The kinds of skills and knowledge individuals and their organisations acquire shape evolving perceptions about opportunities and hence the choices that incrementally alter institutions.

Institutional considerations are significant in the study of economies because they help explain why countries with similar macro-economic initial conditions (for instance, Singapore and Bolivia in the 1960s) could end up with dramatically different patterns of economic development. As much as differential access to capital and technology, it is the institutional differences across countries that seem to be important in determining development outcomes. Notably, in most societies, informal rules are slower to change than formal ones and provide legitimacy for the latter. Thus, simply transferring the formal political and economic rules of successful western market economies to developing economies is not a sufficient condition for good economic performance.

NIE suggests, therefore, that privatisation *per se* cannot be a panacea for addressing poor economic performance (North, 1992). What seems more important is creating a relatively stable set of property rights and enforcement to create competitive market conditions. As expressed in a recent World Bank publication: "[M]arkets and governments are complementary: the state is essential for putting in place the appropriate institutional foundations for markets. And government's credibility—the predictability of its rules and policies and the consistency with which they are applied—can be as important for attracting private investment as the content of those rules and policies". (World Bank, 1997).

The insights of NIE are just as pertinent for sustainable energy interventions. For instance, institutional factors could account for many of the distinctive barriers faced by attempts to improve energy efficiency, promote renewables, and implement power sector reform (Reddy, 1991; Philips, 1991; World Bank, 1992b). By and large, exploiting the opportunities available for sustainable energy requires new organisational choices to be made, restructuring of existing patterns of investment and, as discussed earlier, a major shift in attitude about energy from supply to services. For institutional change to take place in these directions, existing informal norms have to be modified to the extent that individuals perceive that they can do better by restructuring exchanges (political or economic).

The three main reasons for institutional change are changes in relative prices (e.g., land/labour or labour/capital), changes in taste, and changes in enforcement that can be affected by altered governance structures or by new external opportunities that present themselves (North, 1991). But the fundamental source of change is learning by entrepreneurs of organisations. While the rate of learning determines the speed of economic change, the kind of learning determines its direction. An important lesson for sustainable energy intervention is therefore Training: energy actors—manufacturers, producers, consumers, policymakers—must gain a proper understanding of the need for sustainable energy, the opportunities available, and the costs of making a transition.

NIE also describes how institutions are path-dependent, a factor that may be important to understand barriers to implementing sustainable energy strategies. Studies of technological change have described how certain societies have experienced technological "lock-in", where they persist in embracing certain designs that may be sub-optimal (one example being the QWERTY keyboard), simply because there are very high transaction costs involved in shifting from the wrong paths once taken. Technological lock-in sets in under the following conditions: large initial fixed costs tend to ensure that per-unit costs of output are reduced, the prevalence of the product causes more people and organisations to become familiar and dependent on it, and other technologies are tied into the original type and adaptive expectations set in (Arthur, 1989). Institutional lock-in refers to the additional condition of uncertainty in imperfect markets and to the fact that existing organisations may depend on the institutional matrix for their endurance, so that they can form a powerful interest group to assure the perpetuation of that institutional structure. Thus, once an economy is on an "inefficient" path that produces stagnation, this can persist because of the nature of path dependence.

Technological lock-in and path dependence have important implications for sustainable energy. Careful evaluation is necessary to ensure that the choices made now—even with advanced and "efficient" technologies and options—do not have adverse consequences later because of the wrong "paths" taken. In developing countries, since investments in energy infrastructure are still at a relatively early stage, path dependence is clearly significant. For instance, large-scale investments in power plant equipment and fuel supply infrastructure for coal may lock out or at least delay the implementation of alternatives, such as combined cycle gas. Similarly, urban zoning that sustains low-density growth or policies that encourage personal transportation options stands to impede future shifts to public transportation, either because the latter investment requirements are too high or because a large number of individuals have already invested in private vehicles.

Institutional path dependence implies additionally that changing existing ways of using energy may require organisational and political innovation. Thus, manufacturers and distributors of conventional energy devices and systems (for example, incandescent lamps, two-stroke engines, and electric water heaters) may resist the introduction and marketing of more efficient end-use technologies (such as compact fluorescent lamps, four-stroke engines,

and solar water heaters). Such resistance may also be manifested among users, government bureaucrats, financial institutions, etc., even in the presence of official policy that encourages energy efficiency (Reddy, 1991).

Alternatively, policies that are too self-restrictive or over-specify terms in contracts can also create conditions that are costly to reverse after acquiring additional experience. For instance, "take-or-pay" contracts with independent power producers in utility regulation may force governments to be locked-into expensive power purchase terms that cannot be easily reversed. An appreciation of the effects of path dependence is, therefore, crucial for policy makers involved with large-scale "stroke-of-the-pen" changes whose consequences may not be foreseen. However, path dependence is not a permanent constraint, and the way to break it would be for new individuals and organisations to form with sufficient bargaining power to challenge the existing institutional framework. Gradually, when organisations with different interests emerge (as a result of dissatisfaction with the performance of existing ones) and relative prices change, enforcement changes are going to be brought about and prevailing institutions are going to become untenable, while new ones form (North, 1992).

In Brazil, large scale generation of fuel ethanol from sugarcane has been initiated as early as 1975 to reduce the counter-dependence on imported oil, to stabilise sugar production in the face of a volatile international sugar market, and to create employment in rural areas. Ethanol is made from sugarcane for use as a neat fuel (100 percent ethanol-fueled cars) and for blending with gasoline (up to 22 percent ethanol). The Brazilian ethanol industry is based on roughly 400 facilities drawing from areas of 5,000 to 50,000 hectares, with cane production carried out by some 60,000 suppliers.

1.5. UNDP'S ROLE TO FACILITATE ENERGY FOR SUSTAINABLE HUMAN DEVELOPMENT

1.5.1. UNDP Development Goals and Energy

Energy is *not* an end in itself, but rather the *means* to achieve the goal of sustainable human development. A sustainable energy strategy can be a crucial instrument in meeting goals of promoting Sustainable Human Development (SHD). As discussed above, energy affects many aspects of sustainable development—economic and social development and growth; the local, national, regional, and global environment; the global climate; a range of social concerns, including poverty, population, health, and gender-related issues; the balance of payments; and prospects for peace. The need for energy services will continue to grow, driven both by growth in populations and the aspirations of people around the world for a better life.

Whether those energy services can be provided and contribute to achieving sustainable development depends very much on the choices the international community makes in the near term. UNDP can play a role in moving in that direction.

1.5.2. UNDP’s Strategies for Sustainable Energy

In 1996 UNDP, through its Energy and Atmosphere Programme (EAP), developed the UNDP Initiative on Sustainable Energy (UNISE) and adopted UNISE as a UNDP corporate policy. UNISE describes how energy relates to UNDP’s thematic areas and programme goals (poverty alleviation, improvement of the situation of women, job creation, environmental protection, and regeneration) and outlines how energy programmes and projects can become instrumental in achieving sustainable development. UNISE is a strategic document to support UNDP country offices in incorporating an energy and development approach into country-level activities.

UNISE has identified the following as key areas of interventions:

- **mobilising support for indigenous capacity building,** so that countries can identify and make use of new approaches and technological opportunities, as well as train entrepreneurs and implement new financing/credit modes;

- **encouraging countries to create a supportive legal, institutional, and regulatory climate** for sustainable energy development, including an investment climate that attracts private capital;
- **contributing to a leapfrogging strategy** through innovative demonstration projects and through promoting the rapid development and dissemination of key technologies for sustainable energy development; and
- **supporting the formulation and implementation of national energy action programmes** linking measures to goals in areas affected by energy system developments.

1.5.3. UNDP's Activities in the Field of Energy

Country programmes: According to a preliminary survey undertaken in 1999, a total of 43 percent (58 countries out of 134 studied) of UNDP field offices have energy components in their Country Cooperation Frameworks (CCFs) and/or Programme Outlines (POs). For example, in Morocco, UNDP, in conjunction with the Ministry of Energy, has launched a programme aimed at providing energy services to rural population through the use of Photovoltaics (PV), solar thermal and improved use of biomass. A microcredit financing mechanism is being employed to deliver these technologies. In Kiribati, UNDP, in collaboration with the Government of Japan, has implemented a project aimed at strengthening the capability of the Solar Energy Company to undertake rural electrification through the use of decentralised solar photovoltaic systems.

Regional/Global programmes: At the global level, UNDP, through its Bureau for Development Policy (BDP), helps initiate innovative pilot activities at the national level, such as *FINESSE* programmes, and contributes to global dialogues in sustainable energy in international forums, such as UNFCCC and CSD. For example, as an input to "Rio + 5", the Special Session of the United Nations General Assembly (UNGASS) that took place in June 1997, UNDP has prepared *Energy After Rio: Prospects and Challenges*. The analysis has concluded that current approaches to energy development are not sustainable and that a fundamental shift is necessary to move away from energy consumption to look at the level of energy services as the indicator of development. At present, UNDP, in co-ordination with UNDESA and the WEC, has established a World Energy Assessment as an input to CSD-9, which is to be held in 2001 to offer a scientific and technical basis in international forums in pursuit of Agenda 21. As follow-up to the Kyoto Protocol, UNDP has initiated capacity-building activities in the Clean Development Mechanisms (CDM) in selected countries to generate local awareness of the opportunities it may present for promoting socio-economic development.

UNDP, jointly with the World Bank, also manages the Energy Sector Management Assistance Programme (ESMAP). The objectives of ESMAP are to conduct sector assessments and develop

FINESSE - LARGE LENDERS PROVIDE LOANS TO SMALL-SCALE ENERGY USERS

The Financing Energy Services for Small-Scale Energy (FINESSE) project is designed to make the financial resources of multilateral lending institutions available to small-scale energy users who often have no means of accessing credit. Under FINESSE, large multilateral lending institutions provide loans "wholesale" to intermediary organisations in developing countries (e.g., development finance institutions, commercial banks, utilities, private sector firms, non-governmental organisations, etc.), who in turn provide them at market rates at the village level.

FINESSE is a joint UNDP/World Bank, US Department of Energy, and Netherlands project. It operates by: a) bundling renewable energy and energy conservation projects into financing packages large enough to attract international lending agency support; b) incorporating such projects into national energy planning decisions; c) selecting appropriate intermediary institutions; and d) providing technical assistance and training. Through FINESSE, the multilateral institutions are able to provide resources to small-scale energy users without incurring high overhead costs in administering small loans, and end users, who might otherwise lack access to credit, can obtain funds.

FINESSE programmes are currently in operational in the Asian and African regions.

overall energy strategies for developing countries requesting such assistance; to provide technical management, policy and institutional assistance in energy; to carry out energy related pre-investment studies in areas not traditionally addressed by World Bank lending (i.e., energy efficiency and renewables); and to stimulate other development institutions to work toward these efforts as well. The studies conducted are primarily in the natural gas and petroleum sectors, and in the household sector. ESMAP has, at various times, helped to lay the groundwork for subsequent World Bank loans. To some extent, ESMAP's work already supports sustainable energy initiatives. UNDP indends to stimulate ESMAP increasingly to work on sustainable energy approaches outlined in UNISE.

The Global Environment Facility: The Global Environment Facility (GEF) supports projects and programmes with global environmental benefits. In the area of climate change, GEF intends to work to expand, facilitate, and aggregate the markets for the needed technologies to reduce greenhouse gas emissions and promote non-carbon alternatives, as well as to improve these technologies' management and utilisation. The emphasis is two-pronged: a) to remove barriers to implementation of climate-friendly, commercially viable technologies, and b) to reduce the cost of prospective technologies that are not yet commercially viable.

GEF is designated as the interim financial mechanism of the UN Framework Convention on Climate Change and other conventions. The GEF is governed by an Executive Committee and has its own Secretariat. UNDP, UNEP, and the World Bank are implementing agencies within the GEF that are mandated to deliver project assistance. As one of the implementing agencies of GEF, UNDP manages a portfolio of climate change programmes involving a number of renewable energy/energy efficiency projects and valued at about US$225 million, with additionally leveraged US$200 million or so in co-financing. In China, for instance, UNDP is working with the Ministry of Agriculture to raise energy efficiency in the rural industrial sector. The project has targeted the Township and Village Enterprises for demonstration projects, involving improved technologies, innovation, maintenance techniques, technical transformation, and staff training. In Brazil, GEF is conducting a pilot demonstration programme to promote the development of electricity cogeneration through advanced technology gasification of wood chips or sugarcane bagasse on a commercial scale. Preliminary studies have indicated that the approach can vastly increase electricity supply in northeastern Brazil at costs below the marginal system costs, provide large rural employment opportunities and potentially fossil fuels in many developing countries. In India, a small-hydro initiative is assisting the government establish 20 commercially viable demonstration projects to use local hydro resources to provide electricity to nearby villages. The energy services these are designed to provide include lighting, heating, agricultural and commercial services, in addition to opportunities for rural employment.

UNDP also manages GEF's Small Grants Programme, which provides grants of up to US$50,000 and other support to community-based groups and non-governmental organisations for a variety of projects which address climate change, biodiversity, and land-use issues. Examples of recent grants awarded under this programme include the installation of solar water heaters in hospitals in Cote d'Ivoire and the promotion of improved woodstoves in Cote d'Ivoire and Zimbabwe.

1.6. CONCLUSIONS

A sustainable energy path to development is not only necessary to ensure the future survival of humanity, but is also a vital aspect of any agenda to eradicate existing poverty. The success of this enterprise, however, is contingent on people's ability to build robust coalitions to promote sustainable energy policies and programmes. At minimum, these need to be organised around the common concern of ensuring the active and coordinated participation of governments, the private sector, and non-governmental organisations, thus mobilising requisite investment funds, technology transfer, management, and training.

Given the present worldwide concern, particularly over the serious environmental and macro-economic problems associated with conventional approaches to energy, developing countries are at a historic moment and can potentially avoid having to retrace the unsustainable energy path followed by developed countries. However, to accomplish this, they must be provided the investments and technological opportunities that allow them to leapfrog to the new generation of cleaner energy technologies. Of course, making capital and technology is not sufficient for achieving sustainable human development; these must be complemented by institutional measures that ensure widespread access to quality energy services for the poor.

Numerous United Nations conferences have identified targets and goals, as well as formulated international agreements, platforms of action, declarations, and resolutions adopting various commitments to promote sustainable development. Energy's role in major global concerns must be recognised and dealt with, if these commitments are to be fulfilled. The leadership must come from governments, with support from inter-governmental, non-governmental organisations, and business. Development cooperation has to include efforts at human capacity building, the formu-lation of legal and institutional frameworks supportive of these developments, and the demonstration of key new technologies in developing country contexts.

2

SPECIAL TOPICS RELATING TO ENERGY AND SUSTAINABLE HUMAN DEVELOPMENT

GENDER AND ENERGY: HOW IS GENDER RELEVANT TO SUSTAINABLE ENERGY POLICIES?

2.1. FACTORS PROMOTING GREATER ATTENTION TO GENDER AND ENERGY

2.1.1. Women Are Particularly Impacted by Lack of Energy for Development

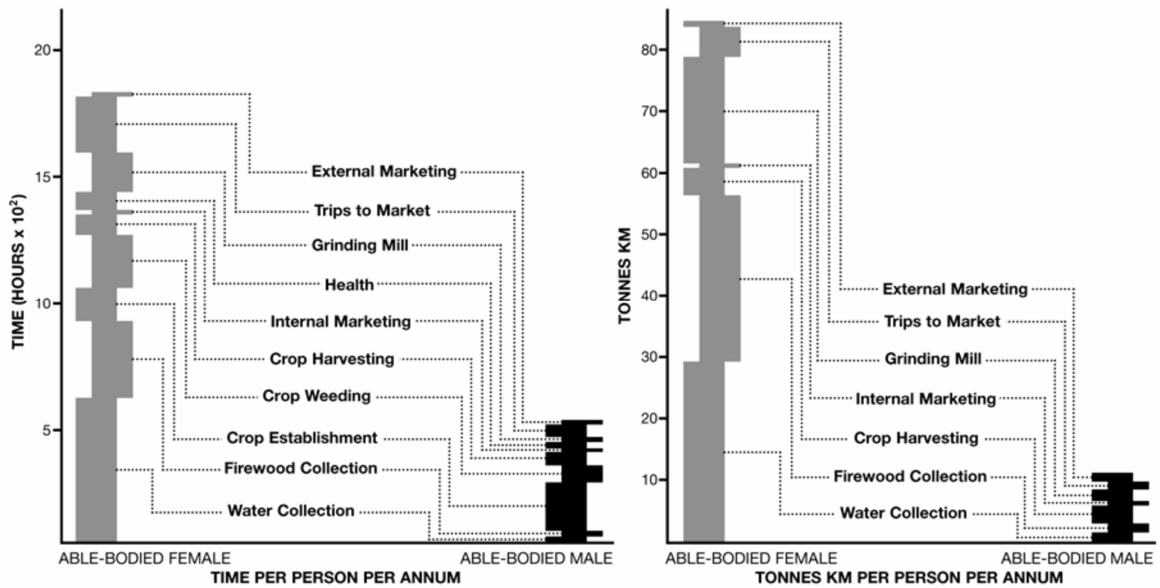
There is no question that energy is a key factor in economic and social development. In the past, energy policies in many developing countries were focused mainly on urban and industrial development, increasing supplies of electricity through construction of large, centralised power plants and long-range electrical distribution lines, and on procuring sufficient supplies of liquid fuels. The needs of rural households, farmers and small businesses were generally less of a priority. Recently, however, a combination of social, environmental, and market pressures have led to the development of new perspectives on energy policies that are promoting greater attention to the social dimensions of energy decision-making, including the disparate gender impacts of national energy priorities.

More than 2 billion people in developing countries, particularly in rural areas, still use traditional fuels, such as wood, charcoal, and dung for cooking, and lack basic modern energy services. This lack of energy services hinders people's efforts to move out of poverty and seriously constrains their ability to improve their living situations, or even to meet their subsistence needs.

People without modern energy services must spend more of their time and physical energy on survival and, therefore, have fewer opportunities to pursue educational and income-generating activities.

Limited access to energy is a problem that has a disproportionate effect on women, especially in rural areas. It is most often women who must expend large amounts of time and physical effort to supply fuel for their households and productive needs, using their own labour to carry heavy loads over increasingly long distances, at great risk to their health and safety (see Figure 1). Other health hazards arise from the fact that women do most of the cooking. They and their young children are exposed to large amounts of smoke and particulates from indoor fires and suffer from a number of respiratory diseases. Greater attention to the needs and concerns of women in these areas could help governments promote overall development goals like poverty alleviation, employment, health, and education through improved energy policies.

FIGURE 1. RURAL TRANSPORT ACTIVITIES BY MALES AND FEMALES IN TANZANIA



Source: UNDP, 1997.

2.1.2. Sustainable Development Requires Greater Social Equity

One major factor influencing current attitudes towards energy is a growing acceptance of the need for sustainable development policies. The 1992 UN Conference on Environment and Development led to international recognition of the need to balance economic growth with concerns for social equity and environmental protection. Extension of the benefits of development to all people, men and women, is fundamental to fulfilment of the social equity objectives of sustainable development.

Although women's roles vary according to their country, income level, ethnicity, age and social status, women throughout the world continue to have fewer options and opportunities than men. In many countries, women face overt inequalities, marginalisation, and discriminatory practices. In 1995, the Fourth World Conference on Women, held in Beijing, emphasised the vital role of women in sustainable development and the need to promote greater overall development opportunities for women. With regard to energy, the Beijing Platform for Action called on governments to support the development of equal access for women to sustainable and affordable energy technologies, including renewable energy efficiency technologies, through participatory needs assessment, energy planning and policy formulation at local and national levels.

Attention to social equity concerns requires energy experts to initiate new types of analyses regarding needs and priorities of end users and to accumulate more extensive data on how people actually use energy. Greater understanding of the differing roles of men and women in particular cultures, in different locales, and at different income levels, can help enhance the effectiveness of energy projects, and development programmes as a whole, particularly in rural areas.

2.1.3. Differing Roles of Men and Women Affect Their Energy Needs and Concerns

The differing work and social roles of men and women are culturally established and vary from place to place. The term "gender" refers to these socially-defined differences between men and women, as opposed to fundamental biological differences. Gender roles may also change as countries and communities pursue social and economic equity through development programmes.

Energy policies and projects by themselves will not change the roles of men and women in a particular society, but they can be used as entry points for promoting greater fairness in the allocation of opportunities and resources. Given the critical role that women play as energy managers in developing countries, greater sensitivity to gender disparities, and in particular to the concerns of women, could improve the effectiveness of energy programmes. Although the application of gender sensitivity to energy policies has not thus far been a regular exercise, some efforts have been made to analyse the impacts of traditional energy usage on the situation of women. These efforts have revealed several crucial aspects of how energy can affect the lives of women both positively and negatively.

Women Need Energy for Household and Productive Uses

In many areas, women are responsible for gathering fuels needed for performing household duties. Widespread reliance on fuel wood and dung increases the scarcity of available biomass resources, imposing further burdens on women and children, who must spend more time and energy collecting and carrying fuels. In many developing countries, girls are involved in traditional women's chores from an early age; long hours spent collecting fuel and water leave them little time or opportunity for education.

Reduced drudgery for women and increased access to non-polluting power for lighting and other household and productive purposes can have dramatic effects on their levels of education, literacy, nutrition, health and involvement in community activities. Moreover, as women become more able to participate in political and economic affairs, they will be more able to seek their own solutions to economic and social problems, with less external assistance.

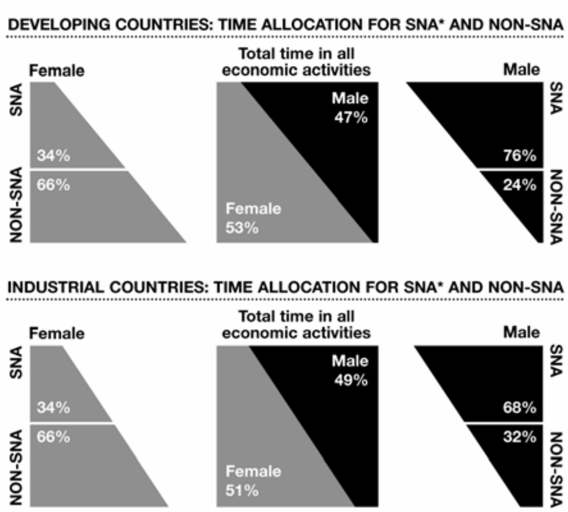
Inefficient Use of Traditional Fuels Negatively Affects Human Health

Biomass fuels account for 80 percent of all household fuel consumption in developing countries, most of it for cooking, which is done primarily by women. As a result, women and their young children are exposed to high levels of indoor air pollution. Cooking fires are generally inefficient and produce a number of pollutants associated with incomplete combustion. Pollutants found in smoke from these fires include particulates, carbon monoxide, benzene, and formaldehyde. In some countries where coal are used as household fuel, more serious adverse effects on health are evident. Exposure to these pollutants can lead to acute respiratory infections, chronic obstructive lung diseases, low birth weights, lung cancer and eye problems.

Women's Time and Contributions Are Often Undervalued

Women's work in sustaining their households, families and communities has generally been ignored in calculations of economic policy because it does not fall within formal, monetarised market activities. Women's income-producing activities are often unrecognised as well, because they take place in the "informal" sector, and are, in many cases, performed on a part-time or irregular basis, often in conjunction with household activities. (see Figure 2). The lack of value placed on women's time and work tends to makes it difficult to implement policies designed to reduce their drudgery. For example, improved stove programmes in rural areas in China have been more successful than in India largely because of greater income-earning opportunities for women. Where women have few opportunities to earn cash incomes, there is little incentive to reduce the time and effort they expend in collecting fuel by adopting improved stoves (Nathan, 1997). This invisibility of women's labour perpetuates policies that reinforce subordinate roles for women.

FIGURE 2. MOST OF WOMEN'S WORK REMAINS UNPAID, UNRECOGNISED, AND UNDERVALUED



** SNA (System of National Accounts) corresponds, in this case, to work recognised and included in official national statistics.*

Source: UNDP HDR, 1995

Diversifying Energy Choices Creates More Opportunities for Income-Generating Activities

Lack of energy services limits women's productive and community development activities. Lack of safe and reliable lighting in the evening makes it difficult for women to pursue educational and entrepreneurial opportunities, or to perform essential child care and community responsibilities. In many cases, women's informal income-generating activities are energy-intensive (see Table 1), and could be made more profitable if better energy choices were available. For example, when a group of women from Sonara, Mexico, evaluated possible income-generating projects to support their families, they chose a bakery project. Because they had an opportunity to invest in solar ovens, they saved time and fuel costs, and were able to make enough profits to repay the loans for the ovens and also pay themselves salaries (Stone, 1998).

2.1.4. Women Can Be Important Agents for Environmental Protection

International concerns about climate change have focused considerable attention on ways of reducing emissions of carbon dioxide caused by burning fuels for energy production. Although historically most of the increased accumulation of greenhouse gases in the atmosphere has been caused by industrialised countries, many of the poorest countries are likely to be most affected by the potential impacts of climate change, such as drought, desertification, flooding, and ecosystem disruption.

Depletion of traditional fuel sources in some areas, together with substantial projected increases in energy usage in developing countries, have prompted calls for new energy models that support sustainable development, emphasising efficiency, cleaner fuels, and adoption of alternative energy technologies that use solar, wind, microhydro, and biomass resources. Since in many developing countries women currently play a key role as collectors and managers of traditional fuels, a transition to less polluting fuels and technologies in these countries will require the active engagement of women in their roles as energy providers and consumers. However, in many countries, women have been effectively excluded from participation in policy formulation and decision-making processes due to their low political and economic status.

TABLE 1. SAMPLE ENERGY-INTENSIVE, SMALL-SCALE ENTERPRISES OPERATED BY WOMEN

ENTERPRISE	COMMENTS
Beer brewing	25% of fuelwood used in Ouagadougou; main source of income for 54% of women in surveyed Tanzanian village/ 1 kg wood/1 litre beer
Rice parboiling	15-20% of firewood in some districts of Bangladesh
Tortilla making	1 kg wood/0.4 kg tortillas
Bakeries	Wood is 25% of bread production costs in Kenya; 80% of those in Peru (0.8-1.5 kg wood / kg bread)
Shea butter production	60% of cash income for women in parts of cash
Fish smoking	40,000 tonnes wood year in Mopti, Mali; 1.5-12 kg wood/kg smoked fish; fuel is 40% of processing costs
Palm oil processing	Extremely arduous, requiring lifting and moving heavy containers of liquid; 0.43 kg wood/l litre oil; 55% of income of female-headed households in Cameroons study
Gari (cassava) processing	Women in 2 Nigerian districts earned $171/year each; 1kg wood/4 kg gari
Hotels, restaurants, guest houses, tea shops	816,865 tonnes wood annually in Nepal
Food preparation and processing	13% of total household income in Nepal; 48% of mothers in Dangbe district in Ghana engaged: 49% of women in one village in Burkina Faso
Pottery making	Men and women both have distinctive roles in different processes
Soap making	Fuel is high percentage of production

Sources: BEST, 1988; Gordon, 1986.

Scarcity of fuel wood in some areas is being caused by land clearing, deforestation, desertification and overuse. In addition, privatisation of land has in some cases deprived women of traditional benefits from what were previously communally-managed resources available to all. Yet, for centuries women have managed forests and used forest products for fuel and fodder, and have developed knowledge of sustainable practices that can represent an important contribution to effective resource management. In some places, women have become strong advocates for greater environmental protection effort, as in the well-known Chipko movement in India.

2.1.5. National Energy Priorities Affect Gender Issues

Energy policies are related to many aspects of a country's economic, social and political situation. Fuel choices, natural resource availability, generating capacity, energy delivery systems, and consumption patterns all have impacts on development that are not generally analysed.

Overall development planning involves complex questions about what sorts of economic, social and political changes are desirable, and how such changes can be accomplished. The actual consequences of specific development interventions are difficult to predict, given the many local, national, and international conditions influencing communities. Moreover, changes generally have differing effects on people, depending on their income level, class, age, race, and gender.

Although most policy-makers view energy policies as gender-neutral, the fact is that men and women are affected differently by energy policies wherever their work roles differ, as is the case in many developing countries. Careful attention to these differing interests is essential for understanding energy markets and consumer needs, for reducing the negative impacts of current energy consumption patterns, and for achieving equitable distribution of energy services. When all stakeholders, including women, are involved, the chances of success and of equitable outcomes are likely to be enhanced.

In many countries, internal and external economic pressures are driving efforts for increased liberalisation and competition in the energy sector. A more market-oriented approach to the energy sector could tend to promote greater understanding of consumer needs for energy services rather than simply working to increase supply. Since women represent a large percentage of energy consumers in rural areas in developing countries, understanding how their priorities might differ from those of men will be increasingly significant for those who are involved in marketing energy services. For example, an evaluation of a biogas programme in India showed that even when men and women both indicated time-saving as a positive feature of substituting biogas for fuel wood, there were differences behind their interpretations of the criteria. Women saw time-saving in terms of reduced fuel collection and food preparation, which would allow them more time to be with their families, whereas men saw time-saving in terms of faster cooking and more timely availability of meals. There were also differences in the criteria of fuel selection. Women valued smoke reduction both for the health benefits and the decreased drudgery of cleaning smoky pots. Men placed a higher value on savings of fuel and money (Dutta, *et al.* 1997).

Although attention to women's priorities as consumers can provide important benefits, past experiences with liberalisation of the energy sector indicate that there could be some negative consequences, often in the form of increases in energy prices that create particular difficulties for people living in poverty. Since women are disproportionately affected by poverty, this negative implication would tend to affect more women than men.

2.2. KEY CONSIDERATIONS FOR GENDER-SENSITIVE ENERGY PLANNING

2.2.1. Stakeholder Participation Can Improve Gender Sensitivity in Energy Policies

In many developing countries, there is clearly room for improving the effectiveness of the energy sector in meeting the needs of growing populations. There is also a growing awareness that more appropriate provision of energy services may require a greater understanding of social conditions, in addition to technical skills. To be successful, sustainable energy planning will require involvement of the stakeholders affected by energy programmes—both men and women. Top-down approaches to introducing new technologies in rural areas have generally met with limited success.

Planning processes that involve widespread participation and consultation can help all parties to understand and address current constraints affecting energy sector programmes, including those related to the status of women. Since, by virtue of their traditional roles, women are often the primary users of fuels and energy appliances, it makes sense that they should be consulted concerning their assessments of energy problems and their suggestions for solutions. However, since there are often cultural and practical constraints limiting women's ability to participate in consultative processes, special efforts generally need to be made if they are to be included.

Some energy projects designed to introduce new efficiency measures or renewable technologies in developing countries have been unsuccessful, in part, because the projects and technologies have been designed by engineers (often from industrialised countries) with little or no input from expected users. Acceptance of new technologies can be enhanced if users, including women, participate in the design of energy projects and adaptation of technologies to fit local needs, preferences and priorities.

Solar cooker projects have been initiated in a number of developing countries, and in many cases women have rejected them, for quite valid reasons, despite the fact that their use can reduce firewood consumption and harmful emissions. For instance, one solar cooker project was set up in a wood-scarce area in South Africa based on consultations with the local and tribal authorities, who were all men. After the authorities gave their agreement, the women were invited to a meeting to have the project explained. Of those women who agreed to participate in the project, about 60 percent used them irregularly and about 30 percent used them more than twice a week. When the project workers left the area, the women stopped using the stoves. They gave the following reasons: that cooking in the middle of the day was too hot; that it was not convenient because the household ate its main meal in the evening; and that the wood fires provided warmth and a meeting place (Annecke, 1999).

While there have been a number of attempts in different countries to introduce more efficient stoves, the most successful efforts have been those where women users were themselves involved in the design stage. These are some of the comments from women involved in an urban stoves programme in Addis Ababa, Ethiopia:

"This stove is good. You can take it anywhere." "I'd like to have a door to regulate the winds." "I'm afraid it will topple over. The legs seem unstable." "What about the pot support? Small pots will slip in." "Could something be done to hold the wood in place?" "This stove will not last as long as a charcoal stove; it is made to burn firewood and if you char the embers with water it is bound to rust." "I think it should accommodate the big absit pot, since we use that to prepare our bread dough every few days." (ILO, 1987)

Educating women, and women's organisations, about energy policy issues can increase their ability to contribute to energy solutions, including the adoption of new, cleaner fuels and equipment. Women in poor households, especially in rural communities, have had very little access to information about available energy options. Analysis of the differences in how men and women acquire information and make various kinds of energy-related decisions can help energy planners and suppliers reach their target audiences more effectively.

Women who are educated about energy alternatives can also play important roles as educators and activists concerning energy efficiency, renewable energy sources, and better uses of traditional fuels. For example, AWAKE, a non-governmental organisation based in Bangalore, India, is run by women to assist other women entrepreneurs in improving their businesses. This group has organised one-week training courses in energy conservation specifically aimed at informing women entrepreneurs. While there are other courses available on energy conservation, the participation by women entrepreneurs in these tends to be low, because of the industrial sectors selected, the training organisations involved, the predominance of men in the entrepreneurial associations, and the ways of advertising the courses (Anon, 1998).

Networking and organisation of women with regard to shared energy concerns can build social institutions that promote the advancement of women and greater fulfilment of their human potential. For example, in 1998, a Gender Equity in the Oil and Gas Sector – Pakistan Petroleum Women's Network was established to support women professionals working in the sector. There are about 669 women out of a total workforce of 34,000. These women face many problems within their working environment. The women report that being able to discuss their problems and to work on solutions with other women is an invaluable resource. Their self-confidence is raised and they feel it contributes to improved job performance and satisfaction (Lele, 1998).

2.2.2. Gender Dimensions of Rural Electrification and Energy Accessibility

In certain countries, there are higher percentages of women than men in rural areas, partly because of limited employment opportunities in the formal sector and consequent migrations by men seeking work in urban areas or industrial zones. Besides reducing the hardships endured by poor rural women, greater energy availability in these rural areas could potentially support new areas of economic growth, and possibly reduce male migrations.

Rural electrification poses special problems for energy planning, because of long distances from energy production plants and consequent distribution challenges. Most national efforts to provide access to electricity in rural areas have not been sufficient to meet the needs of rural populations. Dispersed and relatively low overall energy demand levels in rural areas, plus lack of financial resources to pay for grid extension programmes, have restricted access to electricity for many people. Due to the costs of extending transmission lines over long distances, much of the current need for energy services is unlikely to be met by means of grid extension within the foreseeable future. However, decentralised, small-scale projects promoting energy efficiency and renewable energy technologies could help address unmet energy needs, while at the same time reducing adverse environmental impacts.

There is currently very little information available about the actual impacts of electrification on people living in rural areas, and about the ways in which men and women may be affected differently by electrification programmes. There is some evidence, however, that specifically targeted credit facilities and extended financing arrangements can allow more poor women the possibility of access to electrical services. Women's access to credit has sometimes been restricted by laws or banking customs requiring collateral or cosigners, or because women lack the skills to comply with banking procedures. Electrification programmes that include appropriate financing facilities accessible to poor customers, especially women, would be more beneficial to women than programmes requiring large cash outlays.

An emphasis on providing choices and accessible financing arrangements would help allow women and men themselves to define what they want as energy consumers, rather than having outside experts promote new technologies as simple technical solutions to what are, in fact, complex social and economic situations. Women in rural areas are particularly in need of access to cleaner fuels and better cooking equipment, as well as more efficient and less-polluting technologies that can support income-producing activities. Men, however, sometimes have different priorities. One study indicated that since men usually make decisions about major expenses within the household, use of electrical equipment tends to reflect their priorities. Where electricity within the household was limited to one light bulb, that tended to be placed in the living area and not in the kitchen (Wamukonya & Davis, 1999).

There are a variety of different decentralised energy technologies that could serve to complement grid extension efforts. If women were encouraged to engage in entrepreneurial activities related to energy services and technology distribution, they could play an important role in disseminating alternatives that address rural energy needs. Since they would be familiar with the specific hardships women experience due to lack of energy services, women entrepreneurs would be in a good position to reach other women and explain the desirability of various energy alternatives. They would probably need training, however, in entrepreneurial and business management skills. Women have sometimes been excluded from training programmes as a result of traditional limitations on their travel away from home, lack of child care, illiteracy, conflicting responsibilities, or cultural biases.

Projects specifically targeted towards women can potentially provide greater benefits for women, as well as for rural electrification efforts. Within the context of energy projects, opportunities for women to gain access to technical information and skills training can boost their ability to engage in productive, income-producing activities. For example, the Vietnam Women's Union has been active in the promotion of solar home systems in rural areas through its extensive network of 11 million members. Many of the local technicians responsible for installing the solar home systems are women (Everts and Schulte, 1997). Another rural electrification project in Ayapata, Peru, is run by a democratic electricity co-operative of community members. Women are active in this committee and their influence in decision-making processes has been able to ensure that the end uses favour their needs. For example, they have installed a grain mill to alleviate one of their most laborious tasks, and street lighting to improve safety (Oliveros, 1997).

2.2.3. Including Gender Concerns in Energy Decision-Making

The Beijing Platform for Action promoted the concept of mainstreaming a gender perspective in all government policies and programmes. Mainstreaming involves assessing the implications of all planned actions with regard to their effects on men and women, before decisions are made. In this way, women's concerns and experiences, as well as men's, can be included in the design, implementation, monitoring and evaluation of policies and programmes.

The concept of mainstreaming has emerged as the primary strategy for promoting gender equality, in part, because past projects particularly targeted at women were generally not effective. Many of these projects were marginalised and underfunded, and did not challenge the societal and institutional structures that maintain women in subordinate roles. Development analysts have begun to recognise that what is needed is a broader look at the relative positions of men and women in different societies in order to understand specific gender concerns, and how they can be addressed.

One of the keys to mainstreaming is accumulation of meaningful data about how men and women perceive their energy and general development needs, and what actions they perceive as most beneficial. Inadequate data, or assumptions made about women in communities by planners who are not familiar with their actual lifestyles, can result in misleading conclusions and ineffective interventions.

Gathering economic and social data documenting variations between the experiences of men and women can provide useful information on which to base broad development policies as well as particular projects. Such disaggregated data is not generally available now. Accumulating it can help demonstrate existing disparities between men and women at different income levels, and provide the basis for more targeted interventions.

Evaluation and monitoring of ongoing energy programmes and policies from a gender perspective can focus attention on which approaches have been successful and which have not. Where particular constraints are seen to be affecting women in ways that are different from men's experiences, this information can be used to improve future planning.

In the past, many energy projects looked at the household as the basic unit for non-industrial energy planning, without taking into account the extent to which men and women in certain areas lead very separate lives with distinct financial resources and responsibilities. They also overlooked the fact that many income-generating activities, especially those undertaken by women, are based in the household (Clancy, 1999). Women, who might be the ones most interested in acquiring new energy equipment, might lack the capital to buy it and be unable to obtain it from husbands who have quite different priorities for major household expenses. Since information on these differences is often not readily available, however, and is sometimes difficult to obtain, some effort will be needed to accumulate necessary data.

Women need opportunities to speak for themselves about what they want. For example, they may not see maximising profit as their highest priority. In one situation involving a bakery project, the donor wanted the women to run two shifts a day and double their profits, but the women refused because of negative personal and social consequences (Annecke, 1999).

Male community leaders, and perhaps even some women, may be resistant to special consultation processes with women that are directed by outside experts. Locally-based women's organisations, research institutes, and gender specialists can assist policy-makers by gathering and disseminating specific information about local practices, problems, and ideas for energy solutions. Extension services in rural areas can serve a similar role, although more female extension agents are likely to be needed in order to establish good connections with community women. Overall, male energy planners and policy-makers need to be sensitised to gender issues so that they can understand and support special measures designed to encourage women's participation in the design and implementation of energy policies.

2.2.4. Tackling Priority Issues of Concern to Women

It is important to note that the object of energy planning is not to add a special component on women, but to think in a different way about what kinds of projects to undertake in view of local gender issues. In some cases, however, pursuing this objective may lead to women-targeted energy initiatives. This is because current ways of using energy often adversely affect more women than men and, in some cases, contribute to limitations on women's engagement in other activities, as discussed in section 2.1.3. To tackle these issues, the following actions could be considered:

Mitigating Negative Impacts on Health

National policies that diversify women's choices of household energy sources and promote access to cleaner fuels, as well as more efficient cooking equipment, can have significant benefits in terms of the health of women and children in developing countries. This requires not only appropriate energy policies, but also cross-sectoral co-ordination among concerned entities, such as ministries of health and the environment.

In many rural households and communities, people often have very limited information on alternative energy technologies or how to use them. This presents a barrier to introduction of, and demand for, new energy options. Efforts are required to make information about technology options—such as improved cook-stoves, as well as modern fuels, e.g., Liquid Petroleum Gases (LPG) and biomass-derived fuels—and the technologies themselves more widely available and accessible to people in rural areas. Then, they would be better able to make their own choices out of a range of possible options.

Reducing Drudgery in Women's Lives

Promoting access to modern energy services is a critical input for reducing the drudgery in women's lives and increasing women's productivity and economic power. It can enhance possibilities of new opportunities for education, health, personal development, and entrepreneurial activities. If access to modern energy services were ensured, there would be a good possibility that women would be able to improve their situation by using such things as improved cook-stoves, water pumping systems, cooking gas, etc.

Rural electrification can also be one very effective means of providing modern energy services to women in rural areas, if coupled with a set of appropriate measures that are designed to address the needs of people in poverty who have not enjoyed the benefits of grid-based electricity. While the majority of people in rural areas in developing countries currently lack access to grid electricity, there are a range of options available to deliver energy and electricity services at lower costs than conventional energy sources. These options include renewable energy based technologies at household, community and district levels. Innovative strategies are required to focus more on the provision of energy services to women and people in poverty. For example, in South Africa, the rural electrification programme uses concessions granted to private companies as a way of extending its reach to remote areas. In Argentina, concessions are used to aggregate the market for small-scale systems, thereby facilitating the realisation of economies of scale and reductions in transaction costs per customer. In this process, exclusive market rights in a specified region are given to a single supplier, based on competitive bidding processes, over a certain period of time under specific service agreements. More analysis on sustainable policy strategies is detailed in a later chapter, "*Promoting Institutional Change for Sustainable Energy.*"

Promoting Income-Generating Activities

Technology alternatives that enhance economic activities are the key to sustainability. There are few incentives for women to engage in activities if they do not offer a sustainable income base. But there has been little planning or policy focus on energy for productive uses by women.

Some income-generating projects involve energy itself as a product. For example, in Swaziland and Malawi, biomass briquette pilot projects have involved women in producing fuel for their own use as well as for sale. Other types of income-generating activities, such as food production and processing, require affordable and readily-available energy sources. Both types of activities require a reliable means of transportation to markets.

Decentralised approaches to energy supply open up more opportunities for women engaged in income-productive activities. The challenge is to encourage women and their organisations to become more effective entrepreneurs, including energy entrepreneurs. Since women's businesses tend to be small-scale, labour-intensive and limited to the informal sector, strategic assistance with skills training and access to credit could help small women entrepreneurs improve or expand their businesses. The best entry point for training and supporting women in entrepreneurial activities is through already-organised women's groups that come together for collective productive purposes. Once trained, individuals can break away to pursue separate business opportunities. It is essential, however, to design projects with the potential for private sector development. It is also best to target people already involved in income-generating activities.

2.2.5. Incorporating Women's Concerns Into Energy Projects

Problem Identification: When energy problems and objectives are identified by government officials and energy planners, is the analysis based on information supplied only by experts, or does it take into account inputs from stakeholders and end users, including community women? Are all income groups represented? Consultations with women's groups, and accumulation of gender-specific data, can help identify problems that might otherwise not be recognised or addressed.

Project Design: Men and women may take different approaches to energy projects because their work is different, because they are affected differently by existing circumstances, and because they experience different constraints in terms of access to land, resources, credit, collateral, political influence, training, employment opportunities, and education. Are women, as well as men, invited to participate in planning and design processes? This can enhance the overall effectiveness of energy projects and the fairness of the chosen objectives.

Implementation: Do the organisations involved in implementing the project have gender experts and/or female staff on their teams? There may be practical pressures and societal constraints that limit the ability of women to participate in, or benefit from, project activities. In some cases, special efforts may be needed to encourage women's participation, or to include women in training programmes and learning opportunities.

Monitoring and Evaluation: Who determines whether or not a project is successful, and what criteria do they use for evaluation? Assessments should incorporate the views of participants and end users, both men and women. Community women may have very different perspectives than government officials or energy consultants, but may not have adequate opportunities to express their views. In some cases, it might be useful to conduct separate interview sessions, since women without men present might feel free to reveal concerns they would not express in mixed company.

2.2.6. UNDP Initiatives on Sustainable Energy and Women

Access to sustainable energy services is an essential condition for achieving the key development objectives identified by UNDP: eliminating poverty, supporting income-generating opportunities and sustainable livelihoods, protecting the environment, and advancing the status of women. In 1997, UNDP published *Energy After Rio: Prospects and Challenges,* a review of progress in implementing sustainable energy policies. This publication specifically addresses the relationship between women and sustainable energy strategies and concludes that a new sustainable energy paradigm would facilitate the inclusion of women's concerns in energy decision-making.

More recently, UNDP has been preparing a *World Energy Assessment* report that expands on the relationship between energy and social issues and highlights the strategic advantages of using energy as an entry point for improving the status of women. This publication is being prepared in connection with the ninth session of the UN Commission on Sustainable Development, which will be held in 2001 and which will focus on energy, atmosphere, and transport issues.

In terms of substantive activities, UNDP's Initiative for Sustainable Energy (UNISE) is a corporate policy that examines the linkages between energy and socio-economic development. This initiative is designed to suggest alternative approaches for using energy as an instrument for achieving established human development goals, including gender equality. UNISE will assist and support UNDP country offices and national governments in implementing sustainable energy activities.

UNDP as an institution has committed itself to mainstreaming gender concerns and to promoting greater gender equality through its projects and programmes. In an effort to increase general awareness about the relevance of gender issues in development policies, UNDP has established a Gender in Development Programme (GIDP) within the Bureau for Policy Development. This programme facilitates capacity building for gender mainstreaming in UNDP's assistance programmes. The emphasis is on requirements for institutional change to promote gender equality as well as potential approaches to gender-sensitive design.

Following the Beijing conference, UNDP determined that 20 percent of all programme financing should be directed towards women and development. UNDP's Sustainable Energy Global Programme has committed core resources to promote energy as an instrument for socio-economic development, with one focus being on the linkages between women and sustainable energy policies.

UNDP's Energy and Atmosphere Programme is currently coordinating a project entitled "Energy and Women: Generating Opportunities for Development," in collaboration with UNDP country offices and the Regional Bureau for Africa. There are four main objectives of the Energy and Women project: *(i)* to provide an analytic framework for determining the elements of successful sustainable energy projects that benefit women; *(ii)* to network with a wide range of interested parties in order to share information, and to conduct training and advocacy activities; *(iii)* to support sustainable energy pilot projects designed to generate income-earning opportunities for women; and *(iv)* to document lessons learned and impacts of activities through monitoring and evaluation. The Energy and Women project will also undertake analytic studies on lessons learned from past energy projects, and on the role of microcredit schemes in funding user acquisition of new energy technologies.

The geographical focus of the Energy and Women project is on Africa, where large numbers of people lack modern energy services and where there is great potential for utilising renewable energy resources. The first of three planned regional workshops was held in June 1999 in Pretoria, South Africa. It was attended by country representatives from Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, and Zimbabwe. In preparation for the first regional workshop, participating countries conducted national consultations or surveys on the particular energy situation in each country, especially in relation to women's development needs and priorities. The object was to identify key energy bottlenecks and constraints, to discuss ways to support training and capacity building on women and sustainable energy, and to identify recommended activities involving women, energy systems and entrepreneurship. Some of the common concerns identified in the country reports are listed below.

- Lack of energy services creates particular hardships for women, especially in rural areas.
- Energy planning processes, policies and projects generally have not been gender-sensitive.
- National energy plans need to focus more on rural electrification and to be co-ordinated better with other policies, such as those on land use, forestry, and women's development needs.
- Better analysis is needed regarding past and current energy projects and policies because, too often, pilot projects have simply been discontinued and new ones begun without consideration of lessons learned from what was tried before.
- Participatory approaches are needed in energy project planning.
- Education and training of women is needed to increase their role in energy plans and projects.
- More public information is needed about possible energy options.
- Better affordability and financing arrangements are essential for project continuity, especially credit for women.

2.3. CONCLUSIONS

Although until recently gender issues were not considered particularly relevant to the establishment of energy policies and programmes, it is now apparent that societal pressures for greater gender equality and for more sustainable and effective energy systems can be mutually reinforcing. Energy interventions can become more effective when they are responsive to the needs of different users in differing conditions. Reaching this goal will require changes in how energy programmes are formulated and implemented, in how energy decisions are made, and in who is involved in making those decisions. A more participatory approach to energy policy decisions will allow both men and women in affected communities to be engaged in defining energy problems and in implementing appropriate solutions. Better data collection and analysis designed to reflect gender concerns is also essential.

In many cases, however, special attention should be given to the situation of women in developing countries because they are more affected then men by negative consequences of using traditional energy sources, particularly by indoor air pollution. Better data collection and analysis designed to reflect the differing concerns and needs of men and women is essential in order to effectively achieve sustainable development objectives.

Since access to modern energy services is so critical to the achievement of development goals, UNDP is working to assist developing countries in choosing energy investments that are environmentally responsible as well as socially equitable. Women can play an important role in the adoption of new sustainable energy technologies, but only if they have the opportunities and resources necessary to allow them to participate in the formulation and implementation of energy policies.

CASE EXAMPLES

#1. Beyond Project Boundaries. Improving Gender Impacts of Village Micro-Hydro Schemes.

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This article reviews the gender impact of village-level microhydro projects in Sri Lanka. It suggests how the benefit to women of such projects could be increased, by "doing the project better" and by broadening and deepening its effects beyond the project boundary.

Gender Aspects of the Impact of Sustainable Energy Projects

Gender impacts of decentralised, renewable energy projects can be addressed at two levels: within the project "by doing it better", and by "broadening and deepening" beneficiary impact through the socio-economic linkages brought about by such projects. The latter involves giving greater attention to women's income-generating activities (both beneficiaries and non-beneficiaries).

To maximise beneficial impact, energy projects (particularly those that promote renewable, decentralised supplies) need to take gender-differentiated needs into account. Gender is also significant for the efficacy of operation and maintenance (O&M), and for the sustainability of the energy supply—which are both determined by who is involved and trained. Lastly, energy, because of its links with development, necessitates an analysis of gender within a wider market context.

The wider analysis of gender brings out two points. First, to achieve a more gender-balanced impact, sustainable energy projects must expand their focus from project-specific benefits to broader multiplier effects, which arise from productive activities that generate income. This can also bridge the "exclusion gap" between beneficiary and non-beneficiary and allow greater numbers to benefit. Secondly, possibly to a lesser extent, this implies that any saving resulting from the switch to an appropriate renewable energy alternative (e.g., income that used to be spent on other energy sources, such as kerosene oil) should be reoriented toward productive use. This article argues for a wider perspective on impacts, expanding from project-level impact to a perspective emphasising multi-disciplinary, sectoral and institutional links in renewable energy projects. Such a perspective will also bring into focus women's involvement in informal sector activities that provide energy services for productive (income-generating) end-use activities. Such projects can achieve greater positive impacts on gender relationships by moving from a supply focus towards one of stimulating greater productive use of energy (as against only consumptive use, such as lighting).

The Energy Scenario in Sri Lanka

In Sri Lanka, as in many developing countries, resource constraints include energy poverty.

Communities, particularly rural ones, have little access to reliable energy sources, except biomass energy for household use. Women are particularly vulnerable to invisibility by energy planners and decision-makers as their needs—both productive and reproductive—are easily overlooked by assumptions of gender neutrality.

At a national level, the Sri Lankan energy scenario is characterised by a high dependence on large hydropower reservoir-based supplies. This has increasingly exposed the national supply system to power shortfalls brought about by drought, annual demand growth rates of approximately 10 percent, and poor decision-making. This "energy crisis", together with pressures on government expenditure and the fact that priority is given to the demands for industrial power, acts as a constraint on any rapid household electrification in the short and medium term. Also, phased State rural electrification schemes—characteristically high-cost and low-return—have been financed by foreign bank loans. With current household electrification figures at only 42 percent of all households, the prospects for many rural households (about 65 percent of the population) of receiving grid electricity are bleak. The energy plan for Sri Lanka should include a path towards an optimal mix of thermal, large hydro and renewable energy resources. Microhydro projects, functioning as community level and decentralised power resources, are a significant step towards this scenario. They also offer a decentralised supply option, which is locally manageable, and which can be aimed at identified specific needs. They have a great potential to allow gender into energy services and into wider developmental issues.

Microhydro Projects in Sri Lanka

Village Microhydro projects have been undertaken by Intermediate Technology Development Group (ITDG) since 1991. These have sought to prove that village-level communities are able to successfully harness and use their energy resources to meet their energy needs and to raise their living standards. ITDG has implemented "demonstration" projects, assisted in setting up the services required for this sector through training and monitoring, and worked with government institutions for the incorporation of renewable energy issues in national energy policy.

Projects are usually initiated by individuals, usually male innovators, from communities interested in accessing alternative energy supplies for their village. The benefit is primarily—and often exclusively—lighting, although efforts to develop and test other end uses, such as rice mills and battery charging units, are currently ongoing. Village microhydros are community owned and operated, rather than private enterprise initiatives. The following section looks at the gender-related impacts of such community-level projects, and how such impacts could be broadened and deepened. The analysis is based on a sample study, conducted by the author, of five village hydro project sites in which 150 men and women were interviewed, both from households that were connected to microhydro power (Chhs) and from those that were not (unconnected households or Uchhs).

Project-Level Impacts of Village Microhydro Projects

Project impacts include those related to participation (in project planning and project implementation, in operation and maintenance, and in decision-making), as well as the direct benefits of the use of energy and of energy services.

Women's participation

Community participation in projects ranges from project initiation and planning to project operation. Initiation of a project is often dominated by a dynamic, innovative individual who is often a "natural" leader in the community (and also virtually always male). Wider community participation includes:

- setting up the village-level institution required for community management of the project, the Electricity Consumer Society (ECS);
- undertaking the construction of civil works; and
- operation and maintenance.

The surveys indicate that participation in such activities is greater by men, and greater by those men and women who are to be connected to the new source (the Chhs), as opposed to the UChhs. Average participation rates of women are lower than those of men, and the disparity in participation between Chhs and UChhs is greater for women than for men (Dhanapala 1995). Reasons for the lower participation by women include the following:

- institutional problems related to conflicts associated with the ECS, etc.;
- leadership and attitudes that constrain the involvement of women;
- women's economic role and activities; and
- women's subsistence or household activities and responsibilities.

However, the single most significant constraint is lack of time (a reason given by 50 percent of all female respondents but only 17 percent of male respondents). Other constraints on participation include membership of ECS (listed by more male than female members, but this differs with village characteristics), women's inability to attend meetings which is determined by the meeting place, the time of the meeting (often, inconveniently at night), and the meeting's duration (women wanted short, focused meetings and complained that men often side-tracked meetings with social and political discussions). Constraining influences on participation in operation and maintenance activities include the technical nature of the project. Technology is perceived as something "dangerous" that should be under the charge of men familiar with it. Women and children are often cited as those who need to be "protected" from microhydro power, wiring, etc.; this can act as a barrier to women taking control of such technology. Demystifying technology, while emphasising safety, is clearly an area for attention in such energy projects and should be pursued through training on household end use and maintenance at the household level.

While participation of women in decision-making is advocated by project facilitators and staff, it is perhaps more influenced by local leadership, attitudes, and perceptions of women's role in village affairs. For example, it was noted that, although women act as power house caretakers in two village schemes, they do so on behalf of their sons who are the official (trained) caretakers, and who have devolved their responsibilities to their home-based mothers (Tampoe 1997). Women's participation is also dependent on economic and occupational patterns; women in labour-intensive tea cultivating smallholder villages often cite the lack of time as a constraint on participating in such project activities.

Project benefits

The benefits of village microhydro projects are often limited to lighting, although households give priority to kitchens and other domestic uses of which women in connected households are the main beneficiaries. Overall, all households (both Chhs and UChhs) emphasise qualitative benefits such as quality of lighting and living standards (20 percent), convenience (11 percent), use of TV and radios (11 percent), and ability to work at night (9.5 percent). Although both women and men in Chhs emphasise convenience, women attach more weight to this than men who emphasise general benefits such as better lighting and living standards. Benefits such as enhanced safety for children (when compared to using flammable bottle lamps), improvements in children's schoolwork and increased leisure are cited more often by women than by men in Chhs. In unconnected households, women are less able to benefit from microhydro than men and children, who are relatively more mobile and go to neighbours' houses to view TV, etc. Therefore, women from UChhs benefit least from the introduction of microhydro power.

"Doing it Better" and "Broadening and Deepening" Gender Impact

Gender analyses of project-level impacts of village microhydro schemes indicate that renewable technologies are not gender-neutral and that benefits are viewed differently by gender, according to social roles and responsibilities. Further, the impacts of such projects on all beneficiaries, but particularly on women, are limited by constraints in end use. This relates to the limited access to the advantages of the energy by women in UChhs as mentioned above. Given this scenario, what is the way forward? Recommendations for a "doing it better" approach, that is improvements that stay within the project confines (Dhanapala, 1995), include:

1. **Gender balance in ECS participation.** Greater efforts should be made to integrate women in ECS, by making the latter into family-centred organisations that meet on holidays and at times convenient to all. Developing ECS institutional guidelines and procedures, raising awareness regarding gender balance, and making membership open to all family members over 16, rather than to one designated family representative only, would all improve the situation.

2. **Demystifying microhydro technology—** through household-wide training including safety practices, and through using women in demonstration and training activities.

3. **Knowledge and use of gender disaggregated information** throughout the project cycle. Development facilitators should be trained on gender awareness, on indicators for monitoring purposes, and should be equipped with skills to integrate gender in both the implementation and operational stages of projects. Evaluation visits to both connected and unconnected households should target both genders.

Beyond this, the impact, and especially the gender balance of the impact, of renewable energy projects such as village microhydro schemes, can be deepened and broadened by pushing impacts beyond the limits of project-bound benefits. This requires more linkages between energy services and economic activities, particularly those of women. End uses should be oriented towards existing skills and markets, and, in particular, include informal sector activities undertaken by women (e.g., sewing, *beedi* wrapping, incense stick making, cinnamon peeling). At the time of project implementation, the main benefit of the energy supply was usually that existing activities would be continued after dark, leading to greater outputs. Greater benefits would arise if new mechanised economic activities were stimulated, such as electric sewing, rice milling, carpentry or other workshops. In order to achieve more significant support, energy supplying or facilitating agencies should link with microcredit and business development organisations, which promote activities at the community level.

This emphasis on both improving projects and expanding the extent of their impacts will allow for increased participation by women in projects and their benefits. Benefits will include increased incomes and socio-economic empowerment. Projects will enable greater access to, and awareness of, energy supply options. Given such increase in quantifiable benefits, such projects would, in turn, become more likely to be attractive bankable investments, paving the way for a greater access by communities to localised energy supply options.

References

Dhanapala, Kiran (1995) *Gender Related Impact of Microhydro Technology at the village level*, ITDG - Sri Lanka

Tampoe, Moira (1997) *Project Completion Report for the Village Hydro Project*, draft version

Wijayatunga, Priyantha (1998) *Prospects of new and renewable energy sources in Sri Lanka; pricing and other issues,* Paper presented at LIFE Seminar, Colombo, Sri Lanka, held January 1998

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#2. Why Women Adopt Solar Dryers?

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Traditional Solar Drying

Solar drying has always been an integral part of the African economy, although it is not counted as part of the national energy flow, because women and rural people are never surveyed by the planners who are mostly city-dwelling men. The process of solar crop drying removes moisture from crops to prevent spoilage and facilitate storage. Kenya still loses 30-40 percent of its agricultural produce through such post-harvest losses.

Traditionally, most crop produce was solar-dried in order to preserve it. Pulses and grains were left in the field until they were partially dry and then harvested. After they were harvested, crops, such as maize, beans, sorghum, and millet, were spread out on mats or in woven baskets and left out in the sun. Each morning at sunrise, they were taken out of the store and then returned at sunset. An attendant took in the crops if it rained and scared off birds, goats and other predators. Such drying techniques reduced the moisture content of the crop by between 10 and 12 percent and enabled farmers to store it in granaries for consumption in the dry season before the next harvest, or to sell in times of scarcity and need.

Fishermen along the shore of Lake Victoria split open their catch and dried the fish in the sun to preserve them. They could then be transported inland for sale and consumption. Animal skins were staked on rectangular frames to sun-dry. Other less exotic uses of solar drying include drying (and sterilising) clothes, plates, and cutlery, drying firewood, and producing a distinctive cloth made out of wattle bark and worn by Kikuyu women.

East African agribusiness also depends upon solar drying. For example, the coffee industry relies on solar heat to dry coffee beans which are then roasted and ground. The flowers of pyrethrum, a natural insecticide grown in Kenya, are dried in the sun after harvesting. In other words, there is nothing new about solar drying in Africa.

Modern Solar Drying

Traditional solar drying methods have disadvantages. Crops left out to dry in the sun are vulnerable to rain and pests and need an attendant to guard them. Lack of control over the drying process can result in under or over-drying and consequent loss of overall quality. And solar drying can also change the colour, texture, and taste of the produce and leach out vitamins A, D, and E.

In the late 1970s and 80s, food technologists came up with two new ways to tackle these drawbacks: direct and indirect solar dryers.

The direct solar dryer is a closed, insulated box in which both solar collection and drying take place. Solar radiation passes through transparent glass or plastic into the drying compartment where it heats agricultural produce on racks, carrying moisture away through vents at the top of the compartment. The indirect solar dryer has a flat plate collector and a separate drying chamber. The air is preheated in the flat plate collector and rises to the drying chamber to dry the agricultural produce.

Success Story

There have, however, been some cases in which the market has taken up solar technology and by promoting this has also promoted income-generating opportunities for rural populations. Experience, particularly in Kenya and Uganda, shows that the private sector may be better at introducing solar dryers than research institutions.

One such story began when a FAO/UNDP post-harvest programme at Kawanda Research Station in Uganda recommended small-scale solar dryers for long-term storage and household consumption of fruit and vegetables. However, it soon found that rural groups were more interested in solar dryers for income generation than for food security.

In 1992, the Fruits of the Nile company was formed to exploit this commercial interest by linking rural producers with the market for dried fruit in Europe. It continued the work of developing and promoting small-scale dryers with women's groups and businesses. For an investment of US$100, a group became a supplier of the company and received a simple improved solar dryer with instructions for its use. Within three years, more than fifty groups had taken up the technology. In 1995, the company exported more than 40 tonnes of dried fruit.

The dried pineapples, bananas, and mangoes produced by the rural women's groups are transported to a central collection point in Kampala. Produce is inspected to ensure that it meets quality standards for colour, aroma, and moisture content before it is air-freighted to a marketing group in the United Kingdom.

An example of such a group is the Matinyani Women's Development Group, where Geraldine Roberts has been working. The Matinyani Women's Development Group uses solar dryers to dry mangoes. In thirteen weeks each of the women in the group earned 6,000 Kshs to supplement their income. Fruit was sold to Nairobi and Mombasa, and 3 tonnes were shipped last season. Demand is high and there are export orders for one tonne of dried mangoes per day to London. The mangoes have been tested in London, Brussels, and Tokyo and have been recommended as the best in the world.

Business has expanded so rapidly that the women's groups are starting to worry about their dependence upon Fruits of the Nile company and its ability to serve them adequately as dried fruit production increases. Not only are the women's groups generating significant incomes for themselves, the original food security concerns are also being addressed, because, when they are not drying for profit, the women are drying vegetables and fruits for home storage and consumption.

The obvious conclusion is that the successful introduction of modern solar dryers depends upon their ability to generate income for their users. People are less interested in greenhouse gas emissions and desertification than they are in more immediate things, such as their own standard of living, whether the technology works and is reliable, and whether it will enable them to send their children to school or buy a cassette recorder. No matter how good it looks on drawing boards in the North, any solar technology which fails to address these needs is unlikely to be adopted in the South.

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#3. Promoting Modernised Use of Biomass for Meeting Sustainable Development in Jilin Province, China

This text is based on a project document for Modernized Biomass Energy in China: Jilin, *UNDP, 1999.*

Tackling Women's Concerns Through Energy Interventions

There are several issues relating to the situation of women that require significant attention from an energy perspective. One of the most important of these is the indoor air pollution associated with the inefficient use of biomass for cooking and heating in rural areas of developing countries. Inefficient biomass use accounts for nearly 60 percent of total human exposure to particulate air pollution world-wide. Indoor air pollution creats serious human health problems—especially for women and children. Cleaner and more efficient use of biomass fuels can significantly reduce indoor air pollution levels.

In China, as in other developing countries, availability of rural energy services is essential to support local growth and development. Agricultural residues are the chief source of fuel for rural heating and cooking. About half of agricultural residues generated are either now used or potentially available for use as energy—some of the rest is left in the fields to maintain soil quality, some is used for fodder, and some is used for industrial purposes (e.g., basket weaving). Currently residues are burned in inefficient stoves, which creates a serious indoor air pollution problem for women.

The Northeast Chinese province of Jilin, with 2 percent of China's population, produces some 14 percent of China's corn. Residues of corn production, primarily stalks, are generated in large quantities. These are typically burned in rural homes for heating and cooking, leading to significant indoor and local air pollution. Uncollected stalks are typically burned on the field to prevent insect infestation, leading to substantial outdoor air pollution at certain times of the year. To help mitigate these problems, the Government of China, in collaboration with UNDP, embarked on a pilot project in early 2000 to demonstrate combined cooking fuel, home heating, and electric power generation via gasification of corn stalks in Jilin Province.

Jilin Province

Jilin Province is a main source of grains and corn in China, with an annual grain output that reached 20 million tons in 1997, the highest on a per capita basis in China. The availability of agricultural residues exceeds the amount needed to maintain the nitrogen balance in soils and to meet household energy needs. As a result there is widespread open field burning of excess agricultural residues in order to promote pest control and maintain the productivity of the land. The total crop residues generated in Jilin amount to 42 million tonnes per year (84 percent of which are corn residues), with an energy content of 22 million tonnes of coal equivalent (0.63 EJ) per year, about half of which might be available for energy after accounting for other uses—fodder, fertiliser, and industrial feedstock.

A growing concern in Jilin Province is that as farm incomes rise, the pollution problems associated with cooking and heating are being exacerbated. The new pollution problems are arising as a result of the fact that as farmers get richer, they are becoming less willing to gather biomass residues from the fields and store them for cooking and heating use throughout the year. Farmers prefer coal briquettes instead if they can afford to buy them. The briquettes have some better combustion properties than raw biomass and higher bulk density and are thus more conveniently stored and used; moreover, they can be readily purchased from itinerant merchants as needed, so that storage requirements are minimal. However, coal briquette stoves tend to be even more polluting than biomass stoves. The shift to coal also creates an excess of crop residue supplies that is problematic. The residues dry out quickly in the field and decay so slowly that, if kept on the field, they are not easily absorbed into the soils. The buildup of residues creates an insect infestation problem. To prevent insect infestation, the excess crop residues are increasingly burned off in the fields, creating additional air pollution problems.

Project Strategy

To assist in providing improved rural energy services based on agricultural residues, the Jilin Provincial Government has launched a programme for modernised biomass utilisation. Two demonstration sites have been established by the provincial authorities to generate gas from agricultural residues for heating and cooking purposes. The objectives of the government programme are to provide cleaner, more energy efficient rural energy services to support local development, promote environmental protection, stem the use of coal as a home fuel, and improve the living conditions of rural Chinese, especially women and children who currently face indoor air pollution associated with open burning of agricultural residues.

Building on these government initiatives, this project will support capacity building and technical assistance for construction of a combined heat and power (CHP) pilot generation site at the village/township level to demonstrate integrated sustainable energy production and to analyse the economic issues involved in gas production from biomass. The operations of this site will provide information on system strengths and limitations to improve future design. It will allow the collection of economic, technical, environmental and social data to assess the overall feasibility of the approach. Information on the approach and experience with the CHP system will be widely disseminated in China and abroad.

Scope of Activities

There are three immediate objectives of this project:

- **Capacity Building:** establishing necessary institutional, human and technical capacity in Jilin, China to design, install, operate and disseminate CHP both domestically and abroad;
- **Problem Solving:** improving gas production to (a) achieve quality and content of gas needed, (b) resolve distribution and storage issues, and (c) introduce systems automation as a basis for development of the CHP demonstration project; and
- **Technology:** demonstrating CHP based on the gasification of agricultural residues to provide heat, cooking gas and electricity fully in operation at a village/township scale in Jilin.

3

SPECIAL TOPIC RELATING TO ENERGY
AND SUSTAINABLE HUMAN DEVELOPMENT

ENERGY AND THE ENVIRONMENT: THE CLEAN DEVELOPMENT MECHANISM

3.1. INTRODUCTION

Central to sustainable development objectives is the goal of helping developing countries eradicate poverty. Because the lack of modern energy services correlates closely with many dimensions of poverty alleviation (e.g., economic development, educational opportunities, health care, and functional sanitation facilities), provision of modern energy services to the population, especially those living in poverty, needs to be an essential component of national development strategies. Thus, as developing countries strive for sustainable development, significant growth in the provision of modern energy services is inevitable in the coming decades. As energy consumption in developing countries grows, so too will emissions of greenhouse gases (GHGs); with time, these emissions could become increasingly significant contributors to climate change.

From the developing countries' point of view, however, climate change was originally seen strictly as a "global" environmental issue that was the responsibility of industrialised countries. This was so because, compared to the industrialized countries, developing countries have contributed little to current concentrations of GHGs in the atmosphere. Moreover, developing countries' national priorities are economic development and alleviation of poverty, complex tasks that obscure the global aspects of the situation.

Consequently, a major policy challenge is to devise a means of promoting national sustainable development activities, while reducing the rate of growth in GHG emissions. Focusing on national development by no means precludes actions that can help to reduce the risk of climate change. Specifically, where the rate of growth in carbon emissions can be reduced through measures that enhance development prospects, promising opportunities exist for developing countries to actively pursue socio-economic development, while contributing to solving the climate challenge.

The Clean Development Mechanism (CDM) was adopted in Kyoto in 1997 by the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) as part of the Kyoto Protocol. The purpose of the CDM is to assist developing country parties in achieving sustainable development and in contributing to the ultimate objective of the Convention, as well as to assist Annex I Parties[1] in achieving compliance with their quantified emission reduction commitments under the Protocol.

The CDM offers potential opportunities for developing countries to actively advance their sustainable development objectives, while contributing to reducing GHGs. The CDM is intended to promote "win-win" actions in developing countries—that is, actions that enhance development prospects while reducing growth in GHG emissions. By providing what should be relatively low-cost options for such reductions, the CDM could substantially aid global efforts to reduce the rate of increase of GHG emissions. At the same time, the CDM could aid the development prospects of developing countries by stimulating technological "leap-frogging" and generating new investments.

[1] Annex I Parties are countries trying to return their greenhouse gas emissions to 1990 levels by the year 2000, as per the UNFCCC, including members of the Organisation for Economic Co-Operation and Development (OECD), and countries with economies in transition. Please refer to the annex of this chapter for an explanation of terminology, including Annex I and non-Annex I countries.

Bearing in mind that the operational modalities for the CDM are yet to be determined, this chapter aims to serve as a practical guide to potential implementers of CDM activities at a national level, to be used as a tool in sensitising UNDP Programme Officers, their national counterparts, and other relevant decision-makers on issues concerning the CDM. The chapter outlines the concepts which make up the CDM, as it is currently defined. It also outlines the range of capacity-building needs related to the CDM (based upon inputs that have been provided by developing country governments), explains what activities and investments may potentially be eligible for CDM crediting, and outlines the different potential roles of various stakeholders. As operational modalities concerning the CDM are further defined and agreed, this chapter will be revised and updated accordingly.

3.2. WHAT IS THE CLEAN DEVELOPMENT MECHANISM?*

3.2.1. The UNFCCC and the Kyoto Protocol

Energy and environment were much discussed at the June 1992 UN Conference on Environment and Development in Rio de Janeiro. Agenda 21, produced at the Rio Summit, reached the conclusion that the present energy course is unsustainable. Chapter Nine of Agenda 21, "Protection of the Atmosphere" begins:

"Energy is essential to economic and social development and improved quality of life. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase

** This section is based mainly on* Issues and Options: The Clean Development Mechanisms*, UNDP (1998).*

substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy."

Greenhouse gas emissions and their relation to climate change were dealt with extensively at the Rio Conference and in Agenda 21. The climate change issue was given prominence by the United Nations Framework Convention on Climate Change, which was the result of long and complex negotiations between various groups of countries having very different perceptions of what was at stake. The ultimate objective of the Convention is to stabilise atmospheric concentrations of greenhouse gases at a level that would prevent dangerous anthropogenic (man-made) interference with the climate system.

Signed at the Rio Conference, the UNFCCC entered into force in 1994, and has now been ratified by more than four-fifths of the United Nations member states (as of 14 June 99, the Convention had been ratified by 179 parties). The UNFCCC includes neither binding stabilisation commitments, nor quantified targets and timetables for emissions reduction.

In April 1995, Germany hosted the first Conference of the Parties of the UNFCCC (COP 1) in Berlin. There was an overall consensus on the necessity of strengthening the Convention, and the Berlin Mandate was agreed upon as the basis for negotiations towards this end. At the second Conference of the Parties (COP 2, July 1996, Geneva), the Ministers and other heads of delegations instructed their representatives to accelerate negotiations on the text of a "legally-binding protocol or another legal instrument", to be completed in due time for adoption at the third session of the Conference of the Parties.

The response to this decision was a new protocol adopted in Kyoto in 1997 (Kyoto Protocol). It contained new emissions targets for Annex I countries for the post-2000 period and moved the international community one step closer to achieving the Convention's ultimate objective.

The Kyoto Protocol's new binding commitments for Annex I Parties are:

- to reduce total emissions of six key greenhouse gases by at least 5 percent for the post 2000 period; and
- to meet emissions targets by the period 2008-2012.

The Protocol will enter into force 90 days after it has been ratified by at least 55 parties, including developed countries representing at least 55 percent of the total 1990 carbon dioxide (CO_2) emissions listed in Annex I.

3.2.2. The Kyoto Protocol and the Adopted Mechanisms to Reduce GHG Emissions

The Kyoto Protocol provides several mechanisms that could be used to reduce GHG emissions to meet the reduction targets. In this section, these mechanisms are briefly described, with a view to clarifying differences between the mechanisms.

3.2.2.1. The Clean Development Mechanism (CDM) (Article 12)

The Clean Development Mechanism (CDM) as defined by the Kyoto Protocol, holds the potential to assist non-Annex I Parties in achieving sustainable development, while contributing to the ultimate objective of the UNFCCC—stabilising greenhouse gas levels in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Its potential future operation is based on an incentive structure directly linked to the Annex I Parties' fulfilment of their quantified commitments under the Protocol. Under the Protocol, Annex I Parties are committed to reducing emissions by at least 5 percent below 1990 levels during the period 2008-2012.

Developing countries do not have such commitments, but may, through the CDM, participate actively in the international effort aimed at combating global climate change.

The CDM is an important potential instrument for promoting international cooperation (e.g., through foreign investment in the energy sector) and simultaneously addressing the issue of sustainable human development. The objectives of the CDM, as specified by article 12 of the Kyoto Protocol, are:

- assisting Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention; and
- assisting Annex I Parties in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.

Comment [MSM1]:

Benefits to developing countries will come through investment in cleaner development paths. The benefits to industrialised countries will stem from contributing to reducing emissions at a lower cost than would be the case through domestic action only. In order for the CDM to form a basis for Certified Emission Reductions Units (CERUs), ways of incorporating CDM project activities into developing countries' priorities for development must be taken as the point of departure.

Ideally, the CDM will induce additional capital flows to developing countries, accelerate technology transfer, and enable developing countries to leapfrog to cleaner technologies, while helping developed countries achieve their emission reduction commitments at lower costs. The size of the CDM market will be influenced by a number of dynamic variables. These include: the total size of the global market for carbon credits, the rate of growth in Annex I emissions, the amount and cost of domestic reductions, and the attractiveness of CDM CERUs vis-à-vis joint implementation and emissions trading. A strong financial incentive for firms to participate in the CDM could develop, because, compared to domestic action, the costs of Annex I compliance through CDM credits could, in general, be much lower.

One very simplified example of the process by which the CDM could operate is as follows:

A company from an industrialised country invests in building a highly efficient plant in a developing country, rather than a less efficient plant as previously planned. This results in emissions reductions below what would have been the case without the project investment. Those reductions are certified as credits, and the developing nation and investing company would determine how to share the credits. Through this joint project, the developing country acquires a more efficient technology and capital investment in the plant. The company from the industrialised country acquires a share of CERUs it can use to meet its emissions reduction commitments at home.

3.2.2.2. Joint Implementation (Article 6)

Joint Implementation (JI) allows countries in Annex I to implement measures jointly to reduce their GHG emissions jointly. Like the CDM, its operational modalities are yet to be defined. As it concerns Annex I countries, it is an especially important mechanism for economies in transition.

In order for a JI project to receive "emission reduction units", the activities must incorporate the sustainable development priorities of economies in transition acting as host countries. For this reason, UNDP approaches JI as a mechanism for facilitating the processes of socio-economic transition and sustainable development while implicitly benefiting the global environment. Accordingly, reductions in the growth of greenhouse gas emissions need to be accomplished through activities carried out to meet immediate objectives related to such issues as poverty alleviation, energy and resource utilisation and infrastructural planning and development.

3.2.2.3. Emissions Trading (Article 17)

Emissions trading is a market-based instrument which uses "assigned amounts" to allow for trading between countries that have accepted emission reduction commitments under the Kyoto Protocol, as listed in its Annex I. Unlike, the CDM and JI, emissions trading is not project-related. However, similar to CDM and JI, emissions trading enables achievement of commitments, at least cost, by taking advantage of marginal cost differentials in emissions abatement among countries. Since greenhouse gases are uniformly mixing global pollutants, both the damages from emissions and the benefits from emission reduction are independent of their origins. In order to minimise the costs of global emission reductions, abatement should take place where the costs are lowest. Emissions trading could allow this to happen in an efficient and cost-effective manner. Modalities for emissions trading remain to be established.

3.2.3. Issues Relating to Operational Modalities for the CDM

To operationalise the CDM, there are a number of questions that need to be answered vis-à-vis modalities for the CDM.

3.2.3.1. Governance

The institutional design of the CDM will be the key factor determining its performance. Early decisions are needed from the Conference of the Parties covering:

- the powers and composition of the Executive Board and its relation to the COP/MOP;
- the nature and role of the "operational entities" which are to undertake certification, independent auditing, and verification of project activities;
- the basis for private and/or public entities' participation in CDM activities; and
- the nature and role of the administrative support needed for the Executive Board.

Clearly, one of the main responsibilities of the Executive Board, under the authority and guidance of the COP, will be to define the nature of the projects to be accepted and/or review lists of project activities for which CERUs can be issued.

3.2.3.2. Operational Modalities of the CDM

There are three approaches for the operation of the CDM and exchanges of CERUs:

A unilateral approach: Under this option, the developing country would itself undertake actions to reduce emissions and then subsequently trade the CERUs produced through such actions on the international market.

A bilateral approach: Under this option, countries or private entities would negotiate agreements among themselves. Together, they would set criteria and rules for crediting, akin to the arrangements contemplated under Article 6 of the Kyoto Protocol for Joint Implementation.

A multilateral approach: Under this option, also called the "portfolio" option, non-Annex I countries would offer projects for emission reductions to the CDM, to be picked up by the highest bidder in Annex I countries. Interested developing countries could each present a portfolio of projects and seek financial and technical support for their implementation. Developing countries could issue certificates and present them to the Executive Board for placement in the "market". The corresponding value for each CERU would be determined solely by the market. The Executive Board would have a fiduciary role, as it would be trying to obtain the best price for developing countries' CERUs.

A multilateral approach could remove some of the concerns raised during the pilot phase of the Joint Implementation method, which was based on bilaterally agreed projects. Some Parties considered JI unacceptable because it was seen as interfering with their sovereign choices.

One concern about the multilateral approach arises from experience with sulphur dioxide emissions (SO_2) in the United States. A significant number of projects to reduce these emissions take place among branches of the same company, rather than through an open market mechanism for purchase of SO_2 reductions. Transnational enterprises might do the same with greenhouse gas emissions, acting bilaterally with their subsidiaries in developing countries. In that case, the portfolio approach would lose some of its attractiveness for developing countries.

The bilateral option is likely to be preferred by large private investors who might view an international clearinghouse "portfolio approach" as an obstacle that could increase transaction costs. Small investors have no resources to develop bilateral projects and are likely to prefer the portfolio approach. In practice, the "bilateral" and the "portfolio approach" could coexist, and national governments could establish rules to be followed in their countries.

3.2.3.3. Monitoring, Verification, and Certification

Only "certified emission reductions" can count towards compliance by Annex I Parties. For this reason, there is a clear incentive on the part of all concerned parties to achieve emission reductions. However, that incentive could lead investors in the CDM projects (countries or companies) to seek maximum emissions reductions to be used as credit towards meeting their commitments; it could also lead recipients to overstate the emission reductions to make them attractive. This reinforces the importance of having agreed-upon ways of objectively managing the certification process and achieving credible results.

Therefore, monitoring, verification and certification of the projects is essential. Certification is an accepted ingredient of everyday business activities such as commodities trading (to assure quality and delivery to the buyer as agreed) and goods shipping (to assure goods are delivered according to contracts). One could, therefore, view the CDM as a mechanism which establishes CERUs as a new commodity to be issued and, eventually, traded among parties or businesses.

Submission of certificates could come through public and/or private entities. In any case, the voluntary character of the projects agreed upon by different parties would be preserved, subject to guidelines established by the Executive Board.

Considerable international experience in setting standards already resides within the International Standardisation Organisation (ISO). Their "ISO-Series" covers standards in many areas of industrial and business actions. Compliance with such standards is assessed by a variety of national institutions. Possibly, similar procedures could be adopted by the Parties for the CDM.

This suggests two types of certification activities. The first type would involve the certification of the prospective reductions, resulting, for example, from an energy conservation project. In reality, this would be a "pre-certification", one which occurs before project activities start. The second type of certification activities would involve periodic monitoring of realised emission reductions after the project is implemented. This would need to be an ongoing follow-up activity, particularly for projects with a long time frame.

3.2.3.4. Baselines

Emission reductions can be certified only if the reductions are additional to any that would occur in the absence of the certified project activity. In addition to this criteria, emission reduction types of projects should achieve real, measurable results and yield long-term benefits related to the mitigation of climate change. Assessment of whether CDM projects fulfil these criteria involves comparing the expected emission reductions against a baseline, which is a construct projecting possible activities that may never actually happen.

The definition of baselines is a crucial ingredient of the CDM since, as pointed out above, there is likely to be a strong perverse incentive to overstate reductions or start from inflated baselines. An inflated baseline would create CER units for a project that would have taken place also in absence of the CDM.

Although some experience in establishing baselines has been developed in the Activities Implemented Jointly (AIJ) pilot phase, these baselines were agreed upon bilaterally. For the CDM, a common methodology will have to be established. Baselines using macro-economic forecasts of economic development, population growth, and other factors are possible but difficult to establish in a reliable way. As an alternative, project-based baselines could be designed. These would incorporate the technological development and state-of-the-art activities which would take place in the absence of the CDM.

However, project-specific baseline scenarios do not take indirect effects into account. These can arise, for example, when a project uses goods the production of which causes greenhouse gas emissions. Emissions can also be influenced by price effects which could provide an incentive for greater use of carbon-rich fuels and lead to an increase in greenhouse gas emissions.

3.2.3.5. Equity

Because rapidly industrialising countries have better infrastructure, lower risk, and the largest greenhouse gas saving potential, the CDM might generate financial flows directed toward those countries which are already receiving the bulk of private capital flows from industrialised countries. Since 1990, some 12 developing countries have received over 80 percent of all foreign direct investment. To avoid these patterns being repeated under the CDM, some argue that equity considerations should be factored into the design of the CDM.

3.2.3.6. Share of Proceeds

Article 12.8 establishes that a share of proceeds from CERUs is to be used to cover administrative expenses, as well as to meet the adaptation costs of developing countries that are particularly vulnerable to climate change. What this means is that two charges may be imposed on the proceeds of CDM projects:

- a share for administrative expenses to cover necessary services in support of the Executive Board; and
- a share to cover costs of adaptation as mandated by Article 12.8. "Adaptation" to climate change is particularly important for small island states, but it is also important for many larger developing countries.

3.3. CAPACITY-BUILDING NEEDS

The capacity-building needs of Non-Annex I parties related to the Clean Development Mechanism can be divided into two phases, pre-COP6 and post-COP 6. Pre-COP 6, the rules, guidelines, modalities, and procedures concerning the operation of the Clean Development Mechanism will not have been worked out. Hence, the focus of capacity building should be on sensitising senior-level policy-makers in government, as well as other relevant stakeholders outside of government, to the benefits of the CDM. Support must be generated among developing countires' government officials for participation in the CDM, in order to help relevant government authorities meet national sustainable development priorities. Such support is also necessary to further define the issues and options surrounding CDM design and operation, and to prepare prototype projects which may potentially become applicable at a later point in time. In addition, it is useful and important to raise awareness and understanding concerning the CDM and those who stand to benefit from it, even before all the procedures and guidelines are established. Both developed and developing countries stand to benefit from the CDM.

Under Article 12.3:

(a) parties not included in Annex I will benefit from project activities resulting in certified emission reductions; and

(b) parties included in Annex I will be able to use the certified emission reductions accruing from such project activities to contribute to compliance with their quantified emission limitation and reduction commitments under Article 3 of the Protocol.

At COP 6 (October 2000), the rules, guidelines, modalities, and procedures for the operation of the CDM be established. The focus of capacity building needs will then shift more towards assisting developing countries in being able to take advantage of the CDM to further their sustainable development priorities through prototype projects and capacity-building activities, with a particular focus on utilising the CDM to leverage additional private sector investment.

The Conference of Parties at its fourth session (COP 4) in November 1998 decided to undertake a work programme on all mechanisms related to the Kyoto Protocol, with a view to making decisions on all mechanisms at COP 6 in 2000, specifically identifying work on the modalities and procedures of the CDM, as a matter of priority. In this context, the UNFCCC secretariat was specifically requested to prepare a plan for facilitating capacity building in developing country parties for project activities under the CDM. The following activities related to capacity building and the CDM were identified and adopted by the COP 5.

CDM CAPACITY BUILDING NEEDS

- **Establishment of Institutional Linkages required for Implementation of the CDM;**
- **Project Identification, Formulation, and Design;**
- **Monitoring, Verification, Auditing, and Certification of Project Activities;**
- **Development of Criteria, including for Sustainable Development Indicators (e.g., for adaptation);**
- **Development of Baselines;**
- **Project Negotiation Skills;**
- **CDM Demonstration Projects to enhance capacity building (learning by doing), including assessment of costs/risks (long and short-term); and,**
- **Data Acquisition and Sharing.**

In general, capacity building for CDM activities should follow certain general principles. It should be:

Demand Driven: Technical cooperation for capacity building should be based on national demand, formulated by means of a participatory process that ensures national ownership and transparency. It is also essential for sustainability that other resources be adequate to continue with CDM capacity building activities, once the assistance is over.

Across Levels and Sectors: The decision by COP 5 places a special emphasis upon the capacity building needs of the least developed countries and small island states. Particular emphasis needs to be placed on sensitising senior-level policy-makers, in order to help relevant government authorities understand how the CDM can help meet national sustainable development priorities. Capacity building should also include support for the establishment of a national organisational and institutional framework to identify, assess, validate, and implement CDM projects, and to facilitate subsequent monitoring, verification, and certification activities.

Long Term: Strategies for capacity building require a realistic time horizon (5-10 years minimum), since the building of capacity is a long-term process. Longer-term capacity-building needs include, *inter alia*, the need to develop the capacity among national policy-makers to:

a) formulate a regulatory framework to deal with the regulatory, legal, financial, and technical issues that are unique to CDM projects; and

b) identify and apply baseline parameters in accordance with agreed procedures.

3.4.1. Two General Criteria for Selecting CDM Projects

The CDM has two general criteria for project eligibility:

- projects result in real, measurable, and long-term emissions reductions that are additional to what would have occurred under a base-line situation; and
- projects result in sustainable development benefits for the host country.

The Parties to the Convention need to clarify how the project-level sustainable development criteria will be put into practice. A specific question thrown up by the textual ambiguities and gaps in the text of Article 12 is whether sequestration (sinks) projects are covered by the CDM. Paragraph 3 (a) and the remainder of Article 12 talk about “certified emission reductions” (CERs) or about “emission reductions”. There is no mention of “enhancing anthropogenic removals by sinks” and of counting the sequestration so achieved towards fulfilment of emission reduction commitments. This makes it unclear as to what the role of carbon sequestration projects (e.g., sinks) will be under the CDM.

Beyond these general principles, however, the Protocol does not give any information on the types of projects that are eligible, or the criteria for selecting them. CDM projects must presumably fulfil certain criteria in order to be certified upon completion, but these criteria have not yet been established by the working groups under the Buenos Aires Plan of Action. A particularly important question is what criteria will define “sustainable development" and other benefits for host countries. As there is no internationally-agreed definition of what constitutes sustainable development, this could be problematic. Nevertheless, it is clear that sustainable development must be determined within a national context, in keeping with national development goals, constraints, and natural resource endowments. Setting clear eligibility and selection criteria, allowing open competition for projects, and encouraging experimentation with new project concepts are all important if the CDM is to be effective as a tool for sustainable development and reducing GHG emissions. Possible sustainable development criteria include:

- absence of (or limited) adverse environmental or social impacts;
- absence of (or limited) increase in external debt burden;
- “top end” technology transfer;
- energy efficiency promotion;
- renewable energy promotion;
- equitable distribution of benefits and experiences by sector and region;
- stakeholder participation;
- sufficiently attractive rate of return to investors;
- specific performance or design standards for transferred technology;
- capacity and willingness of both national and local governments to host projects;
- existence and nature of agreements for sharing project benefits (CERs and financial returns); and
- project liability between investor and host.

3.4.2. Type of Activities/Thematic Areas that CDM Is Likely to Cover

Certified Emission Reductions Credits (CERCs) for projects in developing countries, involving both developing and developed country partners, could be granted through the CDM in a number of sectors. In each of these sectors, emissions come from difference sources. Within each of these sectors a number of generalized GHG offset options exist. Table 1 provides information on primary causes of GHG emissions and generalised GHG offset options to reduce emissions. As mentioned above, whether or not “sinks” related issues (such as forestry, agriculture, etc.) will be eligible for the CDM remains to be seen.

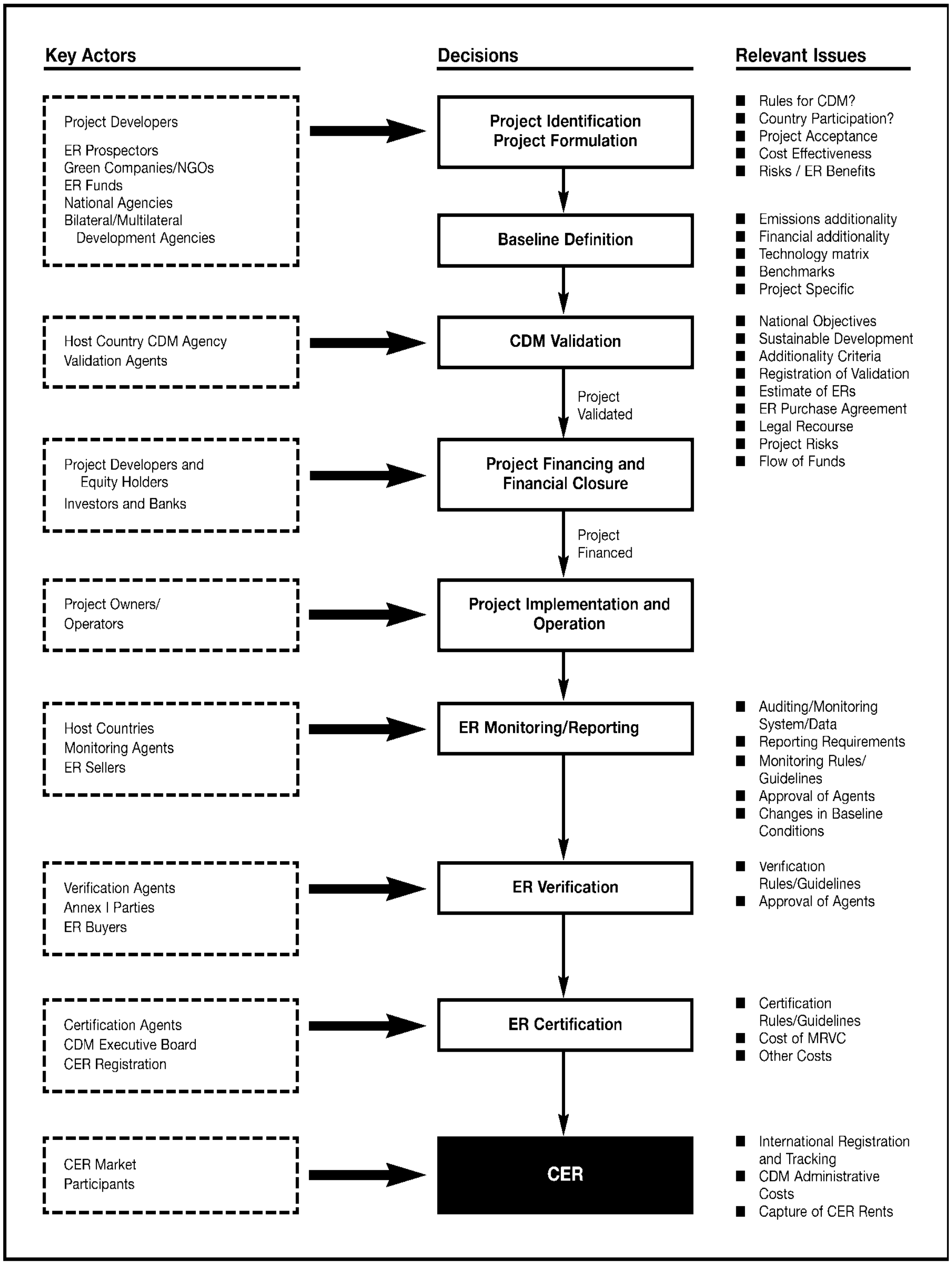
3.4.3. Project Cycle

Figure 1 illustrates a possible flow of activities in the CDM project development cycle. The key actors and relevant issues associated with each major decision in the CDM project cycle are highlighted. Please note that this table is for illustrative purposes only, given that the exact modalities and procedures remain to be established.

TABLE 1. GHG EMISSIONS – PRIMARY CAUSES AND GENERALIZED OFFSET OPTIONS

SECTORS	PRIMARY CAUSES OF GHG EMISSIONS	GENERALISED GHG OFFSET OPTIONS
ENERGY	**From the production, conversion, transportation, and use of fossil fuels (coal, oil, and natural gas). This is the single most important source of GHG emissions in most developed countries, accounting for over 90% of total national GHG emissions annually. The principal emissions are from carbon dioxide, methane, and some nitrous oxide. The principal source is the combustion of fossil fuels for electricity production, heat, motive power, and stationary shaft power. Fugitive emissions from fossil fuel production, conversion and transportation, are also significant contributors.**	**▪ Switch fossil fuels to clean fuels and renewable energy; ▪ Increase efficient production, conversion, and use of fossil fuels; ▪ Capture and use fugitive emissions from fossil fuel chain; and ▪ Capture and use fossil fuel emissions from fossil fuel chain.**
INDUSTRIAL PROCESSES	**Principally, carbon dioxide emissions from cement production, lime manufacturing, and limestone use. Also some nitrous oxide production from fossil fuel production, conversion, and transportation are significant contributors.**	**▪ Improve efficiency of production technology; and ▪ Introduce alternative materials and processes.**
SOLVENT AND OTHER PRODUCT USE	**From the use of solvents and other chemical products that principally result in NMVOCs. This source accounts for a relatively minor (usually less than 1%) fraction of total national GHG emissions.**	**▪ Substitute with GHG-neutral substances; and ▪ Use products more efficiently.**
AGRICULTURE	**These are principally methane emissions from enteric fermentation in domestic live-stock, manure management, and rice cultivation. Also nitrous oxide emissions from the use of fertilizers and agricultural waste burning.**	**▪ Improve livestock/feed management; ▪ Improve manure management; ▪ Modify rice cultivation practices; ▪ Adopt low-methane rice cultivars; ▪ Switch from nitrogen to organic fertilizers; and ▪ Eliminate open-burning of agricultural wastes.**
LAND USE CHANGE AND FORESTRY	**This sector is potentially both a source and a sink for GHGs. GHGs are emitted or stored through land use changes and forest management activities such as deforestation, land clearing, reforestation, draining of wetlands, clearing for urban or agricultural development etc.**	**▪ Protect, conserve, and preserve forests and wetlands; ▪ Increase efficiency of forest management; ▪ Practice reforestation and afforestation; ▪ Enhance forest regeneration; ▪ Improve agroforestry practices; and ▪ Improve soil and grassland management.**
WASTE	**GHG emissions from this sector principally result from the decay of waste disposed in landfills, municipal wastewater treatment and combustion or open burning of waste materials. Landfills are the principal source of GHG emissions in this sector.**	**▪ Reduce and recycle wastes; ▪ Capture methane from waste disposal and waste water treatment; and ▪ Eliminate open burning of waste.**
OTHER	**Any other anthropogenic source or sink not referred to above.**	**▪ Reduce, modify, or eliminate practice.**

FIGURE 1. POSSIBLE CDM PROJECT CYCLE



Source: P. Hassing and M. S.Mendis, 1999, Market Based Framework for CDM Transactions.

3.5.1. Roles of Stakeholders - The Private Sector

The Kyoto Protocol set the targets for GHG emissions reduction for the first commitment period from 2008-2012. In order to meet the targets, Annex I countries would have to take various measures to reduce emissions produced by private companies. The emission reductions that a company is required to achieve over the next 10-15 years will comprise its "emissions gap". Once its emissions gap has been identified, a firm can begin to look for measures and investment options to reduce or eliminate its anticipated gap. The CDM could provide opportunities for firms in developed countries to undertake investments in developing countries that reduce overall GHG emissions.

In order for the CDM to function effectively it is essential that the private sector be engaged in a meaningful manner. This presents several challenges. Greater clarity is needed on the steps necessary to initiate a viable demonstration project. Stakeholders collectively need to build a practical methodology and model for identifying, bringing forward, and selecting prospective CDM projects. This process must generate stakeholder alignment and understanding, and also deliver practical methodologies concerning CDM operations.

In addition, more work needs to be undertaken on exploring the impact of an uncertain additional revenue stream on the attractiveness and viability of a real project (net present value, scope and risks). This analysis will be an important input for understanding how the private sector could operate in relation to the CDM once rules, guidelines, and procedures have been fully agreed-upon and established.

Private sector investment through the CDM will depend upon the extent to which the value of the CERUs increases the attractiveness of the investment vis-à-vis alternative courses of action. In other words, private sector investment in CDM activities will depend completely on commercial viability under GHG emission abatement cost internalisation, with funding applied to provide leverage through risk reduction and a risk-sharing approach.

The incentive structure of the CDM should be designed in such a way as to induce accelerated technology transfer and significant additional capital flows into developing countries (the incentive for developing countries), while at the same time enabling developed countries to achieve their emissions reduction targets at a lower cost (the incentive for developed countries).

For the effective involvement of the private sector, the following might be key elements to consider:

- domestic emissions limitations commitments are in place under the Kyoto Protocol for Annex I parties (i.e., Kyoto Protocol has entered into force), and companies can get domestic GHG offset credit for investing in CDM projects;
- rules for Project Eligibility and Procedures for implementing qualified GHG reduction projects are in place (establishment of procedures for making the project eligibility criteria);
- agreements are in place among investors and host countries to facilitate emissions reductions investments; and
- incentives and mechanisms are in place to reduce the transaction costs and risks associated with GHG emission reduction projects.

Even before all guidelines, procedures, agreements, incentives, and mechanisms for the "modus operandi" of the CDM are finalised, there is a need to explain to people in the private sector, as well as to other relevant stakeholders in government and civil society, the process through which the CDM could operate.

The following is a *hypothetical* example of how a

CDM GHG offset market trade might work. The example is presented for illustrative purposes only and does not represent any commitments, implied or other-wise, by the countries mentioned.

HYPOTHETICAL EXAMPLE OF POSSIBLE CDM GHG OFFSET TRADE

In 2002, according to regulations implemented by the Government of the Netherlands to comply with provisions of the Kyoto Protocol, Dutch POWER generating company has a requirement to reduce its carbon emissions. It will cost POWER more than US$30 to reduce every additional ton of carbon beyond the reductions it has already achieved in its plants. POWER is aware that there are cheaper options available for reducing carbon emissions internationally, and decides to consult with carbon brokers to obtain information on carbon offset investment opportunities. The Netherlands has joined the Kyoto Protocol's CDM, which is for Parties that are capable of registering, certifying, and reporting offsets traded at the international level. Thus, POWER can invest in international carbon offsets in other countries, such as Malaysia, that have also joined the CDM.

Broker 1 can supply verified carbon offsets from a Dutch firm for US$20/ton. Broker 2 can supply carbon offsets from Malaysia for US$8 per ton of carbon reduced, plus a fee to hire a professional auditor and to cover the costs of broker services, for a total of US$9 per ton. POWER decides to investigate the Malaysian offsets. POWER pays Broker 2 to have the offsets audited in order to confirm that they are real, surplus, and additional reductions. Broker 2 hires a private auditing firm, Auditor, which verifies that the Malaysian offsets are in compliance with carbon offset credit rules adopted by the CDM. With such an audit, POWER is assured that the offsets will be certified for international trade, according to rules established by the CDM and agreed to by both the Malaysian and Dutch governments. POWER, therefore, pays Broker 2 US$9 per ton. Broker 2 submits the audit to the Malaysian government for registration and certification. Once the carbon offsets credits are registered and certified by the Malaysian government, POWER submits the certificate to the Dutch government for registration and certification and the results of these transactions are then registered with the appropriate authority designated by the CDM.

This example is not unrealistic. The market is already being used for international trades to buy and sell low-cost emissions reductions. However, very few trades are taking place at present, because trades for offsets created prior to 2000 will not be recognised. The incentives to reduce emissions will be adopted when the provisions of the Kyoto Protocol are implemented. Thus, all that will be needed are the rules. These should be developed and adopted by the COP-appointed International Regulator and the CDM as soon as possible, in order to ensure the widest range of low-cost options.

Source: CDM Issues and Options, *Chapter 12, Hassing and Mendis, UNDP, 1998.*

3.5.2. Role of Stakeholders: Governments

Governments are participating in the development of the operating guidelines, modalities, and procedures of the CDM through the Buenos Aires mandate, as agreed at COP 4. The Buenos Aires mandate is a two-year work-programme, established by the COP 4 meeting in Buenos Aires, November 1998, which is aiming to develop operational rules for the various mechanisms, including the CDM, by the end of the year 2000 at the COP 6 meeting. Key issues being discussed include methodological and technical work on: the purpose of CDM projects; supplementarity to domestic action; Annex I commitments; additionality criteria in funding; criteria for real, measurable, and long-term benefits related to climate change; compatibility with sustainable develop-ment priorities/strategies; and the function of the Executive Board. For effective operation of the CDM, including participation of the private sector, and to ensure that it meets the goals laid out for it in the Kyoto Protocol, there need to be clear, easily understood rules and guidelines from the outset. In determining the structure of the CDM, a balance must be found between the objective set out for developed countries—that of achieving their emissions reductions targets under the Kyoto Protocol—and the objective of developing countries to achieve sustainable development.

3.5.3. Role of Stakeholders: International Organisations

International organisations such as UNDP, UNEP, United Nations Conference on Trade and Development (UNCTAD), United Nations Industrial Development Organisation (UNIDO), and the World Bank have all been assisting countries with capacity-building activities related to climate change. UNDP, UNEP, and the World Bank are all Implementing Agencies of the Global Environment Facility (GEF), which is the financial mechanism of the UNFCCC. In addition, the World Bank is involved in building capacity related to the Clean Development Mechanism through the National Strategy Studies (NSS) Program and the Prototype Carbon Fund (PCF). As the rules and guidelines concerning the CDM are agreed upon, international organisations will provide CDM capacity building assistance in a manner which is consistent with their respective mandates and with the relevant decisions of the Conference of the Parties.

The Secretariat of the UNFCCC, based in Bonn, Germany, serves the needs of the Parties to the Convention. This entails organising meetings of the Conference of Parties (COP) and Subsidiary Bodies (SBI and SBSTA, see Annex for explanation of terminology), as well as preparing documents and papers as requested in decisions of the Parties. After the Kyoto Protocol enters into force, an additional Secretariat to the Kyoto Protocol will be created. This may include the Executive Board for the CDM.

3.5.4. Other Stakeholders: the Global Environment Facility

The Global Environment Facility (GEF) has been designated as the financial mechanism to the UNFCCC. All GEF-funded activities in climate change are designed to be in full conformity with the guidance provided by the Conference of the Parties (COP) to the UNFCCC. The GEF, through its three Implementing Agencies (World Bank, UNDP, and UNEP), provides assistance to non-Annex I parties to the UNFCCC in meeting their obligations under the Convention. No role of the GEF with regard to the Kyoto Protocol and the CDM is currently defined.

The GEF has two long-term climate change operational programmes which deal with removing implementation barriers for technologies. One is for energy efficiency projects, and the other is for renewable energy projects. In addition, the GEF has one long-term climate change operational program which deals with reducing the costs of promising technologies. The GEF may also finance climate change projects that reduce greenhouse gases in the short term, even if they are not part of an operational program. Such projects will be funded if they are country priorities, cost-effective in the short term, and likely to succeed. Finally, the GEF provides support for climate change enabling activities. Enabling activities provide the foundations to address climate change through country-driven activities including "planning and endogenous capacity building, including institutional strengthening, training, research, and education, that will facilitate implementation, in accordance with the Convention, of effective response measures".

The GEF is a fund which provides new and additional grant and concessional funding to meet the agreed incremental costs of projects, in order to achieve global environmental benefits in climate change, whereas the CDM is a mechanism to encourage and stimulate private sector investment in cleaner and more efficient technologies in developing countries by providing carbon credits.

3.6. ROLE OF UNDP - UNDP'S APPROACH TO THE CDM AND SUSTAINABLE DEVELOPMENT

UNDP's support for climate change activities recognises that reductions in the growth of greenhouse gas (GHG) emissions need to be accomplished through activities that meet immediate objectives, such as poverty alleviation, employment creation, energy and resource utilisation, and infrastructural planning and development. Accordingly, the UNDP programme approaches the CDM as a mechanism for facilitating the process of sustainable socio-economic development, while implicitly benefiting the global environment. A strategic objective of UNDP's approach to climate change is, therefore, to help identify and implement programmes and policies that maximise development objectives and, at the same time, limit GHG emissions.

UNDP is already assisting over 100 developing countries with formulating national climate change action plans and strategies, as well as with preparing their initial national communications to the UNFCCC. This assistance aims to integrate the process of climate change planning with economic planning and to ensure consistency with national development priorities. In addition, the UNDP Energy and Atmosphere Programme (EAP) is now promoting a strategic approach to energy under the UNDP Initiative for Sustainable Energy (UNISE). This initiative is consistent with the objectives of the UNFCCC.

UNDP's central goal is the eradication of poverty through sustainable human development. Many of UNDP's activities involve the reconciliation of the need for sustainable development with the mitigation of and adaptation to climate change through both socio-economic development and environment protection. The UNDP programme in support of the UNFCCC and the Kyoto Protocol considers climate change to be one aspect of a wider range of issues that must be addressed within the context of sustainable development. UNDP, therefore, views the CDM as an opportunity to assist its programme countries with achieving sustainable development. Specifically, reductions in the growth of greenhouse gas (GHG) emissions should be included as a significant output of the activities which are being carried out to meet immediate objectives related to such issues as poverty alleviation, employment creation, energy and resource utilisation, and infrastructure planning and development.

3.6.1. UNDP's Pilot Programme for CDM Capacity Building

Following COP 4 in Buenos Aires in 1998, UNDP began capacity building in CDM project activities in Peru, the Philippines, and South Africa. Similar capacity-building assistance related to other provisions of the Kyoto Protocol had previously been established in Bulgaria. The purpose of this work has been to explore, on a practical level, the issues and options raised by the Clean Development Mechanism and related project activities in different national contexts. This work involves national consultant teams working with public and private stakeholders. Activities have included:

(i) analysing possible areas for future CDM cooperation based on national development priorities;

(ii) identifying and formulating possible CDM projects for illustration purposes in different national contexts; and

(iii) convening stakeholder consultations at the local level.

Some of the findings obtained through the work are summarised herewith. Although the national circumstances differ substantially among the participating countries, a number of the experiences gained are viewed to be of general relevance.

Findings that may be considered in preparing strategies and building capacity relevant for the CDM include the following:

- **Win-win project opportunities** for promoting development while reducing the growth in greenhouse gas emissions exist in a number of areas in the participating countries. Priority areas identified for the CDM in these countries tend to relate to energy and the need for more efficient and environmentally sound technologies.

- Policy dialogue related to the CDM should be based on a cross-sectoral, inter-ministerial approach and further involve a broad range of stakeholders, including the private sector. **Timely and broad-based resolution of key issues**, including government endorsement or approval procedures for projects, will demonstrate commitment and stimulate investment under the CDM.

- In order to effectively capitalise on the considerable potential for win-win projects and effectively prepare for the CDM, participating countries should be proactive in clearly defining their sustainable development priorities and enacting **stable and effectively administered laws and regulations**, including labour laws, technical and financial standards, and environmental policies and standards.

- The presence of projects meeting the objectives of the Kyoto Protocol will make the CDM either succeed or fail. During formative stages, policies and programs should be refined using actual project models, i.e., through **learning-by-doing projects.**

- In order to be sustainable in the long term and on a sufficient scale to meet the sustainable development needs of the participating countries, investment projects will need to be implemented primarily through the private sector. Hence, the **effort to develop local capacity should address market issues**. In some cases, technology, project opportunities and financing may abound, but to little avail when there is a lack of real project developers.

- The **availability of innovative and development-oriented financial institutions** is crucial. Development finance institutions, commercial banks, merchant banks, or capital markets in the participating countries tend not to be fully equipped to assist private investors in the energy sector.

- Project case studies in the participating countries reveal that priority project options tend to have a high internal rate of return. Nonetheless, a number of such projects are not taken up by investors. Studies showing good rates of return and other favourable externalities are a necessary, but never sufficient, condition for project take-up by investors. There are also non-economic project barriers. For example, **barriers in relation to renewable energy projects include conservative markets, and transaction costs related to being an early mover**. The role of government policy and action is to sway the decisions of key individuals in the private sector towards those projects that will meet government's objectives.

- The international rules to be agreed for the CDM, including **baseline determination, should be simple in order to minimise transaction costs and requirements on host country institutions.** At the same time, host countries will need expertise to demonstrate that the GHG emission reductions from CDM projects are additional to business-as-usual in order to preserve the integrity of certified emission reduction units and thereby the CDM itself.

3.6.2. Future Activities

Under the coordination of the UNFCCC Secretariat, UNDP is developing a broad framework proposal for CDM capacity-building activities, in collaboration with UNEP, UNIDO, and UNCTAD. Building upon the experiences of the CDM pilot programme, UNDP is examining how it can most effectively serve the CDM capacity-building needs of developing countries. UNDP is planning future CDM-related activities within the framework of UNISE, in which the provision of clean and affordable energy is viewed as an instrument for socio-economic development.

The overall development objective of UNDP CDM capacity-building activities is to generate and understanding of the CDM process in the developing countries, and to help them develop institutional capability and human capacity to fully participate as equal partners with developed countries in the formulation and implementation of the CDM. Capacity-building activities will be aimed at building capacity at the national level to take advantage of sustainable development opportunities. Capacity building can be aimed at several levels and target groups. This includes assistance in:

1. Sensitising senior-level policy-makers on the benefits of the CDM and generating support from government officials in developing countries for participation in CDM activities, in order to help relevant government authorities meet national sustainable development priorities. The specific outputs include:
   - reporting on the assessment of the capacity for national involvement in and commitment to the principles of the CDM;
   - documentating the national value and benefits of participation in the CDM;
   - establishing a focal point agency (national CDM investment promotion office) to coordinate national CDM activities; and
   - organising national and regional workshops to introduce and discuss the CDM framework.

2. Developing the capacity among national policy makers to formulate a regulatory framework dealing with the regulatory, legal, financial, and technical issues that are unique to CDM projects, as well as helping with identifying and applying baseline parameters in accordance with international agreements. The specific outputs include:
   - reporting on the assessment of key government policy-makers in key ministries and agencies and enhanced capacities of key government policy makers to formulate the regulatory and legal framework for operationalising the CDM at the national level;
   - defining regulatory, legal, financial, and technical guidelines to govern the development, validation, implementation, monitoring, verification, and certification of CDM project activities; and
   - defining baseline parameters.

3. Supporting the establishment of a national organisational and institutional framework to identify, assess, validate, and implement CDM projects, as well as facilitating subsequent monitoring, verification and certification activities. The specific outputs include:
   - creating an operational national CDM entity responsible for the validation of CDM projects and for tracking the subsequent monitoring, verification, and certification of resulting emission reductions.

4. Helping strengthen the capabilities of the public and private sector players to identify, formulate, and secure financing for CDM projects. The specific outputs include:
   - strengthening the set of national public and private sector project developers who are knowledgeable about CDM project requirements and are capable of working with the CDM regulatory framework to gain approval for proposed CDM projects;
   - increasing the understanding among the national financial community/ banks of the potential value associated with the emission credits of CDM projects;
   - enhancing capacity within the public sector and research institutions to support project validation; and
   - collaborating actively to secure support for potential CDM projects of national public and private sector project developers and banks with equivalent international counterparts.

5. Supporting the creation of a pipeline of CDM-eligible projects and the institutional capability to help attract potential CDM investors. The specific outputs include:
   - creating national portfolios of validated CDM-eligible projects; and
   - securing investments for CDM-eligible projects.

In general, it is envisaged that these CDM capacity-building activities will be carried out through:

- **in-country dialogues** with the host country governments on strategic approaches to define the capacity required for the establishment of an appropriate regulatory framework, a national CDM entity, and definition of baseline parameters, leading to political endorsement and a needs assessment; and
- **training sessions and workshops** at various levels aimed at developing skills and increasing capacity to define a regulatory framework to support CDM activities, identify prospective CDM projects, formulate investment plans, validate CDM projects, monitor, and report the results of CDM activities.

3.7. CONCLUSIONS

The emerging CDM, as proposed under article 12 of the Kyoto Protocol (1997), constitutes an important potential instrument for promoting foreign investment in developing countries, while simultaneously addressing the issues of sustainable human development and reducing GHG emissions. As a market mechanism in the Kyoto Protocol that will involve both developing and developed countries, the CDM can provide potential opportunities for sustainable development in developing countries, while at the same time helping developed countries to reduce emissions.

Operational modalities for the CDM, which are expected to be agreed by COP 6, remain to be worked out. Effective guidelines for operation are required to attract private sector investments to developing countries. For such investments to contribute to sustainable development goals, the stated objectives of sustainable development must be clarified and quantified in accordance with development objectives of the countries concerned. UNDP, with its Country Offices and strong mandate on capacity building, should play an important role in capacity development and engaging in international policy dialogues on the CDM.

The capacity-building needs of developing countries related to the CDM are numerous and are still being fully defined. However, in the short term, the focus of capacity building assistance should be on raising awareness about the CDM, the issues and options surrounding its design and operation, as well as on preparing prototype projects which may potentially become applicable through the CDM at a later point in time when it becomes operational.

ANNEX 3-1. SELECTED CDM RELATED TERMINOLOGY

Ad Hoc Group on the Berlin Mandate, or **AGBM Working group,** was established by the first meeting of the Conference of the Parties (COP 1) to develop a process aimed at strengthening developed countries' commitments to greenhouse gas reductions in the post-2000 period through the adoption of a protocol or other legal instrument. The AGBM convened for the last time at COP 3 in Kyoto.

Additionality refers to the issue of whether greenhouse gas emissions reduction or sequestration in a Joint Implementation or Clean Development Mechanism project occurs over and above the baseline and constitutes a new reduction that would not have otherwise occurred without the existence of the project.

Allocation is the division of emissions permits or allowances among greenhouse gas emitters for the purpose of establishing a market in tradable permits. There are several possible methods for allocating permits, including "grandfathering" and permit auctioning.

Annex B Countries listed in the Kyoto Protocol are those developed countries that have agreed to a target for their greenhouse gas emissions, including those in the OECD, Central and Eastern Europe, and the Russian Federation. Not quite the same as Annex I, which also includes Turkey and Belarus, while Annex B includes Croatia, Monaco, Liechtenstein, and Slovenia.

Annex I to the UNFCCC lists all the countries in the OECD, plus countries with economies in transition in Central and Eastern Europe (excluding the former Yugoslavia and Albania). By default, the other countries are referred to as Non-Annex I countries. Under Article 4.2 (a & b) of the Convention, Annex I countries commit themselves specifically to the aim of returning individually or jointly to their 1990 levels of GHG emissions by the year 2000.

Annex II to the UNFCCC lists all countries in the OECD. Under Article 4.2 (g) of the Convention, these countries are expected to provide financial resources to assist developing countries in complying with their obligations, such as preparing national communications. Annex II countries are also expected to promote the transfer of environmentally-sound technologies to developing countries.

Assigned Amounts, under the Kyoto Protocol, are the total amounts of greenhouse gas emissions that each developed country has agreed not to exceed in the first commitment period (2008–12). This is calculated by multiplying the country's total greenhouse gas emissions in 1990 by 5 (for the five-year commitment period), and then by the percentage it agreed to, as listed in Annex B of the Protocol (e.g., 92 percent for the EU; 93 percent for the USA).

Auctioning of emissions permits is a method by which permits for greenhouse gas emissions may be allocated among emitters and firms in a domestic emissions trading regime, based upon willingness to pay for these permits. Supporters of this method of emissions trading assert that the advantage of auctioning is that it would provide governments with revenue and provide price signals to the new and developing market for permits. Critics contend that auctioning's disadvantage is that it may be less politically acceptable to those entities that would stand to gain from grandfathering of permits.

Banking entails saving emissions permits or Certified Emissions Reductions for future use in anticipation that these will accrue value over time.

Baseline is a projected level of future emissions against which reductions by project activities can be determined.

Bubble is a term which refers to a group of countries meeting their target listed in Annex B jointly, by aggregating their total emissions and sharing the burden, as allowed by Article 4 of the Kyoto Protocol. The EU nations intend to aggregate and share their emissions commitments under one bubble.

Carbon Sequestration is the long-term storage of carbon or carbon dioxide in forests, soils, oceans, or underground in depleted oil and gas reservoirs, coal seams, and saline aquifers. Examples include: the separation and disposal of CO_2 from flue gases or processing fossil fuels to produce H_2 and CO_2 rich fractions; and the direct removal of CO_2 from the atmosphere through land-use change, afforestation, reforestation, ocean fertilisation, and agricultural practices to enhance soil carbon.

Certified Emission Reductions (CERs) or Certified Emission Reduction Units (CERUs) are verified and authenticated units of greenhouse gas reductions from abatement or sequestration projects which are certified by the Clean Development Mechanism.

Clean Development Mechanism (CDM) is included in the Kyoto Protocol for project-based activities between Annex I and Non-Annex I countries. In Article 12.2 of the Protocol, the parties established the CDM for the purposes of assisting developing countries in achieving sustainable development and helping Annex I parties meet their emissions limitation and reduction obligations.

Climate Change *(UNFCCC definition)* is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods.

COP/MOP refers to the Conference of Parties to the UNFCCC which will also serve as the "MOP" (Meeting of Parties, the supreme body of the Kyoto Protocol). Only Parties to the Kyoto Protocol may participate in deliberations and make decisions. Until the Protocol enters into force, the MOP cannot meet.

Credit for Early Action taken before 2008 has been suggested by some governments. The intent is to stimulate investment in GHG abatement projects in developed countries in the years prior to 2008. Under the Kyoto Protocol, Annex B governments cannot receive credits towards their emissions obligations for actions aimed at reducing greenhouse gas emissions prior to the first commitment period (2008-2012), except under the Clean Development Mechanism (i.e., in developing countries only). Governments may choose to give credits prior to the first commitment period.

Emissions Trading is an economic incentive-based alternative to command-and-control regulation. In an emissions trading program, sources of a particular pollutant (most often, an air pollutant) are given permits to release a specified number of tons of the pollutant. The government issues only a limited number of permits consistent with the desired level of emissions. The owners of the permits may keep them and release the pollutants, or reduce their emissions and sell the permits. The fact that the permits have value as an item to be sold or traded gives the owner an incentive to reduce their emissions.

Flexibility mechanisms, as established by the Kyoto Protocol, seek to increase the flexibility and reduce the costs of making emissions reductions. The three main mechanisms contained within the Protocol are the Clean Development Mechanism, emissions trading, and Joint Implementation (or activities implemented jointly).

Grandfathering of emissions permits is a method by which permits for greenhouse gas emissions may be allocated among emitters and firms in a domestic emissions trading regime, according to their historical emissions. Supporters of grandfathering assert that this would be administratively simple, but some critics argue that this method would reward firms with high historical emissions and unfairly complicate entry into markets by new firms and emitters.

Greenhouse Gases are the gases in the Earth's atmosphere that absorb heat radiated from the Earth's surface back into space. These gases occur through both natural and human-influenced processes. The major GHG is water vapor. Other GHGs include carbon dioxide, nitrous oxide, methane, ozone, and cluorofluorocarbons (CFCs).

Intergovernmental Panel on Climate Change, or **IPCC,** was established in 1988 by governments under the auspices of the World Meteorological Organisation and the UN Environment Programme. The IPCC prepares assessments, reports, and guidelines on the science of climate change, its potential environmental, economic, and social impacts, technological developments, as well as possible national and international responses to climate change and crosscutting issues. It provides advice to the UNFCCC's Conference of the Parties. It is currently organised into 3 Working Groups which address: I) Science; II) Impacts and Adaptation; and III) Mitigation; there is also a Working Group to address GHG Inventories.

Joint Implementation (JI) is a concept whereby industrialised countries meet their obligations for reducing their greenhouse gas emissions by receiving credits for investing in emissions reductions in Annex I countries. Proponents of joint implementation argue that such an international trade in emissions credits would achieve greenhouse gas reductions in industrialised countries at much lower costs.

Non-Annex I Parties are the countries that have ratified or acceded to the UNFCCC, which are not included in Annex I of the Convention.

Non-Annex B Parties are the countries that are not included in the Annex B list of developed nations in the Kyoto Protocol.

No Regrets Options are actions which result in greenhouse gas reductions, and which also make good environmental and economic sense in their own right. These actions are often also called "win-win" options.

Subsidiary Body for Implementation, or **SBI,** is established as a permanent standing body of the UN Framework Convention on Climate Change. It develops recommendations to assist the Conference of the Parties in assessing and reviewing the implementation of the Climate Convention.

Subsidiary Body for Scientific and Technological Advice, or **SBSTA,** is established as a permanent standing body of the UNFCCC, serving as the link between the policy-oriented needs of the COP and the scientific, technical, and technological assessments and information provided by various external groups, such as the Intergovernmental Panel on Climate Change.

Supplementarity refers to whether parties of the Kyoto Protocol, while using flexibility mechanisms such as emissions trading to lower greenhouse gas mitigation costs, also institute adequate domestic energy and other policies for ensuring the achievement of long-term greenhouse gas reduction goals.

Targets and Timetables relate to the total amount of GHG emissions that can be emitted by a country or region in a given time period. A target is the reduction of a specific percentage of greenhouse gas (GHG) emissions (e.g., 6 percent, 7 percent) from a baseline date (e.g., "below 1990 levels"), to be achieved by a set date or a timetable (e.g., 2008-2012).

QELROs, or **Quantified Emissions Limitations and Reductions Objectives** are the greenhouse gas emissions reduction commitments made by developed countries listed in Annex B of the Protocol (see also "Targets and Timetables").

4

OPPORTUNITIES FOR
SUSTAINABLE ENERGY

RENEWABLE ENERGY

4.1. INTRODUCTION

4.1.1. Renewable Energy for Rural Development

Sustainable human development requires a focus on improving the access of the poor to assets, goods, and services such as food (and the means to prepare it), water for drinking and irrigation, adequate shelter, health care, sanitation, education, and employment. In defining these general needs, energy plays a central role. Current patterns of energy supply and use are intimately linked with many of the hardships endured by the poor. Therefore, meeting the needs of the poor and promoting sustainable human development requires transforming and expanding the provision of energy services. (See Chapter 1 for a more complete discussion of the links between energy and the challenges of sustainable development.)

This chapter identifies possibilities for the sustainable use of renewable energy technologies to satisfy these basic needs and to support poverty alleviation and sustainable human development. It presents a range of commercially-available, field-proven renewable energy technologies, examples of renewable energy applications, and supportive policy and institutional frameworks.

There is a large and growing menu of commercially-available field-proven renewable energy systems based on solar energy, wind energy, biomass resources, and hydropower. Many of these were developed, adapted, and deployed to satisfy the energy needs for households, enterprises, and communities in rural areas. Heat requirements for cooking, baking (both at the household and community level), water heating, space heating, water pasteurisation, grain sterilisation, and food drying can all be provided by solar thermal energy or by fuels derived from renewable biomass resources. Virtually all other end-use requirements, including lighting, entertainment, telecommunication, refrigeration, water pumping and purification, grain grinding, food processing, and so forth, can be provided by renewable energy equipment that produces electricity from sunlight, wind, biomass, and hydropower. Many commercially-available renewable energy technologies can provide much greater technical and financial flexibility in meeting an array of local household, community, and economically-productive energy needs, at potentially lower costs than grid extension.

4.1.2. Renewables are Viable and Available

Rural communities in virtually every nation have helped demonstrate the viability of renewables for priority applications. For example, there are several hundred thousand solar home systems in almost every country, providing basic electricity services to off-grid rural households. Solar photovoltaic (PV) and wind-electric water pumping systems are providing reliable clean water supplies. Biomass energy conversion technologies are newly available for reliable production of AC power generation, on a scale that matches the electricity needs of many off-grid rural communities worldwide.

Renewable energy technologies offer opportunities that allow rural communities and community-focused development organisations to make informed choices about their use. This chapter is designed to assist various stakeholders in understanding the possible applications of renewable energy technologies and to provide a means to access the relevant information, expertise, and equipment.

4.2. POTENTIALS FOR RENEWABLE ENERGY[1]

4.2.1. Theoretical Potentials

The world has vast and virtually inexhaustible renewable energy resources. The solar energy falling each year on the Earth's land surface amounts to 800,000 EJ, or nearly 2,000 times the 425 EJ of current annual global energy use. Using just one percent of the world's land surface that is not farmed or under forests and woodlands could tap 5,000 EJ per year. The heat that could theoretically be tapped each year from the top 5 km of the earth's crust is a massive 140 million EJ, of which a sizeable 5,000 EJ per year could become economic within the next 40-50 years.

Theoretical resources for other renewables are more modest, yet in the same range as today's total global energy use. The world's hydroelectricity potential is estimated at 40,500 TWh per year, or nearly 490 EJ per year in terms of primary energy. The equivalent figure for wind energy is 231 EJ. This assumes that no more than 4 percent of the global land area having adequate wind speeds is used for wind farms.

The theoretical potential for biomass energy is more controversial, as it depends both on land availability and on achievable biomass yields on this land. Various studies have suggested that by 2050 biomass might contribute an annual 100 to 280 EJ to global energy supplies. Assuming a biomass yield of 10 dry tons per hectare per year, as used in most of these studies, 500 million to 1,400 million hectare of land would have to be devoted to biomass energy crops. Today, 1,500 million hectares are used globally for cropland and 3,400 million hectares for permanent pasture.

[1] *Much of the data in this section is adapted from* The World Energy Assessment, *a report providing an evaluation of the social, economic, environmental, and security issues linked to energy, and the different energy options in these areas. The WEA will be offered as informal input into the CSD-9 process. The current draft of the report can be found at www.undp.org/seed/eap/activities/wea.*

BOX 1 . RELIABLE HIGH-RESOLUTION WIND DATA STIMULATE WIND ELECTRIC PROJECT DEVELOPMENT

A high-resolution (1 km) wind resource map of the entire Philippines archipelago was completed in early 1999, revealing a theoretical potential for commercial wind electric power generation well in excess of 100,000 MWe. The total installed generating capacity in 1999 was 12,000 MWe. Several thousand MWe or more of commercial wind farms could be developed over the next 15 years, at locations that meet the criteria for wind farm development, including proximity to all-weather roads, transmission corridors, and load centres. Prior to this wind resource assessment, conducted by the US National Renewable Energy Laboratory and the Government of the Philippines, it was thought that the practical potential for commercial wind electric power development was only a few hundred megawatts. The availability of reliable wind resource data has catalysed both public and private-sector wind electric power development activities. It is now expected that there is going to be significant wind electric power development in the country over the coming decade.

4.2.2. Technical, Economic, and Market Potentials

Theoretical resource potentials are much larger than the *technical potentials*, which take into account a host of practical, social, and environmental constraints. Technical potentials are, in turn, usually larger than the *economic potentials*, the technically-feasible resources that can be exploited in a cost-effective manner. The market potential is another useful measure that indicates the amount of energy for which there is an effective market demand. This demand can be increased by a variety of policy or project interventions, as described below.

For example, while the theoretical potential for world hydropower is 40,500 TWh/year, the present technically feasible potential is put at 14,320 TWh/year, and the economic potential at 8,100 TWh/year. Although the latter is down by a factor of five on the theoretical maximum, it is three times the current global hydropower production of 2,600 TWh/year.

Assessments of technical, economic and market potentials are much more relevant to present day development challenges than are the theoretical potentials. They are also much harder to estimate. They are dynamic estimates that reflect changing market conditions and improvements in technology costs and performance. Geographic, social, environmental, technical, and economic factors all must be considered to obtain reasonably robust estimates. These must be developed from detailed, multi-factor, local assessments. A combination of demand-side (or "bottom-up") and supply-side (or "top-down") analyses provides the most realistic assessment for the potential use of renewable energy conversion options.

An example of renewable energy resource estimates is presented in Box 2. It demonstrates the large differences between theoretical, technical and economic resources, as well as illustrates some of the practical and economic factors that may have to be taken into account when making renewable resource assessments at the national, sub-national, or project level.

4.2.3. Local Resources and Project-Level Estimates

The Kenya example shows that realistic resource estimates must be based on detailed surveys. Renewable energy resources are highly local in character; their availability, variability, and intensity vary enormously from place to place. Local factors also dictate where resources can best be exploited. For projects designed to distribute energy widely, factors such as proximity to the power distribution network or to good roads and urban markets, are typically major siting criteria and constraints. With stand-alone applications, energy production is limited to the size of the [anticipated] local market demand, and to local purchasing power, however large the local renewable resource.

In other words, fairly detailed bottom-up appraisals, much like a series of project assessments, must be used both to harness renewable energy resources and to estimate the

BOX 2 . BIOMASS ELECTRICITY IN KENYA

A recent study[2] estimated how much electricity might be generated from biomass for off-grid villages in Kenya. The study is important for national development strategies. There is a huge latent demand for affordable electricity services, 99% of rural populations are not connected to grid-based supplies, and the country has no known fossil fuel reserves. The study was based on comprehensive surveys of the three most likely wood-energy sources: government forests and logging wastes, farm trees, and sawmill wastes.

- **Government forests cover 12,200 km^2 and give rise to about 240,000 tons a year in logging wastes. If converted to electricity at 45% efficiency using modern gasifiers and gas turbines, energy production would be a useful 480 GWh/year—some 12.5% of total national production (3,800 GWh in 1996). However, detailed assessments have shown that logging sites are so remote from potential target villages that connection costs can be prohibitively expensive.**
- **The second possible resource—farm forestry—also has been ruled out. While large in total and close to the potential demand centers, wood production on each farm is for multiple uses, while volumes are individually too small and scattered to allow economic collection and delivery to a central village power plant.**
- **The third possible resource—wood processing residues—was more promising. A survey of the country's 325 sawmills found that 73 produced more than 1,000 cubic meters of logs annually, the threshold at which it might be economic to install a wood gasifier fed by the logging residues and powering a gas turbine or diesel generator. Together, these mills produced 120,000 tons of wood residues per year. If all of this were put into power production, annual output would be a respectable 76 GWh of electricity—about 2% of the national total and sufficient to provide 200,000 household with basic electricity services of one kWh daily. This figure estimated the technically-accessible resource.**

The practicable and economic resources were not estimated by the study. They involved technical and financial constraints that would have to be addressed by implementation of projects in order to be successful. For example, saw mill sizes were highly skewed—some 43% of the resource was due to the five largest mills—and it is the larger plant that was most likely to have the technical and financial capacity to replace its well-tried diesel generators with high-capital wood gasifiers and turbines—assuming this switch was financially justified. For the same reason, they were the most likely to have spare electricity to export to any nearby villages. The practical and economic implications of connecting villages to sawmill generation plant, and the resulting costs and affordability of village power supplies, can be determined only by detailed technical and economic assessments at the individual plant and village level.

realistically-available size of each resource for a region or country—perhaps as a guide for national or regional indicative policy and planning targets. Renewable energy resource estimates that lack such underpinning are somewhat suspect.

Some of the key technical and economic factors which need to be considered in local resource and project assessments are reviewed in Sections 3 and 4 of this chapter. A key premise is that in most developing countries, the economically exploitable renewable energy resource can be greatly increased by enhancing the demand for energy services in various ways.

4.2.4. Expanding Market Potential

In industrialised countries, renewable energy is deployed mainly for environmental reasons, to replace fossil fuels. In developing countries, especially in rural areas, renewables are now used mainly to provide first-time access to strongly-desired modern energy services, such as clean water supply or electric power, to fulfil basic needs. However, the demand for these renewable energy services is fairly low, because only a small amount of energy is required to provide these services, and because of the relatively high costs of renewables relative to the incomes of poor households.

Breaking this constraint can set up a virtuous circle of more energy services, lower costs, and more renewable supplies.This is for two reasons. First, it is because most renewable technologies enjoy large economies of scale—larger installations cost less per unit of output than smaller ones, and both provide lower-cost energy services if used for more hours each day. Second, many energy services, because

[2] *Senelwa, K. & Sims, E.E. (1999). "Opportunities for small scale biomass-electricity systems in Kenya",* Biomass & Bioenergy*, 17: 239-255.*

they can enable income generating activities, spur a demand for yet more energy services. A key energy/development strategy is, therefore, to consolidate the demand for energy services from individual users such as separate households, community establishments (school, water supply, health clinic), and other users. A second strategy is to integrate the provision of energy services with income-generating activities, for example, activities that increase farm productivity (e.g., irrigation), enhance the ability of communities to add value to agricultural goods and market them (grain milling, baking, refrigeration, storage and transport), and generate other marketable products (manufactured and artisanal products) which provide social and economic development gains.

Estimates of market potential based on demand-enhancing strategies like the above are a long way from the theoretical resource assessments which opened this section. They provide a rather more relevant and positive perspective on renewable energy implementation, and they make explicit the connection between renewables and human development.

4.3. RENEWABLE ENERGY OPTIONS: THE TECHNOLOGIES

4.3.1. Practical Options for Using Renewable Energy Resources

Renewable energy resources include sunlight and energy derived from the conversion of sunlight in the Earth's ecosphere. These include wind energy, biomass (especially residues from commercial activities), and the hydro potential of flowing water. A broad evolving menu of renewable energy options is available for application, both for large-scale grid-connected applications and for off-grid use. Many are fully commercial and field-proven, and many applications are cost-effective on an annualised basis, compared with fossil fuel energy. In other cases, the energy services provided by renewable energy options may be more expensive than fossil-fuel options, but their higher reliability, longevity, and ease of maintenance may make them the preferred option. Relevant technologies include wind electric power, photovoltaics (solar electric power), solar heating, small hydropower, and biomass energy conversion systems for production of heat, electricity, or both.

Other technologies such as PV/wind/diesel hybrid power plants for village power applications are relatively new and, although commercially available, are not yet used on a large scale. Still others are under intensive commercial development, but not yet available for commercial use. An example is the technology for small modular biopower units in the 10 kWe to 100 kWe range. Table 1 indicates the status and scale of applications for renewable energy options of special relevance in the developing world.

This section provides brief descriptions of available practical renewable energy conversion equipment, such as photovoltaic modules and systems, wind electric turbines, wind mechanical water pumping, hybrid (wind/PV/fossil fuel) power generation units, solar heating systems, and hydro-turbines for electricity production. It also briefly discusses emerging technology options, such as fuel cells. For equipment that generates electricity, applications for stand-alone uses, local minigrid power, and connection to large regional and national power grids are described.

While this material is meant to be informative, it is only an introduction to renewable energy options, and far more information and data is required to make decisions regarding the use of any of the options described here. Detailed data, information, technical, and financial analysis tools are widely available in other documents, on CD-ROM, in renewable energy equipment catalogues, and on the Internet. The Internet has become the most comprehensive, up-to-date, and valuable source

TABLE 1. RENEWABLE ENERGY TECHNOLOGIES FOR OFF-GRID AND MINI-GRID APPLICATIONS

TECHNOLOGY	EXPERIENCE WORLDWIDE	COMMERCIAL STATUS
Photovoltaics	**Extensive**	**Fully commercial**
Wind mechanical water pumps	**Extensive**	**New commercial designs offer increased reliability and improved performance**
Small wind electric	**Extensive**	**Commercial and evolving rapidly**
PV/diesel hybrids	**Extensive, especially for telecommunications worldwide**	**Fully commercial and the preferred option for remote telecommunications, commercially evolving for village power**
Wind/diesel hybrids	**Significant, not yet extensive**	**Commercial, competitive, and evolving**
Small modular biopower units (10 kWe to 100+ kWe)	**Some**	**Under development, first commercial products becoming available**
Small packaged biopower units (100 - 500 kWe)	**Some**	**Limited but expanding commercial availability; expanded commercialization underway**
Bioenergy > 0.5 Mwe	**Extensive, in wood and agro industries worldwide**	**Commercial site-engineered systems**
Microhydro electric	**Enormous (e.g., China, Nepal, Vietnam)**	**Fully commercial, with innovative products emerging**

of practical information on renewable energy equipment availability, perfor-mance, and price. Much of this information is also available in CD-ROM format. References can be found in this section and supplementary annexes.

4.3.2. Biomass Energy[3]

4.3.2.1. Traditional and Modernised Uses of Biomass for Energy

Currently, biomass energy is used in a vast range of different ways, based on different feedstocks, conversion technologies, and end uses.It has played, and continues to play, a central role in most developing countries—accounting for an estimated one-third of primary energy use—but almost entirely via traditional means, rather than modernised technologies. Over 2 billion people cook by direct combustion of biomass, invariably involving the inefficient use of biomass fuels, largely from low-cost sources such as dung and natural forests. Biomass fuels as used in developing countries today have been called "the poor man's oil", because direct use by combustion for domestic cooking and heating ranks it at the bottom of the ladder of preferred energy carriers.

Biomass might more appropriately be called "the poor woman's oil", as women (and children) in rural areas spend a considerable amount of time collecting daily fuelwood needs and suffer the brunt of indoor air pollution and the resulting respiratory and eye infections caused by direct combustion of biomass for cooking and heating. An astounding 58 percent of *all* human exposure to particulate air pollution is estimated to occur indoors, in rural areas of developing countries.

The picture of biomass utilisation in developing countries sharply contrasts with the picture in industrialised countries. On average, biomass accounts for only 3 or 4 percent of total energy use in the latter, although where policies supportive of biomass use are in place, e.g. in Sweden, Finland, and Austria, the biomass contribution reaches 15 to 20 percent. Very little of this is domestic applications for cooking and heating. The vast

[3] *This treatment of modern bioenergy technologies is adapted from* A Bioenergy Primer: Roles for Modernised Biomass Energy Systems in Promoting Sustainable Development, *recently published by the Energy and Atmosphere Programme of the UNDP.*

majority is converted into electricity and heat at industrial sites or at municipal district heating facilities, which enables a greater variety of energy services to be derived from the biomass and much cleaner and more efficient use of the available biomass resources than is typical in developing countries.

4.3.2.2. The Diversity of Biomass Feedstocks

Bioenergy resources take many forms. A broad classification of these includes: (1) residues and wastes; (2) energy crops; and (3) natural vegetation.

The production of biomass residues and wastes globally, including byproducts of food, fiber and forest production, exceeds 110 exajoules per year at present, perhaps 10 percent of which is used for energy. (This can be compared to a global primary energy demand of roughly 425 exajoules.) Residues concentrated at industrial sites, e.g., sugarcane bagasse and sawmill residues, are currently the largest commercially used biomass source. Some residues cannot be used for energy. In some cases collection and transport costs are prohibitive; in other cases, agronomic considerations dictate that residues be recycled to the land, and in others still, there are competing non-energy uses for residues (as fodder, construction material, industrial feedstock, etc.).

Residues are an especially important potential biomass energy source in densely populated regions, where much of the land is used for food production, since crops can generate large quantities of byproduct residues. For example, in 1996, China has generated crop residues in the field (mostly corn stover, rice straw, and wheat straw) plus agricultural processing residues (mostly rice husks, corn cobs, and bagasse), totalling about 790 million tonnes, with a corresponding energy content of about 11 exajoules. To put this in perspective, if half of this resource were to be used for generating electricity at an efficiency of 25 percent (achievable at small scales today), the resulting electricity generation would be about half of the total electricity generated from coal in China in 1996.

There is also significant potential for providing biomass for energy by growing crops specifically for this purpose. However, dedicating land to the production of energy crops could intensify competition with other important land uses, especially food production. This competition between land use for agriculture and for energy production may be limited if degraded lands can be targeted for energy crops. There are many technical, environmental, socio-economic, political, and other challenges involved in successfully establishing energy crop plantations on degraded lands. Where these challenges can be overcome, it may be possible to use energy crops to help restore to greater productivity some portion of the many hundreds of millions of hectares that have been classified as degraded in developing countries.

Two approaches to producing energy crops include: (1) devoting an area exclusively to production of such crops; and (2) integrating the production of energy and non-energy crops, either on the same piece of land (agro-forestry) or on adjacent pieces of land (farm forestry). The co-production approach might also facilitate meeting environmental and socio-economic criteria for land use. Farm forestry activities in Brazil have been especially successful at involving small farmers in the high-yield production of biomass feedstocks. There is also extensive experience in small-scale fuelwood production in India, China, and elsewhere.

4.3.2.3. "Modern" Bioenergy Technologies

Biomass energy has the potential to be "modernised" worldwide, i.e., produced and converted efficiently and cost-competitively into more convenient forms such as gases, liquids, or electricity. Table 2 lists a variety of technologies (discussed below) which can convert solid biomass into clean, convenient energy carriers over a range of scales from household/village to large industrial. Most of these technologies are commercially available today. If widely implemented, such technologies can enable biomass energy to play a much more significant role in the future

TABLE 2. TECHNOLOGIES FOR MODERNISED CONVERSION OF BIOMASS ENERGY AND ENERGY SERVICES THAT THEY PROVIDE

TECHNOLOGY	SCALE	ENERGY SERVICES PROVIDED
Biogas	**Small**	**Electricity (local pumping, milling, communications, refrigeration, etc. and possible distribution via utility grid)** **Cooking** **Heating**
Producer Gas	**Small to medium**	**Electricity (local pumping, milling, communications, refrigeration, etc. and possible distribution via utility grid)** **Cooking** **Heating**
Ethanol	**Medium to large**	**Vehicles** **Cooking**
Steam turbine	**Medium to large**	**Electricity (for industrial processing and grid distribution)** **Heating (process heat)**
Gas turbine	**Medium to large**	**Electricity (for industrial processing and grid distribution)** **Heating (process heat)**

than it does today, especially in developing countries. Note: there have also been considerable technological advances in the use of biomass as a cooking fuel, through the use of improved cooking stoves. See Chapter 1 of this volume for more information.

Anaerobic digestion of biomass to provide biogas

Combustible gas can be produced from biomass through a low-temperature biological process, or through a high-temperature thermochemical processes (e.g., gasification, discussed below). After appropriate treatment, the resulting gases can be burned directly for cooking or heat supply, or they can be used in secondary conversion devices, such as internal combustion engines for producing electricity or shaft work.

Biogas is the common name for a gas produced by the biological process of anaerobic digestion of organic material. Almost any biomass (except lignin, a major component of wood) can be converted to biogas, which is about 60 percent methane and 40 percent carbon dioxide. Animal and human wastes, sewage sludge, crop residues, carbon-laden industrial processing byproducts, and landfill material have all been widely used. High-moisture feedstocks are especially well-suited for anaerobic digestion.

Non-energy benefits include the production of a sludge that provides a concentrated nitrogen fertiliser that is more readily usable than the biomass feed to the digestor. Digestion also provides for environmental neutralisation of wastes by reducing or eliminating pathogens, and/or by reducing the polluting components of dung and feed materials. Significant declines in parasite infections, enteritis, and bacillary dysentery have been noted in some developing country regions following installation of small-scale digesters.

BOX 3. WIDESPREAD EXPERIENCE WITH ANAEROBIC DIGESTION

Some 7 million household-scale digesters have been installed in China for pig manure and human waste, and over 1.85 million cattle-dung digesters have been installed in India by the mid-1990s. About half of these are no longer working, however, for a variety of reasons including insufficient or improper feedstock supply, and poor construction and repair techniques. Since then, research, development, and dissemination activities have focused greater attention on proper construction, operation, and maintenance of digesters. China also has some 25,000 large-scale digesters operating at large pig farms, other agro-industrial sites, and urban sewage treatment plants. In addition to wide operation of biogas digesters in other developing countries (most notably South Korea, Brazil, Thailand, and Nepal), an estimated 5000 digesters are installed in industrialised countries, primarily at large livestock processing facilities (stockyards), municipal sewage treatment plants, food processing plants, and other industrial facilities.

The basic technological requirements for a biogas digester are simple: water, a sealed environment, and a high enough temperature sustain bacterial activity. Biogas has been successfully produced for hundreds of years, at a variety of scales. Concrete, metal, and plastics have all been effective digester building materials—providing designs that are relatively inexpensive and technologically simple to build and maintain.

Main applications of biogas include:

- *Cooking:* Biogas can be used as a household or service-sector cooking fuel. To distribute biogas for cooking, piping is required, with provision made for removing water that may condense out of the gas in the pipes. Biogas burners are required at cooking points.
- *Electricity or shaft power:* Biogas can be used to fuel internal combustion engines, such as diesel (compression-ignition) engines or gasoline (spark-ignition) engines with only minor modification. Diesel engines are favoured because of their higher efficiency, greater durability and reliability, simpler maintenance, and because diesel fuel (as a backup) is more readily available than gasoline in most developing countries. A disadvantage of the diesel engine is that it requires continuous use of some diesel fuel (typically around 15 percent of normal diesel fuel consumption), whereas spark ignition engines can be operated on pure biogas.

Gasification of biomass to provide "producer gas" for small-scale applications

Thermochemical gasification involves, in essence, burning biomass without sufficient air for full combustion, but with enough air to convert the solid biomass into a gaseous fuel. The intended use of the gas and the characteristics of the particular biomass (size, texture, moisture content, etc.) determine the design and operating characteristics of the gasifier and associated equipment. A gasifier supplier specifies the characteristics of the biomass required for satisfactory performance. For small-scale applications, biomass gasifiers consume from about 5 kg/hour up to about 500 kg/hour of biomass input.

Recent research efforts have produced gasifier and gas cleanup system designs that largely eliminate the technical problems that plagued earlier designs. The process of transferring these research findings into commercial products is ongoing, as interest in gasification has again revived with the growing recognition of environmental and quality-of-life improvements that can be derived from gasifier/engine technology in village-scale electricity generation. Unlike with the previous resurrection efforts, systems are now being offered commercially, with warranties and performance guarantees, by a growing number of companies worldwide. Main applications include:

- *Cooking*: Some gas cleanup is required after gasification to avoid downstream buildup of contaminants. There are a growing number of projects involving cooking applications today, especially in China. Cooking with producer gas offers several advantages over traditional direct biomass burning, including more efficient overall use of the primary biomass resource, reduced indoor smoke and particulate levels leading to improved respiratory health, and reduced fuel collecting time. An important safety concern with producer gas cooking is the toxicity of the carbon monoxide component of the gas. One way to address this concern is to add a non-toxic odour to the gas for early detection of leaks. Educating users about the safety of producer gas is especially important.
- *Direct heating:* One successful recent application of producer gas has been to replace fuel oil or coal in industrial boilers, furnaces, and kilns. This is especially appealing in industries that produce agricultural waste products that can fuel the gasifier.
- *Electricity or shaft power generation:* As with biogas, producer gas can be used in an internal combustion engine. The gas should be cooled and cleaned thoroughly, and can then typically replace 60-70 percent of the diesel fuel requirements of a compression-ignition engine, or 100 percent of the gasoline requirements of a spark-ignition engine.

Steam turbine technology for electricity production

Today, in all parts of the world, the predominant technology for electricity generation from biomass at scales above one megawatt is the steam-Rankine technology. This involves burning biomass in a boiler to raise steam, which is then expanded through a turbine to drive a generator and create electricity. The steam-Rankine cycle is a mature technology introduced into commercial use about 100 years ago. Most steam cycle plants are located at industrial sites, where the waste heat from the steam turbine is recovered and used for meeting industrial process heat needs.

The simplest and oldest boiler designs are for small-scale systems, manually-fed brick-lined burners in which the biomass burns in a pile. More sophisticated techniques have been developed as well, yielding a higher efficiency of electricity production. Generally, turbines in biomass power plants operate with far more modest steam conditions than are used in large, modern electric-utility coal-fired systems. Efficiencies in biomass power plants are typically 14-18 percent (with the very best being 20-25 percent), compared to 35 percent for a modern coal plant.

BOX 4. ELECTRICITY FROM BIOMASS

In the USA, the installed biomass-electric generating capacity exceeds 8000 MW_e, with the majority of this capacity using residues from pulp and paper mills or agricultural processing plants. A significant number of biomass power plants are also found in Scandinavia, especially Sweden, where such systems are used for combined district heating and power production. Most steam-Rankine capacity in developing countries uses bagasse produced at sugar or ethanol factories.

Gas turbine technology for electricity production

Gas turbines fuelled by gasified biomass are of interest for power, or combined heat and power generation in the range of 5 to 100 MW_e. The biomass-gasifier/gas turbine (BIG/GT) technology is not commercially employed today, but intense worldwide interest is likely to lead to its commercial availability within a few years' time, based on the substantial demonstration and commercialisation efforts ongoing worldwide today. Three of the most advanced demonstration projects are in Sweden, the UK, and Brazil. At Varnamo, Sweden, a BIG/GT system has been operating for several thousand hours on forest residues, generating 6 MW of electricity and 9 MW of heat for the local district heating system. At Yorkshire, England, construction is nearly complete of a BIG/GT facility that is designed to generate about 8 MW of electricity from biomass plantations. At a site in the state of Bahia, Brazil, construction is planned to begin in 2000 of a 32 MW BIG/GT power plant using plantation-grown eucalyptus for fuel. The facility also plans to test the use of sugarcane bagasse as a fuel. The Brazil demonstration project is supported by a grant from the Global Environment Facility.

The interest in BIG/GT technology derives from the fact that it enables electricity to be made at double or more the efficiency of the steam cycle (discussed above), which is currently the technology of choice for generating electricity from biomass at similar scales. Moreover, the cost of commercially mature BIG/GT units is expected to be lower than comparably-sized steam cycles. Thus, the overall economics of biomass-based power generation are expected to be considerably better with a BIG/GT system than with a steam-Rankine system. It is expected that electricity can be generated at competitive costs even from higher-cost biomass from dedicated energy plantations

A BIG/GT system involves sizing and drying of the feedstock, followed by gasification (as discussed above) to produce a combustible gas, cooling and cleaning of the gas, and combustion in a gas turbine that drives a generator. Additional power and/or steam for heating purposes can be produced using the hot exhaust of the gas turbine.

Ethanol

Ethanol is a clean-burning alcohol fuel made from biomass. Ethanol can be blended with gasoline up to a maximum ethanol content of about 25 percent for use in standard gasoline-fuelled engines, or alone in internal combustion engines specifically designed for ethanol. Ethanol can be produced from a variety of biomass crops, including starchy crops like corn, sugary crops like sugarcane or sugar beets, and cellulosic feedstocks like wood or grasses. Sugarcane is grown in over 80 developing countries, and provides the least costly route for producing ethanol from biomass today. With further technological developments, the economics of ethanol production from other crops might improve.

At an ethanol distillery, raw sugarcane is washed, chopped, and crushed in rolling mills to separate the sugar-laden juice from the fibre in the cane, called bagasse. The juice is filtered, heated, in some cases concentrated, fermented, and distilled. A typical distillery size in Brazil is 120,000 litres per day, which consumes roughly 1600 tons of sugarcane per day. Although this is, of course, not a small-scale bioenergy application, it is rurally based and can provide revenue and jobs for rural areas.

4.3.2.4. Social and Environmental Impacts

One can imagine a wide range of potential socio-economic and environmental impacts of biomass energy systems. Bioenergy projects are likely to have large impacts, compared to many other energy projects, whether intended or not, for two main reasons: bioenergy is land-intensive and labour-intensive. Therefore, because bioenergy systems interact extensively with their environmental and socio-economic surroundings, they *necessarily* transform their surroundings; *bioenergy strategies are not merely self-contained "energy projects".* Actual environmental impacts depend on how the biomass is produced and used for energy, and the socio-economic impacts related to how production and use are integrated with people and institutions. Consideration of such impacts has often been treated as secondary in the planning and implementation of bioenergy projects, even though they can greatly influence a project's local appropriate-ness and sustainability.

This offers opportunities and challenges. If designed well, bioenergy strategies can contribute to sustainable livelihoods and help address environmental problems, such as land degradation or agricultural waste disposal. However, if designed poorly, they could exacerbate social inequities and intensify pressures on local ecosystems. For this reason, bioenergy activities must be scrutinised along several dimensions: how they contribute to satisfying basic needs, providing income opportunities, enhancing food security, preserving the local environment, promoting gender equity, and empowering communities—i.e., the broad sustainable development agenda.

Socio-economic impacts

Two broad areas of potential socio-economic impacts are especially relevant. First are *gender implications.* Women suffer disproportionately the brunt of hardships that are intimately linked with patterns of rural energy use. Owing to the considerable gender differences in access to, control over, and reliance on biomass resources (both for energy and non-energy purposes), women have different needs, opinions, knowledge and skills compared to men. A village-level bioenergy project is, therefore, unlikely to benefit women—or succeed at all—unless it involves women from the beginning. Second is *land use competition and land tenure.* The simultaneous modernisation of biomass production for energy and for food may make it possible to avoid competition for land. It is essential, therefore, to understand what the local needs are for improving agriculture, and what resources and expertise can help meet those needs—a challenge lying at the very core of rural development. Even when land-intensive activities do not measurably affect aggregate food production or market prices, they can still seriously erode the food security of displaced rural families. It is important to understand legally-recognised land ownership rights, as well as the often-subtle nature of traditional land usage rights.

Environmental impacts

Environmental impacts of biomass production must be viewed in comparison to the likely alternative impacts (locally, regionally, and globally) without the bioenergy system in place. For example, at the local or regional level, the relative impacts of exploiting bioenergy feed-stocks will depend not only on how exactly the biomass is exploited, but also on what can happen otherwise—does the land lay barren and degraded? Are different crops cultivated? Do natural forests thrive?

Many bioenergy conversion technologies offer flexibility in choice of feedstock and how it is produced. In contrast, most agricultural products are subject to rigorous consumer demands in terms of taste, nutritional content, uniformity, etc. This flexibility makes it easier to meet the simultaneous challenges of producing biomass energy feedstocks and meeting environmental objectives. For example, unlike the case with food crops, there are good possibilities for bioenergy crops to be used to revegetate barren land, reclaim water-logged or salinated soils, and stabilise erosion-prone land. They can be managed so as to provide habitat and improve biodiversity relative to degraded land.

The main environmental challenges arising with producing biomass feedstocks are listed below. In addressing these issues, the underlying theme is that the biomass must be produced in a manner that is sensitive to local ecological conditions.

- *Soil quality and fertility.* Soil nutrient content, organic content, texture, and vulnerability to erosion are all intimately dependent on the agricultural activities being practised. Good practices include maintaining sufficient plant matter on the land, minimising soil disruption during planting and harvesting, using nitrogen-fixing species, preventing excessive soil compaction from livestock or machinery, controlling water runoff, and avoiding marginal lands.
- *Biodiversity* of the soil, cropping system, and contiguous natural habitats is affected positively by crops that have intra and inter-species diversity, providing some debris (such as standing and fallen wood) for micro-habitats for guest species, providing protective cropland perimeters, timing major activities (such as harvesting) so as not to interfere with sensitive times in guest species life cycles (such mating or nesting), and preserving some fraction of natural habitat.
- *Energy balances.* For bioenergy systems to be economically sensible and environmentally justifiable, the net life cycle energy outputs have to be positive. This is the case with many bio-energy strategies (including the use of most residues and many energy crops), but not all (such as the production of ethanol from corn).
- *Carbon balances.* Bioenergy systems can affect carbon balances by displacing fossil fuels and by changing the amount of carbon sequestered on the land. Both of these must be taken into account to assess the greenhouse gas impacts of a bioenergy system.
- *Hydrological impacts.* Plants affect how much rainfall reaches and penetrates into the cropland, as well as how much ground water is consumed. Bioenergy feedstock production should be consistent with sustainable use of water resources.
- *Chemical loading of soil and ground/surface waters.* Agricultural activities often introduce fertilisers and pesticides into the environment, which can lead to toxic responses in wildlife and workers, chemical resistance in pests, as well as excessive growth of some species as a result of nutrient overloading. Chemical use can be minimised by using nitrogen-fixing species, organic matter inputs, intercropping, tillage practices that improve soil quality, more labour-intensive means of weed and pest control, non-chemical traps, and intro-ducing beneficial predator species.

4.3.3. Wind Energy

Wind energy conversion systems convert the power in the wind to rotational shaft power and to electricity by coupling a generator to the unit. Wind "turbines" are wind electric power units, and are used throughout the world. Commercial wind turbines range from a few hundred watts to about 20 kilowatts for rural applications. Units designed for grid connection are available in the range of 20 kilowatts to over one megawatt. Where annual average wind speeds exceed about 5 meters per second, residential and village-scale wind turbines can provide electricity at costs competitive with or below those of diesel generators, and can be used in stand-alone applications not requiring a local power distribution system.

4.3.3.1. Wind Mechanical Water Pumping

Wind mechanical water pumps convert the energy of the wind into rotational mechanical energy to drive a mechanical water pump. The forerunners of modern wind pumps were developed in the late 19th century. During the early part of the 20th century, well over a million wind mechanical water pumps have powered the irrigation pumps for farms in North America and Europe. Those early units have required constant attention and maintenance in order to operate reliably. As grid electrification and diesel pump sets have become available, most of the mechanical wind units have been gradually abandoned.

Wind mechanical water pumping has benefited from technical advances in the past two decades. A few manufacturers in France, the US, and elsewhere are now supplying advanced versions. Mechanical wind pumps can pump water from depths of several hundred meters, and can operate effectively at wind speeds as low as three metres per second (3 m/s). One currently-available commercial wind pump can supply 6,000 litres of water per hour in a wind speed of 5 m/s and from a depth of 7.5 metres. At 5 m/s and a depth of 30 meters the pumping rate declines to 240 litres/hour, and further to 90 litres/hour at a depth of 300 meters.

Properly maintained, mechanical wind mills can easily last for decades. One technician can maintain dozens of units. The key to reliable long-term operation is a local infrastructure for equipment supply, installation, maintenance, and repair. Local manufacturing is increasingly common, often with licensing or joint venture agreements with well-established foreign companies.

4.3.3.2. Wind Electric Power

Wind electric turbines convert the kinetic energy of the wind into rotational mechanical energy and, through driving a generator, into electricity. Small (100 watts to 10 kilowatts) wind electric turbines are used throughout the world to provide electricity in locations where alternatives are not available or are too expensive or difficult to provide. There are now several hundred thousand small wind electric turbines operating worldwide (most of them in China). "Medium-sized" wind turbines with rated capacities in the range of 500-750 kWe are now a mature technology, and are increasingly used for grid-based applications in Europe, North America, and Asia, particularly, in China and India. A third of all installed wind capacity worldwide is with turbines in the range of 500-700 kWe, with commercial turbines as large as 1.5 MWe now being introduced to the market. Installed grid-connected wind electric generation capacity worldwide reached 10,000 Mwe in 1999. By the end of 2002 this is expected[4] to grow to over 20,000 MWe, with 3,000 MWe in Asia alone (primarily India and China).

Wind turbines used for village applications are horizontal-axis propeller systems. They consist of a rotor, a generator, a mainframe, and, usually, a tail for orienting the unit into the wind. The rotor has two or three blades, captures the kinetic energy of the wind, and converts it into rotary motion to drive the generator. Blades are usually fabricated from wood or fibreglass. These materials have strength and flexibility and don't interfere with radio and television signals. The generator is usually specifically designed for the wind turbine.

[4] *"European Renewable Energy Institutions", as quoted in* Renewable ENERGY World, May 1999, *p. 135.*

TABLE 3. EXAMPLES OF SMALL COMMERCIAL WIND ELECTRIC TURBINES

POWER RATING AT WIND SPEED	APPLICATIONS	TYPICAL RETAIL PRICE (US$)
300 watts @ 12.5 m/s	**Battery charging**	**$850 with battery, charge controller, mast**
1.5 kW @ 12.5 m/s	**Battery charging, water pumping**	**$5,200 (turbine) $1,500-3,000 (tower)**
3 kW @ 8 m/s	**Battery charging, water pumping, DC & AC power**	**$16,600 with 12m mast**
10 kW @ 12 m/s	**Battery charging, water pumping, DC & AC power**	**$20,000 (turbine) $5,000-8,000 (tower)**

Source: Jade Mountain, Inc.; www.jademountain.com.

Permanent magnet alternators are popular, because they eliminate the need for field windings. Low-speed direct-drive generators are replacing less reliable systems that use gearboxes or belts.

Current products reflect significant technology advances, are quite reliable, and can operate for several years, even at harsh sites, before inspection or maintenance is required. The lifetime of large-scale wind turbines is estimated to be about 20-30 years.

Wind electric turbines for village applications fall roughly into three power ranges. Wind turbines used in "wind farms" or large wind electric power plants of 20-50 MWe are in the larger range of 300 kWe to over 1 MWe.

- Very small commercially-available wind electric turbines are in the 100-400 watt range, and are typically used for individual household needs. In Inner Mongolia, where it is often sunny with little wind or cloudy but windy, portable PV/wind/batter/inverter *mini-hybrid units* (ca. 50 watt PV and 300 watt wind) are widely used for households.

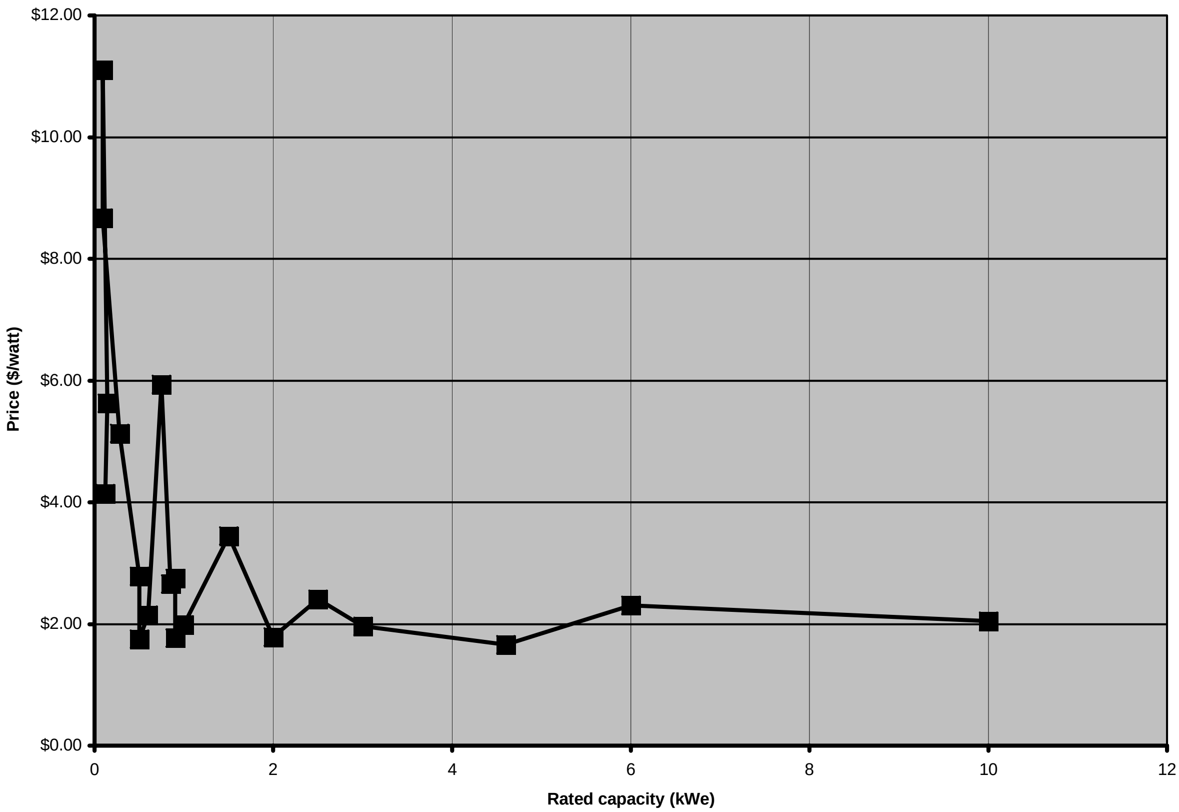
- "Small" wind electric turbines are in the range of 400+ watts to 10 kWe, and, depending on size, are used for battery charging, water pumping, refrigeration, ice making, and small-scale commercial applications.

- An increasingly common use of single and multiple 10 kWe turbines is for wind/diesel AC minigrid applications. A few manufacturers are developing turbines in the 20-50 kWe range, for village-scale applications. Since the wind is intermittent, batteries are required for electrical storage, and back-up petroleum-fueled generators are sometimes used to ensure reliability of electricity supply. In water supply systems, water storage can eliminate the need for batteries.

- Large-scale wind turbines for grid-connected applications are commercially available in the range of several hundred kilowatts to over one megawatt, with most recently installed turbines in the range of 500-750 kWe. The leading suppliers are in Europe (Denmark, Netherlands, Germany), Japan, and the US. Large-scale grid-connected wind electric power plants (wind farms) are now fully commercial. The installed capital cost of modern windfarms is roughly US$1,000 per kWe (plus or minus 20 percent) for capacities in the range of 20-50 MWe or more. The cost of electricity from commercially-financed wind electric power plants is 3 to 6 US cents per kWh.

Units in the range of 1 kWe to 20 kWe cost about US$2 per watt; most are configured to tie into a utility grid, as well as operating in stand-alone applications. The current prices (US$ per rated watt of output) are shown for small wind turbines available from the US, Europe, and Australia. For wind turbines with rated peak capacity in the range of 1 kWe to 10 kWe, the typical wholesale price is approximately US$2,000 per kilowatt. The rated capacity refers to the maximum output of the turbine; wind speeds for rated output vary somewhat among turbines. Electricity costs range from US$0.05 to US$0.20 per kWh for practical applications.

FIGURE 1. CURRENT PRICES FOR SMALL
WIND ELECTRIC POWER UNITS (RETAIL, WITHOUT SHIPPING)



Source: Home Power Magazine.

For grid extension distances as short as one kilometre, a wind system can be a lower-cost alternative for small loads. While the initial cost per rated kilowatt is greater than for diesel gensets, wind electric systems offer advantages to the end users. Donor agencies, for example, often supply diesel gensets at no cost, but leave operational costs and requirements (fuel, maintenance, repair, and replacement) to the recipient communities. This often requires scarce or unobtainable foreign exchange and usually results in limited use and a shortened life of the diesel genset, because of inadequate maintenance. Many countries must also import their fossil fuels, further magnifying the burden imposed by diesels.

4.3.4. Photovoltaics

The direct solid-state conversion of light to DC electricity—the *photovoltaic (PV) effect*—is embodied in perhaps the most elegant power generation technology available. Practical PV units are available commercially from dozens of manufacturers worldwide, in the form of flat panels called *modules*. They have no moving parts, a sunlight to electricity conversion efficiency in the range of 10-20 percent, extremely high reliability, and a potential lifetime of centuries (commercial warranties of 20 years are now common).

Invented as practical devices in 1955 by Bell Laboratories in the US, silicon solar cells have become the power source of choice for satellites and spacecraft. During the late 1960s, spacecraft solar arrays cost a million dollars per kilowatt! In the last decades, bringing the cost and the technology down to earth has been accomplished, and the wholesale price is now about US$4 per watt.

Annual shipments worldwide have grown from 2 megawatts peak (MW_p) in 1975 to 135 MW_p in 1998, with annual market growth in excess of 15 percent. There are now over 1,000 MW_p of PV modules in applications worldwide. During the last five years the quality, reliability, efficiency, and ease of interconnection have advanced to the point where the modern solar panel is the most reliable and simple power generation technology available. Solar panels using silicon PV conversion have efficiencies in excess of 15 percent, and thin film modules are typically 10 percent. The prospect for further increases in efficiency is considerable, with prototype crystalline cells exhibiting efficiencies over 25 percent, and thin film devices—over 15 percent efficiency. Companies such as BP Solar and Siemens are constructing manufacturing facilities capable of annual PV module production in excess of 20 MW_p. Improvements in technology and the increase in production scale are resulting in substantial reductions in production costs.

The present markets for remote PV systems are those in which reliable electricity supply is justified or valued at a cost of more than US$1.00 per kWh. Typically, these applications involve high-value information rather than work in the thermo-dynamic sense. The principal PV markets globally are grid-connected applications (36 percent), industrial use (28 percent), rural households (27 percent) and small consumer applications for the balance.

PV panels are available in sizes from a few watts to 300 watts, and produce DC electricity in the range of 12 to 60 volts. Applications of PV include:

- charging electric lanterns and laptop computers (4 - 6 watts);
- packaged systems (20 - 100+ watts) for off-grid residential lighting and entertainment (radio/ cassette, TV/VCR); and
- grid-connected power (hundreds of kilowatts to a megawatt or more).

The present markets for remote PV systems are those in which reliable electricity supply is justified or valued at a cost of more than US$1.00 per kWh. Typically, these applications involve high-value information, rather than work in the thermo-dynamic sense. The principal PV markets globally are grid-connected applications (36 percent), industrial use (28 percent), rural households (27 percent) and small consumer applications for the balance.

There are modules especially designed for applications in demanding environments including on ships and in humid tropical regions. Practical use of PV modules for off-grid power supply requires their integration into *systems*, which may include batteries, battery charge controllers, DC to AC converters or DC/AC/DC bi-directional inverters, and backup generators run from propane or diesel fuel. System size and design depend on the end-use applications, such as water pumping, DC lighting, telecommunications, medical refrigerators, or other appliances. Microprocessor-based electronic controllers support the use of PV systems for grid-connected applications and in fossil fuel/PV hybrid power plants. PV modules are rugged and have high reliability (20+ year warranties). Single modules are available with ratings up to 300 Wp. The retail price from PV distributors is US$5-7 per rated peak watt, with power ratings typically in the range of 30-100 watts.

4.3.5. Hybrid Power Systems

Hybrid power systems combine one or more renewable energy sources with a diesel or propane genset, batteries, controls, and DC/AC inverters. They generate high-quality AC power at annualised costs comparable to those from part-time diesel power generation. Hybrids are used throughout the world as the preferred power source for remote telecommunications and signalling (e.g. lighthouses) facilities. Increasingly, they are being used to energise community minigrids operating at 220-240 VAC, and to supply power to ecotourism facilities. Hybrid power systems are commercially available, with power ratings ranging from a few kilowatts to over 100 kWe.

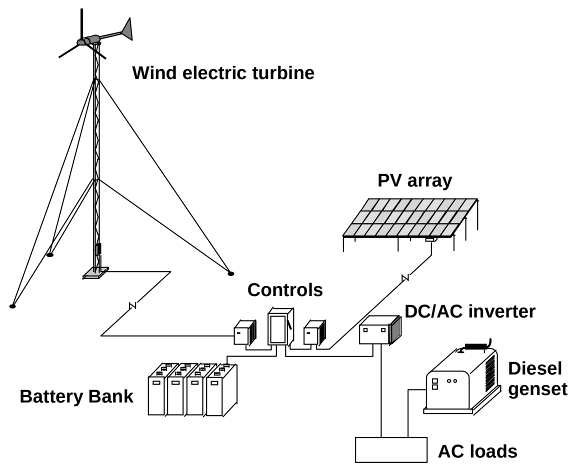
Hybrid power systems for village power applications typically have rated power generation capacity of 10 kWe to ca. 50 kWe, with daily electricity production of 50 kWh to 1,000 kWh or more. PV/diesel hybrid units are widely used for power supply to aboriginal communities in western Australia. PV/diesel, wind/diesel, and PV/wind/diesel hybrid power units provide power to off-grid communities in Mexico, Brazil, Chile, Indonesia, and the Philippines. Most of those installations are considered to be commercial prototypes, using fully commercial equipment, but in custom-designed packages. Continued commercial development is required before these systems can be considered commercially mature.

Detailed analysis of diesel and hybrid power systems indicates that in good wind resource environments, with annual average wind speeds of 5-6 m/s or higher, wind/diesel hybrids can generate electricity at average costs that compare favourably with well-maintained and efficiently operated diesel gensets. In sunny regions (5-6 kWh/m²-day), a PV/diesel hybrid system can compete on a life cycle basis with diesel gensets if full-time 24-hour power is supplied to a community, even if diesel fuel is available at the world market price. In regions where diesel fuel is expensive, due to challenging transport logistics or other factors, hybrids can provide an economic advantage. Moreover, there is no cost penalty or diesel lifetime penalty associated with use of hybrid power systems. Consequently, they are often a preferred option for rural AC minigrids.

Problems and Challenges

The commercial application of hybrid power systems for village power is still limited. Although the equipment is fully commercial, there have been serious non-technical problems that compromise the quality of service and sustainability of many of the applications. Problems include lack of adequate training to local system operators and technicians, lack of equipment manuals in the local language, delays in repair or replacement of equipment after failure, and the general lack of a supportive technical infrastructure to assure timely and expert maintenance and repair. As discussed in Section 5, supply of high-quality electricity services from hybrid power systems requires organisations with the capabilities, size, and motivation to assure sustainability and widespread use. Rural energy service companies are among the emerging institutional mechanisms that appear well-suited to this.

FIGURE 2. PV/WIND DIESEL HYBRID POWER SYSTEM



Source: Bergey Windpower Company

4.3.6. Hydropower

Hydropower energy conversion systems convert the power of flowing water into rotational mechanical power. Waterwheels, an ancient technology for hydropower conversion, are widely used in many rural parts of the world today. These are used directly to operate specific machinery (e.g., grain grinder), without production of electricity. However, rotational mechanical energy is limited to a few applications, and these have to be adjacent to the hydropower unit.

With the exception of small waterwheels used in rural areas, hydropower units are designed to produce AC electricity. Hydroelectric power systems use the rotational shaft power generated by water wheels and turbines to produce electrical energy. The size of hydroelectric units ranges from a few hundred watts to thousands of megawatts. There is no universally accepted definition of the different classifications of hydroelectric power units. The classifications shown in Table 4 are generally consistent with definitions used around the world. However, national definitions will vary. In the Philippines a "mini-hydro" plant is one under 10 MWe and encompasses the definitions of mini-hydropower and small hydropower below. "Small" is used generically in the text unless it refers specifically to installations in the 1-10 MWe range.

TABLE 4. HYDROPOWER CLASSIFICATIONS

HYDROPOWER CLASSIFICATION	POWER OUTPUT RANGE*
Pico-hydro	**< 1 kWe**
Micro-hydro	**1 kWe - 100 kWe**
Mini-hydro	**100 kWe - 1 MWe**
Small hydro	**1 - 10 MWe**
Large hydro	**> 10 MWe**

** Installed generating capacity*

Large hydroelectric power plants are a highly mature technology, and today there are over 750,000 megawatts of hydroelectric installations worldwide. Almost all of the world's hydropower involves large installations with large dams. Micro-hydropower systems are of relevance to rural commu-nities. With a reliable stream or river flow, household and village-scale hydroelectric units can provide full-time AC power, generally at costs far below that of photovoltaics, and even of wind and biomass conversion. Power output is proportional to the water flow and head (drop in elevation). The amount of electricity that can be generated annually depends on the quantity of water available and the variability of flow throughout the year.

The primary electrical and mechanical components of a small hydropower plant are the turbine(s) and generator(s). Several types of turbines have been designed to cover the broad range of hydropower site conditions found around the world. The principal types of turbines are known as *impulse turbines* (e.g., Pelton and Turgo designs), *crossflow turbines* and *propeller turbines*. Selection of a specific turbine depends on the head and water flow available at the site under consideration. Pelton turbines are used for high heads, crossflow turbines for medium heads, and propeller turbines for low heads.

The economics of a hydropower installation depend on the power (capacity) and energy a project can produce, as well as the sale price for electricity, if it can be sold. In a remote community, the value of the power depends on it end uses. When used to provide power for economically productive activities they can significantly increase community incomes. The costs of a complete hydropower installation vary considerably because each site is unique. The retail price of small turbines in the range of a few hundred watts to several tens of kilowatts is roughly US$2.00 per watt. Typical costs for complete installation of picohydropower and microhydropower units are in the range of US$3-5 per watt.

Electricity production through hydropower can generate adverse upstream and downstream effects like soil and forest loss, nutrient loss, silting, large-scale displacement of people, and increased likelihood of malaria due to stagnant water. These effects would vary depending on the size and location of the project. Small hydro-power plants are appealing because their develop-ment time can be short, they are easy to finance and are generally low-risk. They also require little maintenance, typically have low environmental impacts, and cause little or no resettlement. On the other hand, their technical and financial viability, compared to large dams, is very site-specific, and their relatively small storage or run-of-the-river design makes them an often-intermittent source with large seasonal variation. They also cannot benefit from economies of scale, unless linked within a river system through a carefully integrated design, and even so may require more capital investment than a single large dam.

4.3.7. Geothermal Energy

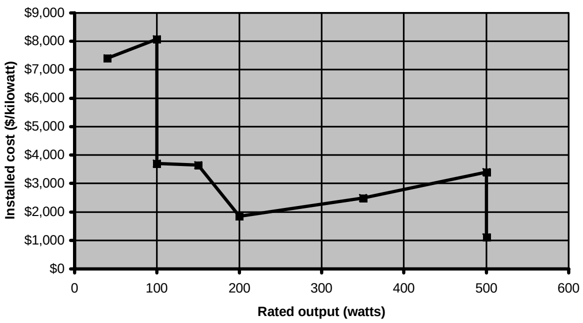
Geothermal resources occur as dry steam or hot water, and can be used for power generation or for thermal processes. Dry steam, a rare resource, can be piped to a turbine to generate power. Geo-thermal energy conversion is a mature technology and is fully commercial. For power generation

BOX 5. SUB-KILOWATT "FIREFLY" MICROHYDROPOWER TURBINE INSTALLATIONS

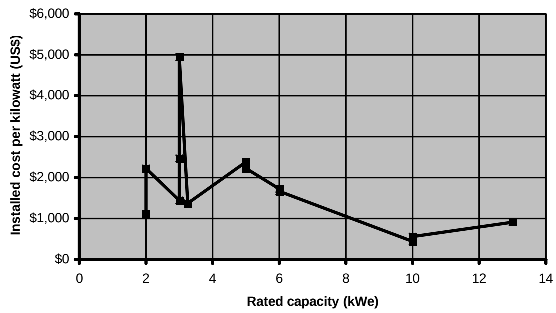
The installed costs of eight pico-hydropower units in the Philippines are shown here. The following chart indicates the installed costs of a number of micro-hydropower plants in the Philippines. The tiny "Firefly" units are used exclusively for battery charging for home lighting and entertainment. The larger (multi-kilowatt) micro hydropower installations are used for residential electricity (local microgrid), and for productive uses including woodworking, grain grinding, and sugar milling.

For small hydroplants in the range of 1-10 Mwe, the development cycle is typically two to five years, from conception to final commissioning. This time is required to undertake studies and design work, receive the necessary approvals, and construct the project. The technical and financial viability of each potential project is site-specific.

COST DATA FOR OPERATIONAL MICRO-HYDROPOWER PROJECTS IN THE PHILIPPINES



INSTALLED COST OF RURAL MICRO-HYDROPOWER SYSTEMS IN THE PHILIPPINES (1994 - PRESENT)



from hot water, there are two primary conversion technologies: flash plants (for resource temperatures >175 degrees C), which rely on flashing the hot water to steam, and binary plants (for resource temperatures of 100 to 175 degrees C), which use the heat of the hot water to boil a working fluid, usually an organic compound. Geothermal power generation is extensively used in the US, the Philippines, Italy, and New Zealand. Individual geothermal power units are typically tens of megawatts to 50 MWe. Low-temperature geothermal resources (<130 degrees C) can be used for direct-use applications such as heat pumps, district heating, space heating and cooling, refrigeration, aquaculture, industrial processes, and domestic hot water. The fastest growing direct-use application is geothermal (ground source) heat pumps.

Mini-geothermal plants in the range of 0.5 MWe to a few megawatts are technically feasible using commercial equipment, but the high costs of geothermal exploration and well drilling generally do not justify investment in small plants.

Geothermal water is sometimes heavily laden with salts and dissolved minerals. Good environmental practice dictates that geothermal water be injected back into the geothermal reservoir, both to replenish the reservoir and to dispose of unwanted dissolved salts. Geothermal power plants also produce some solid residues that require careful disposal.

4.3.8. Emerging Technologies

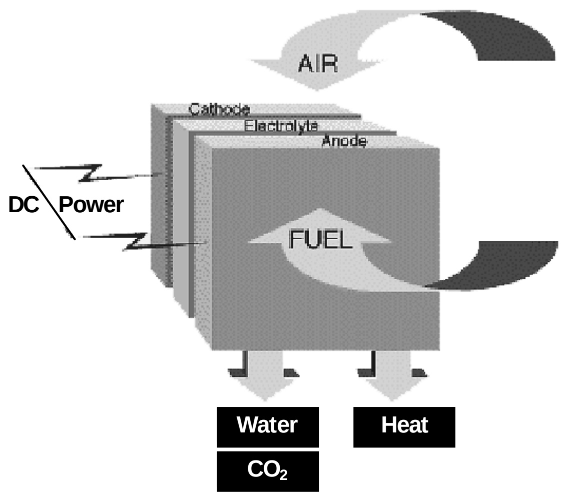
4.3.8.1. Small Modular Biopower Systems

A few private developers are commercialising small modular biopower (SMB) systems. Power

BOX 6. ELECTRIC POWER FROM GASIFIED BIOMASS

A system has been developed that includes a very low emissions biomass gasifier unit that is packaged together with a modified diesel generator system. Designed to use a wide variety of biomass feed stocks, commercial units are offered at 100 kWe, 250 kWe, and 400 kWe. The smallest unit (100 kWe) is suitable for powering an AC minigrid in a large village or small town (typically 3,000 - 5,000 people) in which there is potential for commercial activities (e.g., conservation and processing of agricultural products). The system produces 1 kWh from 1 kg of feedstock, with less than 0.1 litre of diesel fuel enrichment required. This qualifies as a "low-carbon" energy technology, producing 10 to 12 kWh/litre of diesel fuel. A conventional diesel genset of similar size produces 2 to 3 kWh per litre of diesel fuel.

FIGURE 3. FUEL CELL COMPONENTS



generation units will have rated capacities ranging from 10 kilowatts to 5 megawatts. The systems are designed to be flexible, efficient, simple to install and operate, with minimal environmental impact. Systems with rated capacities ranging from tens of kilowatts to several megawatts are expected to be ready for commercial use within five years.

Small modular biopower systems have the potential to supply electric power to unelectrified communities and to individual facilities. These are units that gasify or combust biomass residues to drive an engine/generator to produce electricity, as well as useful heat. The potential exists wherever there are large amounts of biomass available for fuel, such as in communities that produce coffee, coconut, and rice, or have forest product industries.

4.3.8.2. Fuel Cell Technologies

Fuel cells are energy conversion devices that generate electricity from fuel, e.g., natural gas or hydrogen generated from renewables. The benefit of fuel cells is that they provide a cleaner and more efficient way of generating electricity, compared to combustion-based energy conversion technologies.

Figure 3 shows the basic design of a typical fuel cell. The key components are an anode and a cathode, separated by an electrolyte. Fuel is supplied to the anode side, and the oxidant (usually air) is supplied to the cathode side. They react in a controlled fashion that directly generates electricity.

Fuel cells avoid the intermediate generation of heat and the inefficient conversion of heat into electrical energy, and can, therefore, potentially function at very high efficiency. In fuel cells, the fuel and oxidant are supplied as needed to satisfy the demand for electric power. Unless the fuel is pure hydrogen (which is generally not a readily available fuel) the fuel must be processed to make it consumable in the fuel cell. Research is leading to processors that will make various fuels, including natural gas, LPG, ethanol, gasoline, diesel, and even solid fuels such as coal and biomass consumable in fuel cells.

Fuel cells were first demonstrated in the early 19th century, and first employed in a practical capacity in the 1960s, providing electric power on board NASA's Gemini and Apollo space missions. Steady progress over the ensuing three decades has brought fuel cells to the point where they are now being aggressively developed by the private sector, because of their extremely good technical and economic prospects for becoming a major technology in both transportation and stationary generation applications. All the major automotive manufacturers have directed substantial development efforts toward fuel cells, as have several major companies in the generation industry. Several of these development efforts aim to commercialise fuel cell products in the 2003-2005 time frame—a strong indication of the extent of industry confidence.

In addition to their higher efficiency and lower pollution than combustion-based technologies, fuel cells offer the prospect of quiet operation, low maintenance, and cost-competitiveness, even at small-scales. This positions fuel cells as a promising emerging technology for rural applications. Based on already-demonstrated biomass gasification and gas clean-up technologies (see section 3), it may prove feasible to use fuel cells to generate power at village scales, using rural biomass resources, at efficiencies more than twice as high as the gasifier/diesel engine systems that are now in use. Such systems might even prove cost-competitive with centralised power plants, making the export of excess electricity from rural areas to urban demand centres a potential source of revenue for rural development.

4.4. RENEWABLE ENERGY APPLICATIONS

The technologies described in Section 4.3 can be applied to the energy needs of households, communities, and commercial operations. Options available for meeting rural energy needs that can be provided by electricity are summarised below. Sustainable and economically attractive applications require a local infrastructure for supply, installation, operation, maintenance, and repair of equipment. It is the lack of such infrastructure in most of the developing world that limits the longevity and reliability of energy equipment, both renewable and conventional. This central requirement is discussed further in Section 5.

- *Battery charging stations.* There is growing use of PV and wind electric-powered battery charging stations to replace gasoline and diesel-fuelled gensets to charge the automobile batteries that are widely used to run household and community facility lights, radio/cassettes, TV sets, and short wave radios.

- *Individual appliances.* There are a few solar energy "appliances" available in the international marketplace. These include solar flashlights with integrated or detachable PV arrays to charge an internal rechargeable battery set, solar-powered radios, solar box cookers, solar ovens designed for village-scale bakeries, and PV-powered vaccine refrigerators.

- *Commercial systems incorporating off-the-shelf components.* There is a growing menu of pre-packaged, "off-the-shelf" integrated PV or wind systems available from commercial suppliers in many countries. These are typically supplied either in kit form, or with installation and maintenance services included. These options include, for example, street lighting packages, ice makers for preserving perishable products, and home power systems (including battery for storage, a few lamps, and an outlet for a radio, cassette, TV, etc.). Complete custom-configured PV and wind-electric power generation units (and, in the near future, biomass-based units) are also commercially available with battery storage (if necessary) and efficient appliances, configured for specific applications. Such systems are widely used to provide water (encompassing water pumping, cleanup, disinfection, purification, distribution, and storage), and power for schools, clinics, shops, telecommunications/Internet, and small offices. A typical commercial package tailored to a health clinic might include, for example, conventional lighting, some specialised high-intensity lights, an autoclave (for sterilidation of surgical instruments), a vaccine refrigerator, and often a water pump, and a short-wave radio.

- *Microgrid and minigrid systems.* There are many successful examples of small-scale grids serving a village or cluster of buildings including a clinic, a school, a community centre, and some shops, and providing energy for lights, communications, entertainment, water pumps, water purification systems, refrigeration units, freezers, ice-makers, grain grinders, etc. Typically, these are powered by diesel electric generators, but such grids can also be powered by a variety of commercial and emerging renewable energy-based technologies, including hybrid power systems that combine diesel and propane generators with renewables.

In many communities, the most practical and economic use of renewable energy is bound to be a *mix* of free-standing applications and a mini-grid to supply electricity for primary community and commercial activities. This mix also permits maximum flexibility and economy in matching renewable energy equipment to a range of local energy needs. Typical rural community energy end uses and examples of renewable energy supply options are shown below in several tables. All of the units identified are available commercially; many can also be either totally or partially fabricated indigenously.

4.4.1. Selection of Suitable Renewable Energy Technologies

The choice of renewable energy technology—in essence, the package of equipment, installation and support services, training, financing, and community-based support—depends on several factors and considerations. Technical, economic, financial, and socio-cultural considerations must all be included in the decision process to ensure the appropriate choice of technologies for specific applications and environments. This is discussed in more detail in section 4.5.

4.4.2. Lessons Learned

Many renewable energy systems have the potential for providing cost-competitive energy services to rural communities in environmentally and socio-economically desirable ways. Yet, thousands of well-intentioned renewable energy projects have failed throughout the world, because the conditions for sustainability were not present. Experimental and, sometimes, very complicated equipment has been used, rather than rugged, field-proven commercial products. Systems have been poorly designed, with mismatched components, undersized PV arrays, poor quality batteries and charge controllers, etc. Lack of funds, spare parts, tools, and manuals have made it virtually impossible for local technicians to maintain and repair RE equipment.

TABLE 5. SOME STANDALONE RENEWABLE ENERGY APPLICATIONS FOR HOUSEHOLDS AND COMMUNITY APPLICATIONS

APPLICATION	USES	TECHNOLOGIES
Households	**Lighting, radio, TV/VCR**	**Battery charging stations PV and wind home systems, PV/wind hybrids with village microgrids**
Community water supply	**Pumping, storage, distribution, filtering, disinfection, monitoring**	**PV, wind electric, UV disinfection, electronic monitoring of water quality**
Education - rural schools	**Lights, computers, fans, TV/VCR, water pumping and purification, hot water, water pumping and purification**	**PV, wind electric, hybrids, solar water heating**
Health - rural clinics	**Water pumping and purification, lighting, communication (e.g. SSB radio), TV/VCR, autoclaves, hot water**	**PV, wind electric, hybrids, solar water heating**
Community halls	**Lighting, TV/VCR**	**PV, wind electric**
Public lighting	**Lighting**	**PV public lights, street lights**
Roads	**Illuminated signs, call boxes, street lights, traffic signals**	**Free-standing PV/battery units**
Rural telephones	**Cellular stations, public call centers**	**PV/battery systems for powering all applications**
Telecommunications	**Microwave repeater stations, transmitters, receivers**	**PV and PV/engine genset hybrids (e.g. propane-fired)**

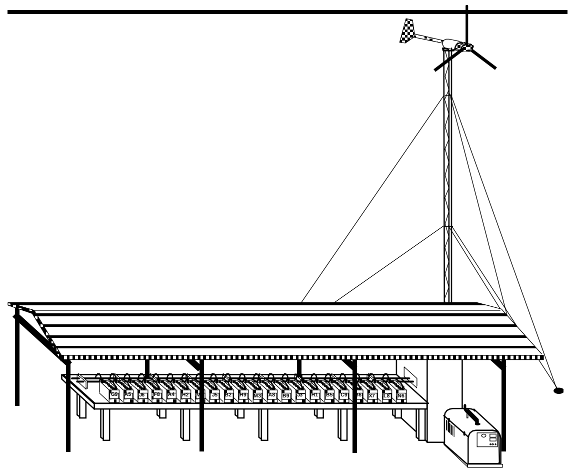
Renewable energy projects have often lacked the active participation by the intended beneficiaries regarding the types of systems or the use of the energy, and mechanisms for repair and replacement. End users have not been trained in the proper use of the equipment, resulting in abuses of the systems or components (especially batteries). Many international donor aid programs have dumped equipment in developing countries without consideration of the impact on local markets, or of the financial and institutional requirements for keeping the equipment operational and reliable. Usually, it is difficult or impossible for equipment and service suppliers or renewable energy project developers to obtain suitable financing, because many banks still regard renewable energy investments as exotic or undependable.

Achieving sustainable economic and widespread use of decentralised RE systems requires a conjunction of effective policies, meaningful financing, and international cooperation with industrialised countries. Innovations in policy and financing are required to facilitate the use of renewables on any significant scale both for grid-connected and off-grid use. Grid-connected renewable energy-based power generation stands to take place amidst major restructuring, reform, and privatisation of the power sector in many developing countries. For off-grid communities, renewables can provide meaningful levels of energy and power for high-priority needs, including residential lighting, community services (education, health, clean water, telecommunications, etc.) and for economically productive uses. Important new models are emerging that can support the large-scale use of decentralised renewable energy options.

4.4.3. Household Energy Services

In many developing countries, kerosene lamps provide lights for homes in unelectrified communities. This type of light is of poor quality, polluting, and relatively expensive for the amount of light provided. People in rural communities want electric lighting. Many of these households are willing and able to pay for

FIGURE 4. WIND ELECTRIC BATTERY CHARGING



these services, especially when special financial arrangements, such as leasing, system financing, or rural energy services options, are available. Lighting, access to information, and entertainment are high priorities for rural families in unelectrified areas. This has resulted in a worldwide commercial market for renewable energy-based home electricity systems. There are several renewable energy options for households that are used worldwide. These include PV battery charging systems, PV solar home systems, wind home systems, and small PV/wind hybrid units. PV solar home systems are the most widely used, but other options are available and are increasingly used in a wide range of applications.

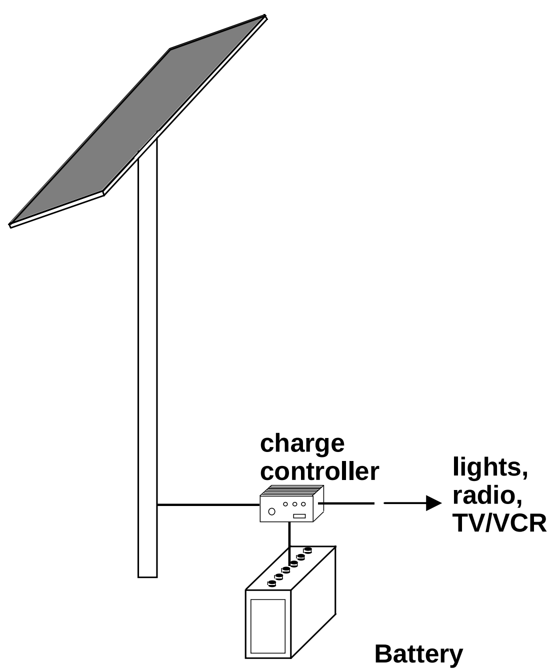
4.4.3.1. PV and Wind Electric Battery Charging Stations

In most developing countries, rural families obtain rudimentary electrical service by charging 12-volt automobile batteries from small diesel gensets and from power provided by the closest available grids. Often, these batteries must be carried tens of kilometres to be charged. The cost of electricity from such informal arrangements is usually in the range of US$1-3 equivalent per kWh. PV and wind battery charging stations are an emerging option for providing entry-level electricity services to rural households. PV battery charging stations are used in parts of Africa, Asia, and Latin America, as well as in the Pacific Islands.

Transport of the batteries to and from the household is typically the responsibility of the household, but in some cases, this can be provided as part of a commercial battery charging service operated by local entrepreneurs. Batteries can be individually owned, leased from a local charging service, or households can pay a service with the batteries owned by the charging service organisations. Batteries can be charged on a set schedule, or as the batteries need a recharge, or when the users have the cash to pay for the service. The latter is, perhaps, the most common situation, with rural families buying electricity in the same fashion that they purchase kerosene. If high-quality batteries are used, and the charging systems are operated properly, battery charging stations appear to be able to bring affordable electric service to very low-income populations.

Leasing batteries has several benefits, including standardisation of batteries, cost leverage from bulk procurement, and the potential for regular maintenance at a station. The advantage of individual ownership system is that the individual or family is responsible for their own battery maintenance and is less likely to overcharge, discharge, or otherwise abuse the battery. A centralised battery-charging business is more likely to be financed than several hundred individual PV users, and cost recovery responsibilities are with a single entity. High up-front costs are the limiting factor for complete solar home systems in some communities. Battery charging is a lower-cost option than ownership of a PV solar home system, and households with irregular incomes can have batteries charged when they have the money. Solar home systems require regular periodic payments for financing, leasing, or monthly energy service fees.

FIGURE 5. PHOTOVOLTAIC SOLAR HOME SYSTEM (SHS)



There are environmental and safety issues associated with all systems that require the use of batteries. Recycling needs to be a required component of all battery programs. This, however, requires a large effort, since recycling industries in many developing countries do not yet exist or are far from the rural areas. A battery-charging enterprise could facilitate recycling by collecting batteries and working with battery recyclers, when available. South Africa and Brazil are among the countries that have initiated battery recycling programs.

4.4.3.2. PV Solar Home Systems

PV household applications—commonly known as Solar Home Systems—typically combine a 20-100 watt PV module with a battery, charge controller, three to five high-efficiency florescent lights, and a power point for a small DC appliance (cassette tape player, boom box, black and white TV). In larger systems, a small DC/AC inverter is sometimes provided to permit operation of small AC appliances. In very sunny conditions. a 50 watt PV system can provide about 0.2 kWh/day, sufficient to provide evening lights and entertainment for a household, the operation of a radio during the day, and up to 4 hours of TV viewing.

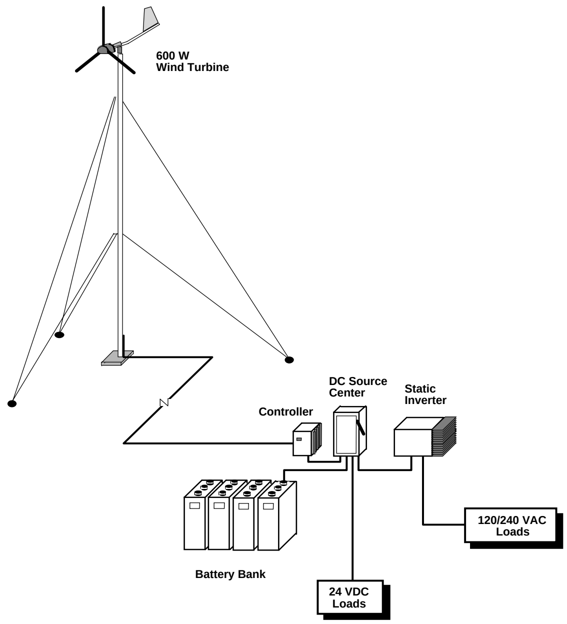
Appliances such as irons or washing machines are energy-intensive and require high power levels, compared with lighting, radio, and TV. These higher energy and power requirements are well above what standard solar home systems are designed to deliver. The primary benefit of solar home systems to rural households has been reliable high-quality light and access to information and entertainment. A 50-watt system typically costs the equivalent of US$500-700 installed, with local surcharges, import duties, and other factors sometimes driving the price to over US$1,000. Commercial systems in the 20-75 watt range are most commonly used. Larger systems, with several hundred watts of PV capacity, are also increasingly used. In most developing countries, the markets for solar home systems are characterised by sales-oriented companies that are often not capable of providing quality after-sales service. Other problems can include limited financing options for suppliers and end users, poor quality components and system design, and improper installation.

Over the past two decades, there have been well over 200,000 Solar Home Systems (SHSs) installed, with major markets in such diverse countries as Mexico, Argentina, Brazil, South Africa, Kenya, Zimbabwe, the Dominican Republic, India, and Indonesia. Suppliers of PV solar home systems packages and components now can provide extremely rugged and reliable PV modules, locally produced batteries, charge controllers, high-efficiency lights, and small DC/AC inverters.

4.4.3.3. PV Wind Home Systems

Small (300-600 watt) wind turbines combined with charge controllers and batteries are increasingly used for residential energy supply in areas that are fairly windy much of the year, such as near-shore and small island environ-ments where the trade winds are fairly regular. The small turbines operate in a battery charging mode, with any AC power needs provided through use of a small DC/AC inverter connected to the battery. Small wind systems can provide residential electricity services at costs well below those of PV solar home systems, when the annual average wind speeds exceed ca. 4.5-5 m/s. Figure 6 shows the components of a typical system, which includes a small DC/AC inverter to power AC appliances.

FIGURE 6. SMALL WIND ELECTRIC SYSTEM



4.4.3.4. Examples: Renewables for Household Applications

<u>Case Example:</u>
<u>Solar Home Systems in Zimbabwe</u>

The UNDP/GEF PV project in Zimbabwe has stimulated the establishment of dozens of PV SHS suppliers and installation companies, and over 7,000 systems have been installed over the past seven years. The majority of these suppliers, however, did not have a very firm commercial base and have closed down after the project ended. The project has developed a credit mechanism with the Agricultural Finance Corporation (a national bank with offices throughout the country). The AFC loans for household PV systems at 15 percent per annum. Another outlet mode was the incorporation of the national electric utility company. The Zimbabwe Electricity Supply Authority (ZESA) has established a pilot fee-for-service business operation for 500 systems. During the project, import duties on PV components were eliminated and access to foreign exchange became far easier for businesses. The project has bought PV system components in bulk through the United Nations procurement centre thus achieving economies of scale, and made these available for sale to local PV companies. This, in effect, eliminated the capital risk associated with a small company maintaining an inventory of expensive equipment. An evaluation of the project by external consultants has suggested that the fee-for-service approach is the preferable way to use PV systems for off-grid communities.

Case Example: PV/wind Home Power Units in Inner Mongolia

The largest application of small wind turbines is for nomadic residential use in China. Small wind electric units are widely used in Inner Mongolia, China, supplying over 500,000 herdsmen with mobile AC electric power. The turbines are rated at 100 watts (at 7 m/s) and are mounted on a 5m tower. Included in the systems are a 3 kWh battery and a 250 watt DC/AC inverter. They typically produce 1 kWh per day.

Over 120,000 systems have been installed since 1984. Twelve megawatts of small wind turbine name plate capacity have been installed in Inner Mongolia in the last seven years. Present production capacity is 35,000 units/year. These systems cost about US$250 in local currency equivalent. Today, it is common to find Chinese herdsmen whose wind-powered yurts (felt tents) have small washing machines, TV sets, and even VCRs! Twice a year, the nomadic Mongolian herdsmen pack up all their belongings, including the wind turbine, and move to new pastures.

Many herdsmen are using small PV/wind hybrid units. These include a 50-watt PV module, a 100-300 watt wind turbine, a battery, a controller, and a small DC/AC inverter. In their climate, it is typically either windy but not sunny, or sunny but not windy. These highly portable systems provide reliable lighting and communication (radio, TV) service, the latter through the small inverter. The World Bank is currently implementing a project in China to support the production and use of 30,000 new PV/wind hybrid units for residential use.

4.4.3.5. Costs and Economics

The capital costs for three approaches to serving rural households with PV, wind, and hybrid power units (discussed below) are shown in Table 4.2. Rural households typically provide a downpayment or "connection" fee charged by the equipment or energy service supplier, in addition to the monthly payments. For a US$500 PV Solar Home System (SHS) a monthly charge equivalent to ca. US$10-15 is common, depending on whether the system is purchased, leased, or owned by a rural energy services company (RESCO). A proportionately higher

TABLE 6. ILLUSTRATIVE COSTS FOR RENEWABLE ENERGY-BASED HOME ELECTRICITY SYSTEMS

TECHNOLOGIES	SYSTEM AND APPLICATIONS	ESTIMATED COSTS* (US$)
PV solar home system	**50 watt PV panel, battery, controller, and lights and wiring. For illumination and entertainment**	**$500-700**
Wind home system	**300 watt turbine, batteries, controls, and small inverter.**	**$1,200-1,600**
PV/wind/diesel Hybrid	**200 kWh/day, 200 households in a "compact" community, 240 VAC local minigrid.**	**$500-1,000 per household connection**
DC Battery systems with renewable charging,	**12 volt 70 AH battery to power DC lights and entertainment**	**$80 every two years, plus $3-4 per month for weekly charging**

** This assumes that PV and wind systems are being installed in sufficient quantities (ca. 100 or more) to permit economies of scale in equipment, transport, installation, and commissioning. Costs do not include import duties, taxes, or special fees.*

monthly fee would be charged for the wind home system illustrated. For hybrid power systems, a monthly fee of ca. US$20 for a full-time AC power service is limited at about 1 kWh per day.

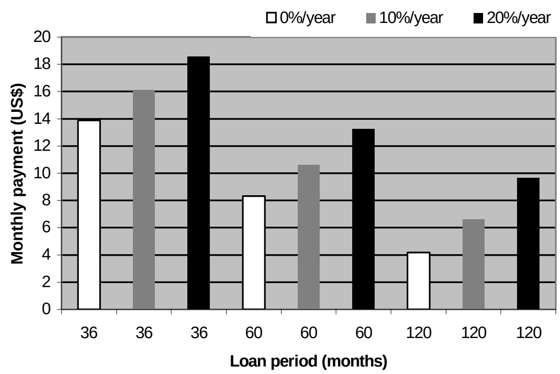
If a solar home system is purchased outright, the monthly payments depend on the terms and conditions of the loan. Assuming a system cost of US$600, with a US$100 downpayment, the balance of US$500 must be amortised over the loan period. Batteries usually require replacement every two to five years, depending on their quality (and hence, price). This means an expense of roughly US$100 every 2-3 years or US$200-300 every 4-5 years. The monthly payments are shown in Figure 7 for three loan periods (36, 60, and 120 months), and for three interest rates (no interest, 10 perent per year, and 20 perent per year). A five-year loan at 10 percent annual interest requires a payment of US$10.60 per month, which is well within the willingness and ability of many rural households. To reach poorer households, a combination of smaller and less expensive systems, combined with a leasing program using low-interest capital, can provide basic lighting and entertainment services for roughly US$4-6 per month.

4.4.3.6. Cooking

Cooking is the central energy-related activity in rural communities.Biomass is the principal cooking fuel for much of the rural population in developing countries. Family-scale and community-scale biogas systems are used in some countries (e.g., India and China) to provide gas for cooking, with the advantages of flame control and low emissions compared with traditional cookstoves. Pipes distribute the biogas, with biogas burners located at cooking points. (See Section 4.3.1 for details).

As with biogas, producer gas from biomass can be used as a household or service-sector cooking fuel. Some gas cleanup is required after gasification, to avoid downstream buildup of contaminants. There are a growing number of projects involving cooking applications today, especially in China.

FIGURE 7. MONTHLY PAYMENTS (PRINCIPAL AND INTEREST) FOR A $500 LOAN



Cooking with producer gas offers several advantages over traditional direct biomass burning, including more efficient overall use of the primary biomass resource, reduced indoor smoke and particulate levels leading to improved respiratory health, and reduced fuel collecting time. An important safety concern with producer gas cooking is the toxicity of the carbon monoxide component of the gas. Educating users about this safety issue is important.

Solar cooking techniques have advanced significantly over the past decade, with reliable designs now increasingly used. However, solar cooking tends to be used where the cookers have been actively promoted by women's groups and NGOs, and they are not as widely used as they might be. This is because factory-produced solar cookers are generally too expensive for rural households, and the solar cookers introduced through local promotion are usually constructed by the women who use them.

Biomass briquettes are a more flexible and easily used cooking fuel than wood. Briquettes and pellets are produced by compacting machines that produce a uniform, good quality fuel. Coal/

biomass briquettes have also been introduced in a few markets in Asia and Africa, and these can be produced in such a way as to minimise both particulate emissions and ash.

4.4.4. Community Energy Services

There are many community services that can be energised by stand-alone renewable energy technologies. These include community water supply systems, schools, health clinics, telecommunications (including rural telephones and Internet access), and public lighting (including streetlights, light-houses, beacons, and signage). Another application is in the preservation of natural habitats, parks, and environmentally-sensitive and protected areas by providing electric power to watch towers and environmental research stations. Several examples are presented below.

4.4.4.1. Community Water Supply

The most important priority for rural communities is the *reliable supply of safe drinking water*. Most of the deaths in the developing world are children who have not yet reached their fifth birthday; most of those deaths arise from water-borne disease. Commercial equipment that permits supply of clean water is available, either directly from aquifers (which are generally sources of safe drinking water), or through filtration and disinfection. The other principal uses of water in rural communities are for irrigation and livestock (chickens, geese, pigs, cattle, etc.).

The use of renewable energy systems for community water supply, including cleanup and disinfection, must be conducted in the context of an assessment of local water supply and quality. It is strongly recommended that any electrified water pumping program, whether by renewables or other sources, be designed in collaboration with local water resource experts and in the context of an overall water resource management program.

Wind-mechanical, electric, and solar-electric water pumping are well-established and reliable commercial applications. PV pump-sets are used in almost every developing country, and in spite of their higher initial cost, they are often preferable to kerosene, gasoline, and diesel pumpsets, because of their inherent reliability and freedom from fuel requirements.

BOX 7. RENEWABLES CAN POWER WATER PURIFICATION IN A VILLAGE ENVIRONMENT

Reliable electricity is needed to power a water purification and delivery system. Elements of an effective system include the pump, filters to remove large particulates, a slow sand filtration system to remove fine particles, and a water-polishing filter. A 0.5-micron carbon block filtration process removes any remaining sediment, bad tastes, odours, colour, and smell, biological threats such as giardia and cysts, and many harmful chemical contaminants. Following this step, which results in clear water, a low-power ultraviolet (UV) disinfection unit destroys any remaining microorganisms.

UV radiation kills or neutralises bacteria and viruses that cause typhoid fever, dysentery, cholera, infectious jaundice, hepatitis virus, influenza, and enteric fever. Properly operated systems achieve virtually total elimination of such threats. UV disinfection is widely available, primarily in industrialised regions, including some developing countries. However, they are *not yet widely used in rural communities*. PV and wind electric systems can provide the modest level of power and energy required by these systems.

Wind Mechanical Pumping

Mechanical pumpsets are used worldwide to provide water for human consumption, livestock, and irrigation. The principal advantage of wind mechanical water pumps over wind electric units is the ability to provide a useful pumping service at lower wind speeds (2.5-3 m/s). Somewhat higher wind speeds (>4 m/s) are needed for wind electric systems to operate. They can also be fabricated locally. There are also some disadvantages of mechanical systems. They must be located atop the well, while the best well locations and the best local wind sites often do not coincide. The units are less reliable than wind electric pumps, which can operate reliably without service for several years. They generate shaft power, but do not generate electricity.

Wind Electric Water Pumping

Wind electric water pumping is increasingly used in off-grid communities and remote locations around the world. Small wind turbines are linked to submersible water pumps and have the advantage of not having to be located directly above the bore hole like mechanical windmills.

Additionally, they can pump from relatively deep wells at economical rates. Using newly developed wind-electric pumping technology, wind turbine systems are being used for village water supply and irrigation, and can power water disinfection systems. These new wind pumps provide an attractive alternative to the traditional diesel powered pump in regions where there is a good wind resource. In many off-grid communities, a single wind-electric installation powers one or more pumps and supplies electricity for community and productive uses. The electricity can be used to power filtration and disinfection units as well.

There are a few disadvantages of wind electric systems. Wind turbines are produced in few developing countries, and have to be imported. This can increase the cost of water production and decrease reliability, unless there is a local stock of spare parts, tools, manuals, and trained technicians. In a UNDP/GEF project in Mauritania, where small (1-3 kWe) wind turbines are used for water pumping in tube wells, the project has supported technology transfer from a European firm. Except for the blades, all of the components for the turbines are produced in country. The local supplier also provides installation and contract maintenance services, and guarantees a 72-hour turnaround on repairs. Since the community potable water storage tanks have a capacity of at least a week, the sustainability of clean water supply is assured.

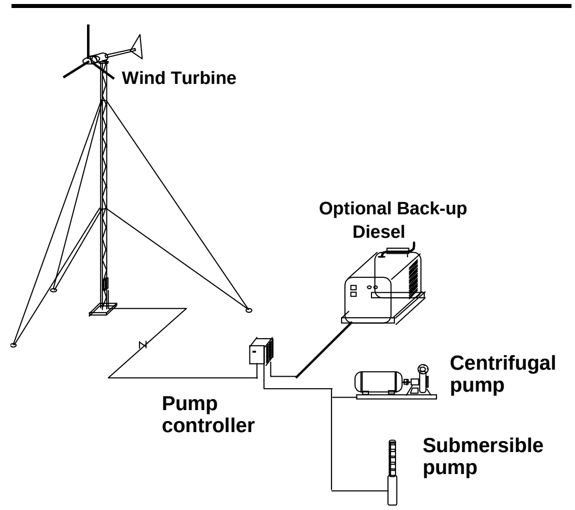
Photovoltaic Water Pumping

Tens of thousands of commercially proven PV-powered water pumps are in use worldwide. Solar electric water pumping systems use photovoltaic (PV) arrays to power electric water pumps for applications including potable water supply, livestock watering, and irrigation. Stand-alone PV water pumping systems are widely used for pumping applications that are larger than can be provided by hand pumps and smaller than those provided by large engine/generator-powered systems.

The principal components of a PV water pumping system are the PV array, DC water pump, electronic controller, and (for some applications) battery bank. Other components are a water storage system, which includes a covered tank for potable water and an open tank for livestock and small cash crop gardens. In some systems, water is distributed from the covered storage tank via plastic pipes to standpipes in a village. A filtration system (incorporating cloth filters, sand, and activated charcoal) may be used to remove suspended materials, and a disinfection system may be incorporated following the filtration. A common disinfection option is drip chlorination at the potable water storage tank. A new high-efficiency electrically-powered ultraviolet disinfection technology can also kill all bacteria, parasites, and viruses in the water entering or leaving the storage tank, but provides no residual disinfection capabilities.

Batteries, which add capital and operating expense, as well as increased maintenance, are usually not required. If elevated water storage can fully compensate for electricity storage, batteries can be eliminated. Because it is generally much cheaper to store water than to

FIGURE 8. WIND-ELECTRIC WATER PUMPING



Source: Bergey Windpower Company

store electricity, most PV water pumping systems do not include batteries, and water distribution is through gravity feed or through the use of a small pressure pump. However, for wells with a maximum sustainable pumping rate that is close to the average daily water supply requirements, batteries can permit the well to be pumped continuously at an optimal rate, and the pump can be operated with maximum efficiency. Twelve and 24-volt DC pumps typically require 50-150 watts PV modules, depending on the head. Commercial PV systems are also available in the 1-5 kWe range to drive larger standard AC motor pumpsets by converting DC electricity to AC electricity at 50 or 60 Hz, using a variable frequency AC motor controller.

When high-quality commercial components are used, properly configured, and installed, PV water pumping systems are highly reliable, amenable to automatic unattended operation, and require little maintenance and no fuel supply. They generate no air pollution and are very quiet. In general, they are easy to install, and their capacity can be matched to water demand.

Disadvantages relative to engine/generator pumpsets are that PV pumpsets have higher initial costs, and that water production rates depend directly on the incident solar radiation. In areas with good winds (at least 4-5 m/s annual average), wind electric water pumping is less expensive than PV water pumping, and can provide a highly reliable source of energy, assuming winds are available year round. Backup generation can be used when winds are seasonal.

An ongoing problem with PV water pumps and other PV-powered equipment is theft of the PV modules. Without a strong sense of community ownership of these systems, security is often low and can result in the disappearance of modules. Early community participation in PV projects and the use of security personnel at night is necessary to reduce theft and system abuse. While diesel gensets are much harder to steal, fuel theft is a major problem in many areas. Small diesel power plants that can run unattended often have diesel technicians living adjacent to the plant, in part to protect the equipment and fuel from theft.

Costs and Economics

In sunny regions (300 sunny days/year) or windy regions (5 m/s annual average wind speed), the cost of water supply varies from less than US$0.10 per cubic metre for a water depth of 20 metres, to US$0.50-1.00 per cubic metre for a depth of 200 metres. Suppliers of PV and wind-electric water pumps provide tables and calculation methods to determine the amount of water that can be pumped from a specified depth for specific sunlight intensity or wind speed. These costs are illustrated for commercially available wind and solar electric pumping systems. Not included are the costs associated with drilling the well and installing the casing, import duties, value-added taxes (VAT), or other fees, or the costs of pump system shipping, installation, and commissioning. Non-well related costs could be 30 percent or more of the selling price of the system from the supplier.

TABLE 7. ILLUSTRATIVE COSTS FOR PV AND WIND ELECTRIC WATER PUMPING

PUMP TYPE	DEPTH (M)	M^3 PER DAY	COST (US$), WATTAGE	WATER COST (US$/$M^3$)
Wind electric	**20**	**20**	**$10,000 1,500 watts**	**$.07**
	200	**2**		**$.60**
Photovoltaic	**20**	**20**	**$3,400, 300 watts**	**$.10**
	200	**2**		**$.90**

Note for Table 7: Water cost calculated assuming the installed systems are financed for 10 years at 10%/year interest. Insolation = 5 kWh/m²/day annual average, 300 sun days/year, annual average wind speed of 5 m/s.

Case Example: Community Water and Electricity Services Supply in Mauritania

A Mauritanian/French team has demonstrated the benefits of a well-designed wind electric power application to provide clean water to a village at serious risk from drinking badly polluted water from the Senegal River. In the small Mauritanian community (3,000 people) of Keur Macene on the Senegal River, a 2 kWe wind turbine energises a clean water supply system. The turbine powers a floating electric pump on the Senegal River. This pumps water from the river through a slow sand filtration unit (with a cloth pre-filter and activated carbon final filter) and then to covered storage tanks where drip chlorination provides disinfection. Water is then distributed from the tanks (on a small hill) via underground plastic pipe to standpipes for collection. Prior to the introduction of this system, the villagers obtained their drinking water by truck from the heavily polluted Senegal River. Since the installation of the system in 1996, the incidence of serious water-borne disease has decreased from over 80 percent of the population to around 5 percent.

4.4.4.2. Electricity for Public Services

Rural Health Clinics

Small health posts and clinics provide essential primary health care services to hundreds of millions of people throughout unelectrified regions. Most of these facilities are unelectrified, and this seriously limits their effectiveness and their ability to deliver health services and medicine, as well as to attract and retain nurses and physicians. Electricity also makes possible much more effective community education about vital health needs such as prenatal care, vaccinations, and minimising the spread of infectious diseases.

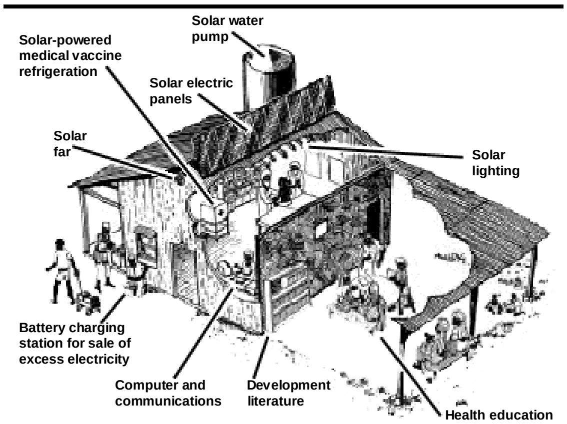
The electricity needs for a typical rural health facility are modest—under roughly 10 kWh per day. Photovoltaics are providing electricity for a growing number of health posts to ensure availability of lights, water pumps, medical refrigeration for drugs and vaccines, medical instruments, fans, and sterilisers. In sufficiently windy areas, small wind turbines are being used as well, and some clinics also have back-up generators when there is inadequate energy available from solar and wind sources. For clinics with electricity usage of several kilowatt-hours daily, the annualised cost of energy is roughly US$1.00 per kWh, or the equivalent of a few dollars per day. On-site power also permits the use of telemedicine systems to allow remote diagnosis and intervention for ill or injured people in rural areas.

The World Health Organisation is a strong advocate for the use of renewable energy technologies—especially PV—for medical refrigeration and, more broadly, to meet the energy needs of these clinics. The US National Renewable Energy Laboratory (NREL) has prepared an extensive practical guide[5] to the use of renewable energy for rural health clinics, including an economic comparison of PV, wind, and diesel energy supply options.

Case Example:
Rural Health Clinics in Colombia

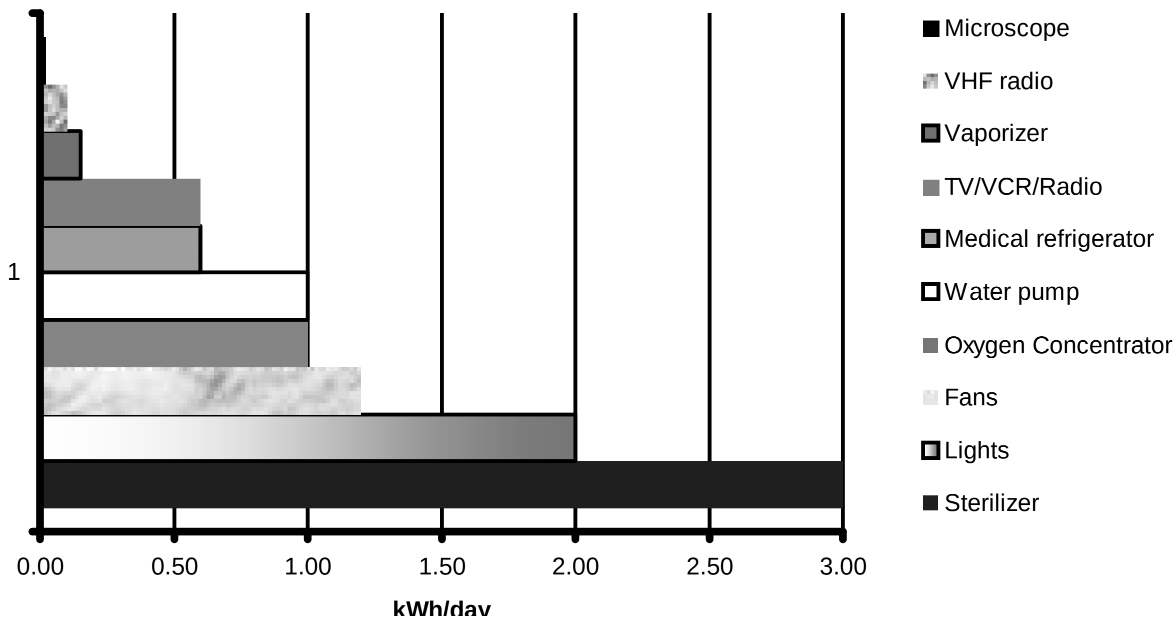
Four rural remote communities in the Province of Chocó, on the Pacific Coast of Colombia, utilide PV systems to provide health care services such

FIGURE 9. SOLAR-POWERED COMMUNITY HEALTH CENTER



5 *NREL (1998)* Renewable Energy for Rural Health Clinics *(available for download as a PDF file at www.nrel.gov)*

FIGURE 10. DAILY ELECTRICITY NEEDS OF A SMALL RURAL HEALTH CLINIC (KWH/DAY)



as vaccine refrigeration, lighting, communications, and medical appliances. Each of the four communities has established community councils to create micro-enterprises to generate funds for maintenance of the PV systems. The community councils have received PV systems to power micro-enterprises including four video theatres, two battery charging stations, and the sale of PV powered lanterns. Four churches also have received lighting systems. Two technicians were selected from each community and trained in the installation, troubleshooting, maintenance, and repair of the systems.

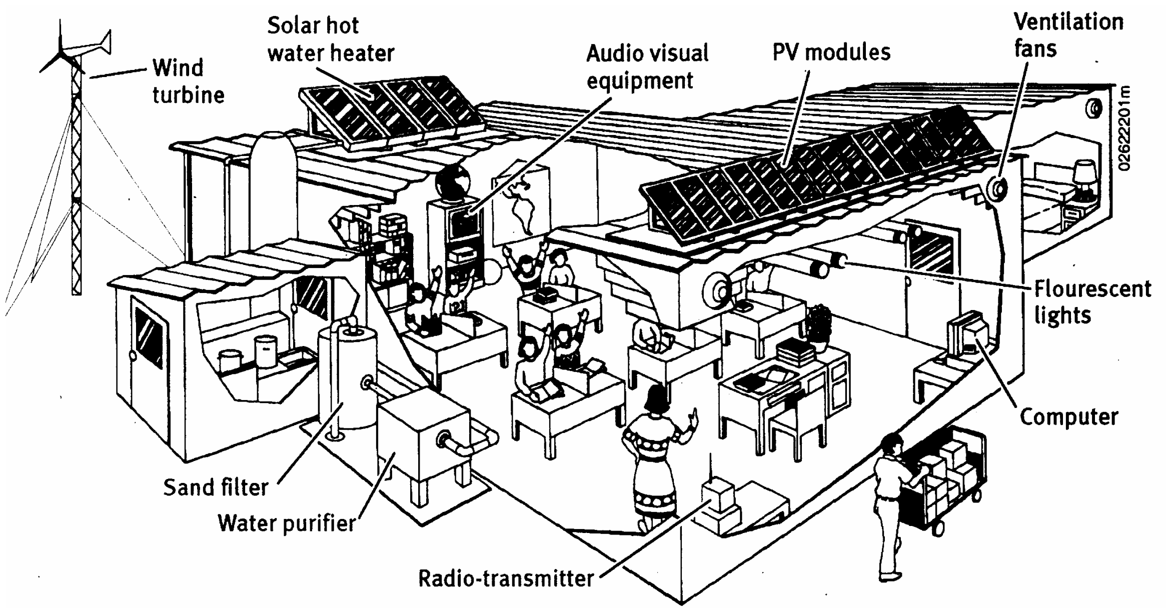
Income generated by each of the four communities for operations and maintenance at the health clinics during April-December 1995 averaged US$450. The project was well accepted by each of the communities and health institutions. Rural health services were improved by the availability of the PV systems. Vaccination coverage was increased; the diagnosis of Malaria was more rapid; emergency communications were effective; lighting greatly improved the quality of health clinic night visits and the quality of the staff residences. Health education was improved, there was a reduction in home accidents from kerosene lamps; and community participation was effective in generating funds to maintain PV systems for health care.

Rural Schools[6]

Universal access to education is a central objective of human development.Improved education is essential for sustainable increases in productivity and development. Yet, most schools in developing countries—especially in rural and peri-urban areas—lack access to basic services, including running water, toilets, and lights. Rural schools are typically the last to receive funds, school supplies, and books. Yet, in rural areas schools often must fill a larger local role than urban schools. They are often used as community centres, and where lighting is available at night, there is often a local demand for adult education. Rural schools must provide clean water and often food for students.

[6] *NREL has published an extensive 50-page guide to the use of renewable energy technologies for schools.* Renewable Energy for Rural Schools *is available at www.nrel.gov.*

FIGURE 11. COMMUNITY SCHOOL



Renewable energy systems, especially photovoltaics and small wind turbines, can provide the electricity services that can transform the quality of rural schools. They can support use of computers, Internet access, and expand the learning potential through the provision of energy services. Computers and the Internet have spread rapidly through most developing countries, but their availability is limited primarily to urban areas. Other school needs include hot water, refrigerators and freezers, space heating and cooling, TV/VCR, AM/FM/cassette units, and hand power tools. Depending on the physical size, layout of the school, and the number of students, daily energy requirements typically range from a few kilowatt-hours to 10-20 kilowatt-hours.

<u>Case Example: School Electrification in Salta Province, Argentina</u>

While most of Argentina's population lives in electrified communities, there are some 2.5 million people without electricity, widely dispersed in rural areas. Because of the prohibitively high cost (estimated at US$8,000 per household) of bringing electricity to this population via grid extension, the national government has established an innovate program of rural energy concessions for private sector participation. The private company (concessionaire) installs and maintains residential PV systems in the province. It also is installing PV systems in many of the 700 unelectrified rural schools in the province. By February 1999, 130 schools have received PV systems using two to four 75-watt PV modules, together with batteries, charge controllers, and associated equipment. In most cases, the government subsidises the system installation cost, with the school/community paying for maintenance and repair.

Village Minigrids

In regions where line extension from a backbone power grid is not technically or economically feasible, local low-voltage minigrids are often used to provide local electricity services. In most cases, these are energised by one or more diesel gensets with an aggregate capacity of twenty kilowatts to several hundred kilowatts. Unless the community is quite large, with significant daytime, economically-productive loads, power is generally available only at night, for four to six hours in many cases, and sometimes until dawn.

Renewable energy systems can be used to provide power on a full-time basis to such communities. Microhydro systems are increasingly used for full-time community power. Hybrid power systems are also being used. PV/diesel units are widely used in Australia for providing power to aboriginal communities, and, on a much more limited pre-commercial pilot basis, for communities in a few other countries, including Chile, Mexico, and Brazil. On an annualized basis, hybrids can provide electricity at costs in the range of US$0.40-0.80 per kWh, generally comparable with the full costs of electricity from small diesel gensets in off-grid communities. However, further technology development and industry expansion is required if this promising option is to be used on a significant scale in a routine manner. Small (10 kWe) skid-mounted pre-packaged PV/propane generator units are commercial products today, but larger systems are typically custom-configured or engineered. Another option for powering community minigrids in some regions is with biomass. Options include biomass combustion, gasification, or biogas production to drive an engine/generator. For further details on biomass technologies, see section 3 of this chapter.

Case Example: PV/Wind/Diesel Hybrid Power System for the Community of Joanes, Brazil

A 50 kilowatt PV/wind/battery hybrid power system has been installed in the village of Joanes in the municipality of Salvaterra, on Marajù Island, in the Brazilian state of Parç. The system operates primarily in a grid-interconnected mode. Renewable energy-generated electricity goes directly to the grid or to charge the battery bank to dispatch its full 50 kW capacity to the grid during times of peak demand. The Joanes system uses a rotary converter (shaft-coupled DC motor and synchronous alternator) for power conversion. It incorporates four 10-kW wind turbines and 10 kW of PV modules. Renewable generation in Joanes is expected to reach 115 MWh/year, supplying 45 percent of the total current demand. A concurrent energy conservation program in the village is expected to boost that percentage to more than 60 percent. The village has 170 consumers, plus public lights. Similar villages could obtain all of their power needs from such hybrid units energising a village minigrid, without the need for a connection to a larger grid system.

Case Example: Biogas-Based Rural Electricity and Water Supply Utilities in India

Pura is a village with about 500 residents in the Kunigal Taluk of the Tumkur District of Karnataka State, India. Beginning in 1987, traditional means for obtaining water, illumination, and fertiliser in the village were replaced with a biogas-based Rural Energy and Water Supply Utility (REWSU), which subsequently has operated successfully for a decade[7].

The Pura system was developed and implemented by the Centre for the Application of Science and Technology to Rural Areas (ASTRA) at the Indian Institute of Science in Bangalore. Beginning in 1995, the International Energy Initiative (IEI) based in Bangalore launched an effort supported by a grant from the Rockefeller Foundation to replicate the Pura experience in nine more villages.

Hardware installed at the REWSU included a biogas generator, a dual-fuel diesel engine generator, a water pump and borewell, and electricity and water distribution networks to individual households equipped with tube lights and water taps. The institutional arrangements around the REWSU included a Grama Vikas Sabha (GVS), or Village Development Society, consisting of about 15 villagers. The GVS managed the operating revenues and expenditures of the REWSU (and achieved very high revenue collection efficiencies). Additionally, a plant operator handled day-to-day operations, including dung collection, sludge disbursement, revenue collection and expenditure, etc.

An implementing agency, the Karnataka State Council for Science and Technology, provided

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[7] *Rajabapaiah, P., S. Jayakumar, and A.K.N. Reddy (1993). "Biogas Electricity—the Pura Village Case Study", in* Renewable Energy: Sources for Fuel and Electricity, *Johansson, T.B., H. Kelly, A.K.N. Reddy, and R.H. Williams (eds.), Island Press, Washington DC, 787-815.*

initial (government grant) financing, managed the plant construction, and provided training and ongoing technical support (in conjunction with ASTRA) to the GVS. An essential administrative step contributing to success at Pura was the establishment of the dung collection and sludge return system based on a set delivery fee that went primarily to women, thereby insuring their involvement.

Analysis of extensive data collected at Pura indicated the REWSU to be highly successful in terms of providing physical benefits to villagers in the form of electricity, water, and an improved fertiliser, as well as social benefits of village cooperation, improved quality of life, and training and employment opportunities for a few villagers.

Based on the capital and operating costs incurred at Pura, the cost of electricity generated by the REWSU was calculated to be competitive with central station, coal-based power delivered to the village if the REWSU were to operate for at least 15 hours per day. During the decade of operation at Pura, the electricity demand in the village did not reach high enough levels to enable this much running time. The addition of small industries or irrigation pump sets in the village would enable higher operating hours to be reached, as would sale of excess electricity to the utility grid.

Assimilating the lessons learned from the replication efforts in all nine villages, the IEI formulated a set of general guidelines for future replications (see Shivakumar *et al.,* 1998). Within these guidelines, there are lessons relevant to other types of community-scale rural energy development projects as well.

Project commencement:

- Villagers must want a REWSU, i.e., there should be a perceived need for drinking water, lights, etc.
- Sufficient resources of dung, well water, and land must be available, and villagers must be willing to commit these to the REWSU.
- There must be clear communication regarding villagers' obligations to the REWSU, including dung requirements, operating costs, tariffs per household, GVS involvement, record keeping, periodic meetings, etc.
- Women must be involved in the decision to establish a REWSU.
- Local and state government officials should be informed of the project goals and should provide official support for implementation, placing a REWSU effort on par with government-sponsored rural development schemes.

Construction of REWSUs:

- Quality construction (qualified supervisors, clear reporting procedure, etc.) and practical schedules are important.
- Expenses need to be carefully monitored; escalations above budget should be adequately justified.
- Project promoters need to be sensitive to any discomfort on the part of villagers with the project and take confidence-building steps to address any concerns.

Initial REWSU operation:

- Revenues must be sufficient to cover operating expenditures, including a 10-20 percent contingency. (This assumes grant funding of the capital.)
- Local and state governments need to be kept aware of the implementation so as to avoid any potential conflict with government-sponsored schemes planned for the village.
- Villagers' confidence in the GVS is essential.
- Sufficient representation of women in the GVS is important. A suggested guideline is 50 percent women in the GVS, including an office-bearer such as President or Secretary.

Financial sustainability:

- Revenue collection should be sufficient to allow for long-term capital replacement in the future.
- Proper, transparent, and public record keeping, along with regular GVS meetings are important to ensure that villagers are fully aware of monthly revenues and expenditures.
- Villagers must have confidence that the GVS is committed to the long-term welfare of the REWSU.

- The possibility of selling excess power to the grid needs to be explored to provide for additional revenues.

Overall lessons learned:

- A variety of implementing agencies can successfully replicate the original Pura village experience.
- Either a local village stake or a strong desire and capability of a non-local implementing agency to build local confidence in the REWSU concept is essential.
- Democratic and transparent institutional arrangements at the village level are critical for sustained operation of the REWSU.
- Government agencies should be closely involved with large-scale REWSU implementation, treating REWSU projects on par (e.g., offering similar administrative and financial support) with other rural development schemes so as to insure no conflicts arise between a REWSU and other government-backed schemes.
- Government involvement is essential, but government organisations as implementing agencies may not be efficient.

4.4.5. Promoting Economically Productive Activities

Renewable energy systems can provide the energy needed for economically productive activities. Diversification and increase of incomes and of jobs is an urgent need throughout the developing world. Investments in renewable energy equipment, by end users and by energy service enterprises, become attractive if these investments are coupled with increased economic productivity. Because most productive applications require AC power, the use of micro-hydropower plants, biomass-based power generation, and hybrid units may be economically attractive. Such options can be purchased or leased by local end users. These facilities can also be developed and operated by rural energy service companies (RESCOs), rural electric cooperatives, or other organisations able to provide reliable power on a cost-recovery basis. This stands to free entrepreneurs and businesses to focus on income generation and not on energy supply, and can, therefore, save them the capital required to purchase the energy supply systems. Table 4.5 indicates some essential applications for renewables for expanding and diversifying local incomes.

Applications include the use of electricity for irrigation, ice making, refrigeration (crops, produce, fish, etc.), food processing, shops, and other income generating activities. Some applications such as irrigation and ice making, do not require fuel-fired generation back-up, if the region is reasonably windy all year. In reality, this is rarely the case, and some form of back-up generation will be needed, at least for a portion of the year. In this case, the use of small wind turbines can substantially reduce fuel requirements and significantly increase the life span of fuel-fired generators.

Many more conventional applications of renewable energy for productive uses are generally well-understood. There are some that are less well-known, and these are mentioned in vignettes here.

Case Example: Cyber-Kiosks in Bangladesh[8]

The Grameen Bank in Bangladesh has created an innovative enterprise known as *GrameenPhone*. This is bringing PV-powered mobile telephone service to villages in Bangladesh. Photovoltaics provides the power for the telecommunications, computer, and lighting needs of these kiosks. The mechanism is women-owned "teleshops", with the local entrepreneurs funded through loans from the Grameen Bank. Together with Canada's International Development Research Centre (IDRC), they are establishing "cyber-kiosks" that provide Internet access, as well as telephone connectivity to villages. The kiosk owners earn money from telephone and Internet services, as well as from offering computer classes and selling other services, including e-mail, word processing, printing, and even desktop publishing. Using digital cameras,

[8] Time, *11 October 1999*

TABLE 8. ECONOMICALLY PRODUCTIVE APPLICATIONS OF RENEWABLE ENERGY SYSTEMS

END USES	ENERGY SERVICES	RE TECHNOLOGIES
Community bakeries	**Heat and forced convection**	**Solar ovens, biogas**
Rural telephone kiosks	**Cellular telephones**	**PV**
Shrimp farming	**Continuous fail-safe aeration, refrigeration freezing, and ice making**	**PV/diesel hybrid or wind/diesel hybrid, SMB**
Fish farms	**Aeration, refrigeration, freezing, and ice making**	**PV/diesel hybrid or wind/diesel hybrid, SMB**
Fishing (ocean, lake, river)	**Refrigeration/cold storage, ice making, and freezing**	**PV/diesel hybrid or wind/diesel hybrid, SMB**
Large-scale irrigation	**Water pumping and distribution**	**Wind-electric and wind/diesel hybrids, bioenergy**
Small-scale irrigation (< 1 ha)	**Water pumping, distribution, storage**	**PV and wind electric with optional engine backup**
Livestock management	**Water pumping, electric fencing**	**PV and wind electric with optional engine backup**
Agriculture	**Drying, grinding, extraction, milling, processing, packaging, preservation (cold storage, freezing)**	**Solar thermal drying with forced air (electric blowers); hybrid power systems, biomass gasification/ engine gensets at mills**
Crop loss reduction	**Illumination to trap moths**	**PV lanterns**
Woodworking, furniture production	**Electric hand tools, machine tools, lights**	**PV/diesel hybrid or wind/diesel hybrid, small modular biomass**
Machine shops	**Metal working, grinding, milling, drilling, welding, etc.**	**Wind/electric hybrids**
Stores, shops, restaurants	**Lighting, refrigeration, freezers, hot water**	**PV, hybrids, solar hot water**
Ecotourism facilities	**Lighting, refrigeration, freezers, hot water, fans, air conditioning, telephone/ telecommunications, water pumping and purification, air for dive tanks**	**PV/wind/diesel hybrids, solar water heating**

local craftsmen and artists could promote and sell their products over the Internet.

Case Example: Small-scale Wind-Electric Irrigation for Income Generation in Eastern Indonesia

A farmer in Eastern Indonesia is growing onions on a tiny plot of land (0.065 hectares) to earn money to support his family. His annual income has been the equivalent of US$550, and 1,040 hours of family labour have been required each season to haul water to his plot to bring the crop to harvest. A small (1.5 kW) wind electric water pump was installed nearby in 1998. Because it was no longer necessary for him and his family to carry water to the onion plot, his required labour was reduced to 100 hours per season, permitting his children to attend school. The value of his crop increased to US$2,200 due to sufficient water availability.

Case Example: Improvement of Crop Yields through PV Lantern Pest Control in India

In a region of Southern India, farmers had been losing up to 50 pecent of crops from insects. Use of pesticides was expensive, increasingly toxic, and increasingly ineffective. Through a collaborative initiative with the NGO Winrock International, a group of farmers tested a new approach to pest management based on renewable energy.

TABLE 9. BIOMASS-FIRED COGENERATION PLANTS IN MALAYSIA (COMMISSIONED IN MID TO LATE-1990s)

TYPE	OUTPUT	PAYBACK (YEARS)	NOTES
Rice husk-fired	**450 kWe**	**3**	**Grid-connected; solves rice husk disposal problem, reduces power draw from the grid, uses exhaust heat for paddy drying**
Wood chip-fired	**10 MWe**	**2**	**Off-grid; system replaces diesel generation, solves wood residue disposal problem and eliminates on-site need for fossil fuel**
Wood waste-fired boiler	**1.5 MWe**	**3.5**	**The rapid payback is due to the savings in bunker oil, diesel fuel, and wood disposal costs**

Source: EC COGEN Programme, www.cogen.ait.th

PV lanterns were placed throughout a 40-hectare trial area in the fields, and suspended over kerosene-filled vats. The insects were attracted to the light, disoriented, and subsequently killed when falling into the kerosene. Crop losses were reduced from 50 to 4 percent in short order.

Case Example: Solar Bakery Project in Sonora, Mexico[9]

In a poor neighborhood of Ciudad Obregon (a city of 400,000) in Sonora, Mexico, a group of women have started their own bakery using a commercial-scale solar oven they have constructed with assistance from an international NGO. The oven uses plywood, double-pane insulating glass, and shiny aluminium reflectors to achieve baking temperatures. A battery-powered adjustable fan permits improved temperature regulation and better baked goods. The battery is recharged by a small PV array. A local micro-enterprise group has helped the women establish sound business practices and effective marketing.

4.4.5.1. Cogeneration of Heat and Power at Agro-Industrial Sites

Both heat and electricity are necessary inputs in many industrial processes. Usually, fuel is burned on-site to provide the heat, and electricity is generated in power plants and obtained via the electric grid system. However, when electricity is generated in a power plant, less than one-half of the energy contained in the fuel is converted to electricity—the remainder is wasted as unusable heat. In many cases, a much more efficient and cost effective strategy is to generate electricity on-site and simultaneously meet industrial heat demands with the resulting "waste" heat. This is referred to as *cogeneration* of heat and power (CHP)—and avoids the unnecessary consumption of fuel for separate generation of heat and power.

The most cost-effective industrial contexts for implementing CHP are where there is an abundance of residues that can serve as a source of fuel—which is typical of many agro-industries. In Southeast Asia, efficient non-polluting cogeneration technology has been introduced into the palm oil, sugar, rice, and wood products industries. Installations range in size from 0.5 MW to 40 MW, with the thermal and electrical outputs designed to match the plant requirements for heat and power. The financial payback time[10] for most of the modern plants is in the range of two to four years. A few recent examples of biomass-fired cogeneration plants in Malaysia are shown in Table 5.

[9] *Adapted from a report by Solar Energy International, www.solarenergy.org*

[10] *EC-ASEAN COGEN Programme, www.cogen.ait.ac*

BOX 8. COGENERATION OF HEAT AND POWER AT SUGARCANE PROCESSING FACILITIES

The production of sugar or ethanol involves the crushing of cane to extract the sugary juice, leaving a fibrous byproduct called bagasse. Bagasse is often used as a fuel for the generation of steam and power to supply the sugarcane processing facility with its process energy requirements (i.e., CHP). However, the technologies that are typically in use for power production at sugarcane processing facilities are far from optimal. The potential for more efficiently producing power and making sugar mills net exporters of electricity is largely untapped.

Bagasse accounts for about 30% of the weight of fresh cane and over half the cane's energy content. An additional resource is cane trash (cane tops and leaves), which is typically burned on the field to promote pest control and facilitate harvesting, although the resulting air pollution has motivated some governments to ban this practice. As an energy resource, cane trash is comparable in magnitude to bagasse, and is being investigated in several countries (including Brazil, Cuba, India, and Thailand) for energy applications. If all cane processing facilities in the 80 cane-producing countries were producing power from bagasse and 80% of cane trash using BIG/GT generation technology, the amount of electricity produced (additional to plant needs) would be more than one-third of aggregate electricity demand in those countries. Recognising this as a tremendous untapped resource, many developing countries are more actively examining technologies and institutional arrangements that can allow sugar mills to become exporters of excess electricity. Some governments are providing incentives (e.g., guaranteed power purchase agreements) to encourage sugarcane-based electricity generation, and demonstration projects are being developed in a number of countries.

A further energy resource from cane distilleries is stillage, a potassium-rich liquid drained from the bottom of the distillation columns. Stillage is a suitable feedstock for biogas production, providing up to 25% of the energy in the alcohol. The anaerobic digester process removed pollutants from the stillage top a level that the digester effluent can be safely returned to the soil of the sugarcane plantation.

4.4.6. Using Renewable Energy for Regional and National Electricity Grids

Conventional large renewable energy systems are widely used for bulk power generation. These include hydropower and biomass cogeneration at agro-industrial and forest products industry sites. Wind electric power has become a fully commercial grid-connected option, with over 10,000 MWe of installed capacity worldwide, most of it in Europe and the United States, but with growing components in India (ca. 1,000 MWe) and China (several hundred MWe). Grid-connected biomass cogeneration plants are well-established commercial options. Photovoltaic power generation is not yet an economic option for grid strengthening, but the installed costs of megawatt-scale PV systems are within a factor of two of being economic, according to PV industry analysts. According to the International Finance Corporation (IFC), there are more than 300,000 MWe of potentially suitable hydro-power plants in sunny regions of developing countries that could benefit from combined PV/hydro operations.

<u>Case Example: Grid-Scale Biomass Cogeneration in Malaysia</u>

In 1994, the Malaysian timber company Aokam Perdana Berhad made the decision to use their wood residues for grid-scale power production. The investment in a wood-fired power plant stands to generate significant economic savings, while addressing the environmental problems previously caused by the incineration of the wood residues and the combustion of fossil fuel for power production. The company has installed a plant consisting of a wood chipper with a capacity of 20 tons per hour, a silo for storage of residues, a woodchip-fired steam boiler, and a 10 MW generator, costing approximately US$7 million. The annual savings are expected to be roughly US$4 million in diesel purchases and more than US$200,000 in expenses for disposing of the wood residues, yielding a payback time of roughly 2 years. The project has also yielded technology transfer benefits, as important components of the energy system, including the woodchip boiler, were manufactured in Malaysia using technologies licensed from a UK collaborator. Moreover, it is anticipated that the licensing arrangement will evolve into a joint venture. The project has been supported by the EC-ASEAN COGEN Programme, an economic cooperation program between the European Commission (EC) and the Association of Southeast Asian Nations (ASEAN), coordinated by the Asian Institute of Technology (AIT), Bangkok, Thailand.

Case Example: The IFC/GEF Grid-Tied PV Project in Mindanao, Philippines

The International Finance Corporation (IFC) and the Global Environment Facility (GEF) are collaborating with a Philippine electric utility company to co-finance a 1 MWp PV system[11] in their regional grid in conjunction with a recently commissioned 7 MWe hydropower facility. This plant is designed to provide the first full-scale demonstration of the environmental and, ultimately, economic benefits of the combined use of hydropower and PV-based power. It also stands to be the first significant use of grid-connected PV in a developing country.

The project is under preparation by the IFC's Environmental Projects Unit for consideration by the GEF. Such applications have been characterised as economically feasible when the total installed cost of the PV system, with all balance of system components, declines to about US$3-4 per installed peak watt. Based on current PV industry activities, such costs are expected to be achieved within the next five years.

Case Example: Integrated Solar Combined Cycle Power Plant Project in Mexico[12]

In 1998, Mexico had a total gross installed capacity of 36,000 MW to serve 95 percent of its population of 100 million people. Almost 80 percent of electricity production comes from fossil fuel sources. The Mexican government has established policies to reduce or mitigate the emissions of thermal generation, including the development of renewable energy projects. A World Bank pre-feasibility study is underway to determine the potential for development of a combined cycle gas/solar thermal electric power project. The proposed project involves the construction of a solar thermal/natural gas-fired hybrid power plant. The solar component uses the parabolic trough technology, which has been technically proven through successful operation of more than 350 MW of Solar Electric Generating Stations (SEGS) in California for over a decade. The project intends to use the newer Integrated Solar Combined Cycle System (ISCCS) approach, which involves the integration of a solar parabolic trough field with a conventional combined cycle power plant, thereby boosting the efficiency of both the solar and natural gas energy used.

4.4.7. Costs and Economics of Renewable Energy Installations

Renewable energy technologies are generally characterised by relatively large initial costs and low running costs, compared with fossil fueled systems. When energy system investment decisions are made on a first-cost basis, diesel and propane gensets are usually selected, even if over the long run they are less reliable and more expensive than renewable energy optiond designed to provide the same energy service. Conventional economic analysis for power generation investments reflects the nature of fossil fuel units, and economic discount rates of 12 percent or more are often used in economic evaluations of competing power generation options. This undervalues the long-term operation of renewables relative to fossil plants. It also ignores the significant uncertainty in long-term fuel prices. In contrast, the costs of many renewable energy systems are largely "front-end loaded", which means that the long-term costs (and net present value) of these systems are much more predictable than systems in which fuel costs dominate the long-term system costs.

Many conventional energy systems enjoy built-in or hidden subsidies that provide them with an insurmountable financial edge. For example, the costs of the numerous environmental impacts, caused by conventional (fossil) energy production and use, are generally not reflected in the price of these fuels and are not recovered from the users of these fuels. As such, society bears these costs. Additionally, fossil fuels enjoy a number

[11] *International Finance Corporation (IFC) Project Brief:* Philippines – CEPALCO Distributed Generation PV Power Pant. *Project Number 502486*

[12] *Source: World Bank (June 1999)*

of direct subsidies from reduced transport tariffs to resource depletion allowances. In many countries where fossil fuels are imported, they are exempt from import duties. Alternately, renewable energy systems seldom enjoy direct or indirect subsidies, because of their environmental benefits. In addition, many renewable energy products, if imported, are subjected to import duties and taxes. The net result is that renewables face higher financial costs when compared to conventional energy systems. In effect, the benefits of renewables are taxed, while the damages from conventional systems are subsidised.

4.4.7.1. Models for Financial Analysis

Actual project financial analysis is quite complex and involves detailed information on the renewable energy resource (usually hourly for a year), the full capital, operating, and maintenance costs over the financial life of the project, as well as relevant financial parameters, such as the ratio of debt financing to equity investment, interest rate, financial term, and other factors. A very useful set of Excel spreadsheet templates (RETScreen™)[13] has been developed by the Canadian Ministry of Natural Resources. RETScreen is a pre-feasibility analysis model for performing a preliminary evaluation of possible grid-connected renewable energy power plants. RETScreen is not a feasibility analysis tool, nor is it a detailed design tool. However, it fills the need for a low-cost approach that does not require too much detailed information to quickly screen various potential renewable energy projects.

RETScreen is not suitable for financial evaluation of decentralised applications of renewables. For these applications, including PV, wind, hybrids, and various diesel power configurations, a suite of computer models has been developed at the US National Renewable Energy Laboratory. One of these, *HOMER*, permits determination of the least cost life cycle financed option, once the input parameters are specified. These include the end-use energy demand profile (kWh/hour over a day or more), renewable energy resources (hour by hour over a year), the local price of diesel fuel, the capital and operating costs of the various options, and the relevant financial parameters. Access to the model is available via the NREL web site at www.rsvp.nrel.gov.

[13] *The templates and user's guides are available for download at no cost. The Internet address is: http://cedrl.mets.nrcan.gc.ca/e/412/retscreen_new_1.html*

4.5. SUSTAINABLE IMPLEMENTATION OF RENEWABLE ENERGY OPTIONS

Achieving sustainable economic and widespread use of decentralised RE systems will require a conjunction of effective policies, meaningful financing, and international cooperation with industrialised countries. Innovations in policy and financing will be needed to facilitate the use of renewables on any significant scale, both for grid-connected and off-grid use. Grid-connected renewable energy-based power generation will take place amidst major restructuring, reform, and privatisation of the power sector in many developing countries. For off-grid communities, renewables will be able to provide meaningful levels of energy and power for high-priority needs, including residential lighting, community services (education, health, clean water, telecommunications, etc.), and for economically productive uses. Important emerging new models will be able to support the large-scale use of decentralised renewable energy options.

As discussed in section 1.4 of Chapter 1, there are several key strategies that can be instrumental in bringing about the necessary changes for sustainable energy. Operationalising these strategies requires effective measures that represent programmatic entry points. The following summarises key implementation measures and policy instruments for each of the overarching strategies.

4.5.1. Creating Supportive Policy and Institutional Climates

Electricity markets worldwide are becoming increasingly competitive, deregulated, and privatised. Policies that support renewable energy technologies become increasingly important, because the benefits of using renewables are not fully accounted for in a competitive marketplace. First-cost considerations often determine investment decisions in competitive markets. For several reasons, competitive markets tend to act against the use of renewable energy systems, so it is important to support renewables as a matter of public policy. A broad array of policies has been effective many countries to stimulate renewable energy technology development and applications. For more detail, please refer to Chapter 1 and Chapter 6, and to referenced documents. Some examples of effective policy initiatives are the following:

- *Eliminate subsidies to conventional fossil energy resources*, which in many regions are very large, making it difficult for renewable energy technologies to compete, draining public sector resources, and compromising market efficiency;
- *Remove tariffs for imported equipment*, which in some countries increase the price of renewable technologies by large margins;
- *Internalise environmental externalities* in order to properly account for benefits of sustainable energy strategies relative to conventional energy sources in terms of costs to the environment and public health;
- *Promote market-transforming initiatives* to help usher into the marketplace viable renewable technologies, for example, instituting minimum renewables requirements (See Box 9) for the electricity sector;
- *Provide public support for renewable technology assessment, transfer, and adaptation* to establish a base of knowledge on technology options so that private and public enterprises might make renewable energy-based rural energy services available to end users; and
- *Grant producers of renewable electricity the legal ability to sell electricity to the grid* through regulatory measures, such as those that have already been demonstrated in some countries to successfully spur the development of independent power producers using renewable technologies.

4.5.2. Developing Innovative Financing Mechanisms

The financing of renewable energy projects cannot be accomplished with a single project or business finance strategy in the way that many large-scale conventional energy projects and enterprises are often financed. Renewable energy projects vary considerably in scale, capacity, energy resource characteristics, points of sale for output, targeted clientele, and commercial maturity. For example, a biomass cogeneration project may need to rely on several sources for fuel supply. It may have a few principal points for its energy

BOX 9. RENEWABLE PORTFOLIO STANDARDS

One recent policy innovation under active consideration in some developing countries is the renewable portfolio standard (RPS), adopted by six states in the US and by several European countries. The RPS is a new concept, first promoted in the mid-1990s. If properly implemented, the RPS can be a cost-effective policy for developing a significant market for renewable energy applications.

An RPS requires that all energy distributors or generators (depending on how the standard is designed) use renewable energy to meet a specified percentage of electricity sales or total generation. The standard ensures that a minimum amount of renewable energy is included in the country's energy portfolio. Standards can be dynamic, designed to increase the renewable energy market share over time, in order to expand the renewables market. By establishing long-term market demand for renewable energy, this type of policy encourages investors to develop renewable resources.

sales: an industry for its steam and electricity and, if necessary, an electricity distribution company for its power outputs. Alternately, a solar home systems enterprise has no need for a fuel supply contract, but needs to sell its energy services or sell or lease the equipment to individual homeowners. For financing purposes, renewable energy projects must not be aggregated into a single category, rather they need to be assessed individually (see Table 4.5.1). See chapter 7 for more details about financing for renewable energy initiatives.

4.5.2.1. Capacity Building for Development of Financially Viable Renewable Energy Projects

The traditional approaches to renewable energy development have been grant-based; however, to stimulate the market, projects must now be financially viable and able to meet strict lending criteria, in order to leverage private and public resources. Although there have been some programmes targeted at investment in renewable energy projects, there is still the need for capacity building at the national level for financial institutions and project developers, in order to put together financially-sound projects that are attractive to the private sector. Implementing renewable energy projects entails much more than merely providing renewable energy equipment. In order to successfully implement projects that are viable and sustainable in the long term, while contributing to expanding markets and roles for renewables, it is necessary to broaden renewable energy initiatives beyond their historical focus on providing equipment. Programmes have to address the need for infrastructure development to support operation and maintenance of the renewable energy systems, increase the awareness of potential consumers and suppliers of renewable energy services, promote market development, and spur the growth of indigenous commercial capacity.

An example of an initiative that helps establish an enabling environment for renewable energy activities is the EC-ASEAN COGEN[14] Programme, an economic cooperation program between the European Commission and the Association of Southeast Asian Nations, coordinated by the Asian Institute of Technology. It has helped implement 14 demonstration projects worth over US$100 million in Malaysia, Thailand, and Indonesia, based on proven biomass energy technologies. Typically, these projects have financial payback periods in the range of two to four years. COGEN stands to accelerate the implementation of proven biomass energy technologies within the industrial sectors in the Asia region, through partnerships between European and ASEAN companies. COGEN provides pre-investment analysis, assistance in securing financing, project implementation, market and technical studies, technical and business advice, training and outreach, and monitoring of biomass energy projects.

[14] www.cogen.ait.ac.th

BOX 10. 10 RESOURCES AVAILABLE FOR SUPPORTING RENEWABLE ENERGY

Some resources have been dedicated for renewable energy development including[15] the World Bank's Asia Alternative Energy Unit (ASTAE), which has helped the Bank finance over US$1 billion for renewable energy projects in the Asia region since its inception; the Solar Development Corporation; and the recently launched US$100 million Renewable Energy and Energy Efficiency Fund (REEF), which is designed to invest in private sector projects. The Asian Development Bank has recently approved a US$100 million loan to the Indian Renewable Energy Development Agency for biomass cogeneration projects in India. A number of "green banks" or "green funds" which support renewable energy projects are also emerging. These include the multilateral Global Environment Fund and some national and private sector banks, such as the Dutch government's Triodos Bank, the Development Bank of the Philippines - Loan Window III, and the Grameen Bank in Bangladesh.

[15] *For more information see "APEC Guidebook for Financing New and Renewable Energy Projects", 1998, Sustainable Energy Solutions*

TABLE 10. RENEWABLE ENERGY TECHNOLOGY CHARACTERISTICS RELEVANT TO FINANCING

RENEWABLE ENERGY PROJECT TYPE	SCALE	POINT OF SALE	STATUS OF TECHNOLOGY	FUEL SUPPLY
Biomass	**L / M / S**	**G / IG**	**M / NC / E**	**K / P**
Geothermal	**L / M**	**G**	**M / NC**	**K**
Hydropower	**L / M / S / Mi**	**G / IG / NG**	**M**	**P / U**
Windpower	**M / S / Mi**	**G / IG / NG**	**M / NC**	**P / U**
Solar Thermal Power	**L / M**	**G**	**NC / E**	**P / U**
Photovoltaics	**M/S / Mi**	**G / IG / NG**	**C**	**P / U**

Scale: L = Large, >20 MW; M = Medium, 1-20MW; S = Small, 100kW-1MW; Mi = Micro, <100 Kw
Sale: G = Grid-connected; IG = Isolated grid; NG = Non-grid
Status: M = Mature; NC = Newly commercial; E = Experimental
Fuel Supply: K = Known; P = Predictable; U = Uncertain

BOX 11. FACTORS RELEVANT TO RENEWABLE ENERGY PROJECT FINANCING

SCALE: The scale or capacity of a renewable energy (RE) project determines the level of financing needed. Many RE projects are small-scale and, therefore, difficult to finance cost-effectively, as the ratio of project development costs to total project costs can be much higher than conventional projects. Some RE projects are as small as several kilowatts or tens of kilowatts. In such cases, RE projects may have to be aggregated into a single, larger-scale megawatt (MW) range project, before applying for commercial financing.

POINT OF SALE: The point of sale determines the risks and difficulties associated with guaranteeing the revenue generation of the project. For some RE projects, there can be many widely dispersed points of sale, in contrast to a single point of sale common for most conventional projects. When securing financing for a project, points of sale must be shown to be "financially-sound" and capable of meeting their "power purchase agreements". When points of sale cannot be demonstrated to be financially sound, project financing is far more difficult to secure.

TECHNOLOGY STATUS: Many RE technologies are perceived to be either recently commercialised, or still experimental. This misconception translates into a perception of higher or unknown project risks. Financial risk relates to engineering, procurement and construction (EPC) costs for the project, operation and maintenance (O&M) costs, performance reliability, and project life. RE projects based on mature and commercially-proven technologies are much easier to finance than those using newly commercialised and relatively unproved technologies.

FUEL SUPPLY: The assurance of fuel supply is an extremely important factor in conventional power projects. The "fuel supply contract", along with the other contracts (EPC and O&M),is necessary to demonstrate a limited risk of cost overruns. A fuel supply contract is a necessary assurance that the project has the fuel to generate power. Many RE projects rely on nature for the supply of their fuel (e.g., solar, wind, hydropower and wave energy). In these cases, there are no fuel supply contracts and, therefore, no recourse when projects fail from a lack of fuel (e.g., a drought, no wind or extended cloud cover). With no guarantees on fuel supply, there can be no guarantees for power sales and, similarly, no guarantees for stable revenue generation. Of course, assessments of average conditions can help estimate the average revenue generation potential of an RE project. However, repayment of project financing must take into account that, in the short-term, there could be considerable variation from the average expected conditions and therefore a resulting variation in the average expected revenue stream of such RE projects. In the case of biomass-based energy, project developers must pay very careful attention to the availability and sustainability of the fuel source, integrating the acquisition of biomass feedstocks with pre-existing local agricultural, industrial, and community needs.

4.5.2.2. Developing Microfinance Schemes for Rural Energy Service Delivery

High initial costs are often an insurmountable barrier to accessing rural energy services, especially for poor households. The availability of financing is the key to overcoming this barrier. Microcredit is the provision of small amounts of credit to clients who are under-served by traditional, formal banking institutions, because of their lack of assets. Micro-finance is characterised by small loan amounts, given short-term working capital, repayment in small frequent intervals, and a focus on women. (See Chapter 7 for an extensive discussion of microcredit for energy end users.)

The premier example of microcredit for making renewable energy services accessible to poor households is Grameen Shakti, a not-for-profit financing NGO in Bangladesh that was founded on US$150,000 of seed funding from the Grameen Bank. It has grown substantially since. Grameen Shakti provides loans at 8 percent with a two-year loan term, which has proven adequate for putting solar home systems within reach of hundreds of households to whom they would otherwise be unaffordable. See Chapter 7 for further details.

4.5.2.3. Supporting Alternative Models for Rural Energy Supply

There are several models for using renewable energy equipment to provide energy services in off-grid communities, including direct sales (with consumer financing or cash basis), leasing, and fee-for-service.

Table 11 illustrates some of the characteristics of three approaches to providing renewable energy-based services to rural communities. These are: (1) fee for service; (2) equipment leasing; and (3) equipment sales with consumer financing. The latter two are transaction-focused activities, with little or no investment by the private sector in developing local markets, and market support infrastructure. The first—fee for service—is the basis of several new rural energy service companies (RESCOs), in which the private sector, sometimes in partnership with the public sector, is investing[16] in long-term supply and support of energy services, using a mix of renewable and conventional energy technologies.

The fee-for-service approach is now being pursued by perhaps a dozen companies worldwide, through rural energy service companies (RESCOs), and is particularly promising from the standpoint of ensuring the full complement of supportive infrastructure. Because the RESCO owns and operates the equipment that supplies the energy services and generates revenue, there is a long-term commitment that can underpin sustainable and reliable energy service delivery. Sales and leasing, by contrast, are transaction-driven activities, and rarely provide a basis for long-term service and maintenance. The entry of private sector RESCOs into the rural energy market for off-grid communities is a recent phenomenon, and, in part, reflects the increasing privatisation and restructuring of the electric power sector in many developing countries. For more details, please refer to Chapter 7.

[16] *Case examples of the fee-for-service approach are presented in Winrock International (March 1999),* Private Sector Roles in Rural Renewable Energy Services Delivery. *Workshop Report.*

TABLE 11. CHARACTERISTICS OF THREE MODELS OF FINANCING FOR RENEWABLE ENERGY PROJECTS

CHARACTERISTIC	FEE FOR SERVICE	LEASING	CONSUMER FINANCING
Affordability	**High**	**Moderate**	**Low**
Interest rate	**Low**	**Medium**	**High**
Repayment period	**Long**	**Medium**	**Short**
Downpayment/fee	**Low**	**Moderate**	**High**
Security/collateral	**System**	**System**	**System/other collateral**
Risk to lender	**Low**	**Moderate**	**High**
Administrative cost	**High**	**Moderate**	**Moderate**
System ownership	**SP owns generation components only**	**User (at end of lease)**	**User**
Potential consumer protection	**High**	**Medium to Low after final payment**	**Medium to Low after final payment**
Level of customer service	**High**	**High during lease; Low to Medium after**	**Medium to High during loan; Low to Medium after**

4.5.3. Promoting Private Sector Involvement

Private sector involvement is often critical for several reasons: private sector actors can be a source of investment capital that is simply unavailable in the public sector, they have an incentive follow through with project implementation and see each through to successful completion to realise a return on their investment, and they are often the source of technological innovations, either through their independent research, or through collaboration that ushers public sector research efforts into the market.

4.5.3.1. Promoting Joint Ventures and Public/Private Partnerships

National and local government bodies working with others can identify where public/private partnerships are needed to attract private sector investment and expertise, and, moreover to specify the operating rules for these partnerships. Government oversight and facilitation is especially needed in situations that call for the involvement of international private sector actors. For example, local governments may contract with local cooperatives to provide renewable energy-based services to households and others, with the cooperatives, in turn, entering into joint ventures with private sector firms, both domestic and international.

An example of an effective joint venture and public/private partnership is the undertaking between Shell International (Netherlands), Community Power Corporation (US), and the Province of Aklan, Philippines. Shell and Community Power Corporation have established a provincial RESCO (rural energy service company) to serve households in unelectrified communities in Aklan. In coordination with this joint venture, the mayor's office in a community in Aklan is investing in a low-voltage AC mini-grid system for 120 households, using municipal funds. The governor of Aklan invited the RESCO into the province and permitted the new enterprise to charge a cost recovery-based fee for service to end users. The joint venture corporation would have been unable to recover its costs if it had to charge the same subsidised rate per kilowatt-hour that is applicable in rural areas. Shell intends to replicate this model in at least ten more communities over the next few years, with the potential to expand this business widely in the unelectrified regions of the Philippines.

4.5.3.2. Establishing Enterprises for Rural Energy Supply and Applications

The use of decentralised renewable energy (as well as fossil fuel options such as diesel generators) on a significant scale in off-grid communities in developing countries depends on the presence of supportive local infrastructure in the areas of sales, financing, delivery, installation, and maintenance for renewable energy applications. In the absence of such infrastructure, well-intended renewable energy projects cannot operate very long or very well. Attesting to this are abandoned projects and the rusting remains of such poorly supported projects. The absence of supportive infrastructure—and not the lack of commercial renewable energy equipment—has been the reason for such failures. The following is one example of a UNDP/GEF project designed to establish the necessary in-country infrastructure.

<u>Case Example: Renewable Energy for Rural Social and Economic Development in Ghana</u>

Over 4,000 communities in Ghana lack electricity services, and for most of them, the cost of basic electricity services from grid extension would be considerably greater than the costs of supplying these services from decentralised renewable energy systems. A US$2.5 million UNDP/GEF project, with US$1 million in funding and PV equipment (from a Spanish bilateral development assistance loan) from the Ghanaian government, has been launched early in 1999 to establish sub-Saharan Africa's first renewable energy-based rural energy services company (RESCO). This enterprise is desgned to provide electricity services to off-grid communities for household, community, and economically productive uses. This renewable energy services project (RESPRO) is to be operated as a *for-profit* enterprise, to be "spun off" as a private sector company, following the GEF project period. It is to have the fiscal and managerial discipline of a private for-profit enterprise, rather than a government project. Revenues are to come from fees for services rather than kilowatt-hour tariffs.

Initial operations are in a pilot region of off-grid communities not scheduled for grid electrification for at least a decade. Customers include community-based organisations (CBOs), NGOs, local government units, farmers, fishermen, cooperatives, small enterprises, and households. They are to contract for the energy services they need (grain grinding, commercial refrigeration, vaccine refrigeration, community water pumping, household lighting, etc.). The RESPRO intends to own, maintain, and repair the electricity supply equipment and, in some cases, may supply and own some end-use appliances. The electricity services are to be provided from stand-alone photovoltaic (PV) units and, for a few larger communities, from local 220 volt A/C minigrids employing PV/diesel hybrid power units, provideing full-time AC power to local *microenterprise zones*. The project is not technology-driven, and all relevant renewable and low-carbon energy technologies can be used in principle.

Energy service fees are to reflect the revenue requirements for sustainability and growth of the enterprise. They are not to be tied to any national electricity tariff structure. A preliminary household energy/economic survey, conducted as part of the project preparation efforts, indicates that the willingness and ability to pay for a menu of desirable and useful energy services is present in the target region. The project intends to conduct a more comprehensive follow-on survey for the region. The RESPRO is to establish the technical, financial, institutional, and socio-cultural requirements for sustainable provision of renewable energy-based electricity services in Ghana. This is an essential element in being able to attract private investment for provision of off-grid electricity services in Ghana, and to catalyse the establishment of other RESCOs throughout Ghana.

4.5.4. Ensuring that Local Needs Are Met by Renewable Energy Projects

The factor that most limits the role of the private sector is that it is able to respond only to effective demand—that is, demand that is backed by purchasing power.Some of the unmet demand for energy services in rural areas of developing countries comes from potential customers, whom the market does not yet serve, even though they could pay for energy services. But much of the unmet demand comes from low-income residents who do not have sufficient resources to pay for energy services, even if there is an active market. Since markets alone cannot address this low-income population, governments have a responsibility to either directly address this population, or shape the rules that guide market forces in ways that promote universal access to modern energy services. Among the most effective ways to ensure that renewable energy projects help fulfil local needs is to make the projects participatory.

4.5.4.1. Addressing Poverty and Gender Through Community Participatory Approaches

If the intended beneficiaries are the poor—especially women, whose involvement is repeatedly demonstrated to be crucial—then projects need their participation. Too often, the visible and prominent community members are easily accessed, while the disenfranchised are—almost by definition—underrepresented. Their participation, therefore, is elusive and must be deliberately sought. A forum has the potential to more successfully elicit their participation if it targets the poor, is unthreatening, and, perhaps, comes with a minor incentive, such as a meal. In many cases, women can only effectively voice their opinions and discuss their concerns in separate women-only forums. Participatory approaches should underlie every stage of the biomass energy project, including data collection, project design, implementation, continued operation, and ongoing evaluation[17].

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[17] *For reference, see UNDP's* Participatory Assessment, Planning and Implementation for Sustainable Livelihoods – Users Manual *(New York, 1998), the World Bank's* Participation Sourcebook *(Wash. D.C., 1995), and the World Conservation Union's* Community Participation: the First Principle *(IUCN, Karachi, Pakastan, 1992).*

Project developers, as they collaborate with the target communities, need to conscientiously address some of the inevitable points of opposition that arise in response to renewable energy programs—either by educating the community and/or adapting the project to account for local concerns. For example, in many countries[18] with a history of highly subsidised uniform rural electricity tariffs, unelectrified communities are not entirely satisfied with anything less than a national government commitment to provide them with "real" electricity (220 volt AC power) at the national rural tariff, rather than the higher-cost, lower-power, and often intermittent supply of DC electricity typical of many small-scale renewable energy systems, which might ultimately delay the establishment of a full-fledged grid connection.

Women often have an especially keen appreciation for family needs and the ability to articulate them and identify solutions. However, they rarely express their needs in terms of energy, per se, but rather in much more concrete terms that are unique to their context and are best identified by themselves: the endemic prevalence of diarrhoea among infants, the prohibitively high cost of kerosene, and the lack of paying work. See Chapter 2 for a further discussion of strategies for mainstreaming a gender perspective into energy policies and programmes.

4.5.4.2. Investments for Social and Economic Development that Promote Renewable Energy

Generally, renewable energy projects will most effectively address sustainable development objectives, and are going to be taken up most readily by development organisations, if they are integrated with broader development objectives and programmes. Energy project developers need to support the use of renewables, where appropriate, for the energy component of programmes and initiatives that build rural community infrastructure (potable water, health, education, telecommunications, public lighting, etc.) and initiatives that develop and expand economically productive activities. Such initiatives, therefore, need to be coordinated with other agencies responsible for these non-energy sector activities.

Private sector actors can also be effective in this regard. Rural enterprises can be established to address not only energy services, but also to include supply, service, and maintainence of end-use equipment for schools, hospitals, grain grinding cooperatives, community water supply systems, irrigation systems, etc. This may allow them to be more profitable than by providing energy services alone, and can provide rural commu-nities with a greater array of services than they can otherwise have.

An example of an organisation that is effectively integrating rural energy services with broader human development objectives is DESI Power in India. This is a not-for-profit organisation that is focussed on establishing independent rural power producers (IRPPs) at the village level, as joint ventures with local communities and entrepreneurs. DESI Power provides roughly 25 percent of the funding, the local partner 25 percent, and 50 percent is raised from the market.

4.5.5. Building Institutional Support for Renewable Energy Applications

4.5.5.1. Training

There is a need for the trained technical personnel to establish and expand in-country assessment, development, and transfer of renewable energy technologies, as well as a need for people with the training and experience required to establish enterprises and implement projects. While some of this expertise is arising within the private sector, there is much scope for public support for such capacity building. For example, the public sector can help introduce practical technical and engineering curricula in renewable energy into trade schools, colleges, and universities; it can

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18 *Communities in Brazil, Argentina, Ghana, South Africa, Fiji, and Indonesia, among others, have voiced such concerns and complaints in the face of proposed PV energisation programmes.*

support technology research efforts in government and academic institutions, and it can make renewable energy training available to those in positions to set up enterprises and manage projects. The public sector can also support joint ventures with international private sector firms which can facilitate the transfer of renewable energy technologies.

For example, The Centre for Applications of Science and Technology to Rural Areas (ASTRA), at the Indian Institute of Sciences in Bangalore, was set up within a science and technology research institute as a program with faculty from various engineering departments. Its mandate is specifically to address applied science and technology issues to meet the needs of rural people.

4.5.5.2. National Standards for Renewable Energy Systems

In most developing countries, there are no implemented standards for renewable energy equipment. Standards are needed for equipment manufacturing quality, field performance, systems installation, and maintainability. It is recommended that appropriate agencies (e.g., national standards agencies) review and adapt the emerging international renewable energy standards to the needs of their markets and industries. Lending by national and regional development banks for renewable energy enterprises and projects requires due diligence, which, in turn, requires standards against which the banks can evaluate projects proposed for lending. Active expert standards committees, with representatives from government, industry, academia, and others need to be convened to publish preliminary standards (equipment, installation, testing, etc.) as soon as possible, for technologies including photovoltaic, wind, and hybrid power systems.

One of the barriers to wide dissemination of PV is the lack of national standards and codes in developing countries, which often results in unreliable system performance. To address this barrier, a Global Approval Programme for Photovoltaics (PV-GAP)[19] has been established to develop guidelines on how to produce a reliable product, assemble a complete system, and how to install and maintain PV systems in developing countries. Manuals have been produced outlining a set of procedures to follow, in order to meet quality requirements. These manuals will assist local manufacturers in complying with national and international PV standard and codes, thus assisting in enhancing their capabilities to make products that meet these standards.

4.5.5.3. Renewable Energy Resource Assessments

Many developing countries have extensive renewable energy resources suitable for commercial development. Yet, in most countries, these resources—including sunlight, wind energy, biomass residues, and hydro-electric potential—are not known in detail. Governments should initiate, with international assistance, the development of national inventories and databases for hydro-electric potential, commercially available biomass residues (e.g., from production of timber, coffee, cacao, palm oil, coconuts, rice, etc.), solar radiation, and wind energy, which stands to help attract investments in renewable energy facilities.

One example of this is the UNEP/GEF project initiated in December 1999 to prepare an international activity to establish high-resolution wind and solar maps and databases for developing countries worldwide. Subject to approval by the GEF Council in late 2000, this project is scheduled to begin operations early in 2001. See Section 4.2 above for further discussion. A second example is the European Community's COGEN Programme for the ASEAN nations, which has compiled a reliable biomass residue database for several ASEAN countries, based on information provided by industry, government agencies, and via field surveys.

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[19] *For more information see the PV-GAP website at http://www.pvgap.org/*

4.6. CONCLUSIONS

Projects based on commercial field-proven equipment that works reliably and which are economically-viable have the best chances for succeeding and being widely replicated. There is also a need, however, for pilot projects that seek to demonstrate emerging approaches to sustainable delivery of renewable energy-based services. It is not the hardware that is being demonstrated, but the means to apply it reliably and affordably for large numbers of households and communities.

The "technology" for renewable energy use is not just the equipment used to convert renewable energy resources into heat, electricity, and fuels. It includes the full ensemble of measures and capabilities required to continue to use this equipment on a large scale, sustainably and reliably. This includes the establishment of the infrastructures (to supply, install, commission, and service renewable energy equipment), financing vehicles (for end users, intermediaries, and suppliers), and policies and regulations which promote investment in the use of renewable energy. It also includes the financing mechanisms available to in-country manufacturers, suppliers, service companies, and end users. Increasingly, both public agencies and private sector enterprises, multilateral development banks and bilateral development aid agencies are promoting initiatives that build markets and renewable energy supply infrastructures. Many countries are pursuing new and, sometimes, uncharted paths to large-scale sustainable use of renewable energy technologies to support social and economic development. These path-finding initiatives are going to determine the feasibility of that goal.

5

OPPORTUNITIES FOR
SUSTAINABLE ENERGY

ENERGY EFFICIENCY

5.1. ENERGY AND SUSTAINABLE DEVELOPMENT

Energy is used throughout the economy, and is one of the most important drivers for modern economic development. It is used to manufacture all kinds of consumer goods, heat or cool buildings, cook our food, and provide light and communication. These activities are also called energy services. We are interested in performing the energy service, rather than in using energy. There is a growing awareness of the serious problems associated with the provision of sufficient energy to meet human needs and to fuel economic growth worldwide. Environmental, health, social, economic, and security issues are affected directly or indirectly by energy use.

Current energy production and usage patterns rely heavily on combustion of fossil fuels, a key factor in the unprecedented increase in carbon dioxide (CO_2) concentrations, which contribute to climate change, in the Earth's atmosphere. Other key environmental problems are regional (acidification of soil and water), local (smog, urban air quality, solid wastes, effluents, and thermal pollution), and indoor air pollution. In many areas of the world, particularly the developing country mega-cities, the health and environmental effects of such patterns of energy use are even more extreme, as technologies and policies for abating pollution and producing cleaner energy are not always available or implemented. Health is adversely affected not only by environmental pollution, but also by indoor use of fuels and the supply of energy.

Energy supply and use are directly connected to the economic and social agenda. Many studies have shown that low-income households often have no access to commercial or low-polluting fuels. The use of biomass for cooking in many parts of the developing countries results in negative social and health impacts, especially for women. Reliance on energy imports also affects the security of many countries, directly and indirectly. Increased reliance on imported fuels makes the economy more vulnerable for supply disruptions and may lead to social conflicts, as many primary commodity prices are influenced by energy prices.

Historically, countries concentrated on the increased supply of energy sources, despite the potential negative impacts on sustainable development. However, in 1987, the World Commission on Environment and Development (WCED) concluded that the best route to sustainable development of the energy system is a *"low energy path"*, which means that nations should take the opportunities *"to produce the same levels of energy services with as little as half the primary energy currently consumed"*. The improvement of energy efficiency is now generally viewed as the most important option to reduce the negative impacts of the use of energy and/or fossil fuels in the near term. Energy efficiency is defined as *decreasing the use of energy per energy service without substantially affecting the level of these services.*

The main factors affecting energy growth in an economy include the energy consumed per unit of economic activity, the size and structure of the economy, and the rate of population growth. If an economy is growing rapidly, or population growth is high, then energy demand rises commensurately, assuming there is no change in the level of energy consumption per unit of economic output. The amount of energy consumed per unit of economic growth is affected by how efficiently energy is used to provide energy services in an economy. Shifts in the structure of economies also influence energy use, specifically in economies where the overall level of enerfy services—required to produce additional economic output—changes. All else being equal, reducing economic or population growth also leads to reductions in energy demand. In the near and medium term, the most effective and feasible policies for restraining energy growth involve improving the efficient use of energy and encouraging the shift to a less energy-intensive economic and industrial structure.

Despite the limited access to energy in many developing countries, large potential for energy efficiency improvement exists in all sectors. However, many barriers may limit the implementation of energy-efficient practices and technologies. Policies and actions by many stakeholders, including policy-makers, consumers, and private industry, affect the barriers and the actual implementation of energy efficiency. In this chapter, we discuss energy use, the stakeholders, barriers, and potential actions that can be taken. We start with a discussion of the potential benefits of energy efficiency improvement measures, followed by an overview of current energy use patterns around the world and in developing countries, by sector. We then assess practical approaches to energy efficiency improvement, including assessment of opportunities and mechanisms. Although many different mechanisms can be used to implement energy-efficient practices and technologies, we highlight one as an example, i.e., energy service companies (ESCO). An energy service company takes over the supply of energy services, rather than supplies energy sources. This description is followed by a more generic description of barriers and policies which support implementation of energy-efficient practices and technologies.

5.2. MAKING THE CASE FOR ENERGY EFFICIENCY

5.2.1. Introduction

Energy efficiency opportunities can be found in almost all energy end uses, sectors, and energy services. Many studies over the past decades have assessed the potential for energy efficiency

improvement, and always have found opportunities. Much of the potential of energy efficiency improvement depends on how closely the processes used have approached their thermodynamic limit. Thermodynamic analyses of many processes have demonstrated a large difference between the thermodynamic energy needed to provide an energy service and the actual observed energy consumption. The difference is called the theoretical potential for energy efficiency improvement. In practice, the thermodynamic minimum energy consumption can not be achieved, and extra energy added to the thermodynamic minimum defines the technically achievable minimum energy consumption.

Furthermore, there are differences between what is technically achievable as an energy efficiency improvement in a specific instance, what is economically feasible, and what is actually possible. We can identify an economic potential for energy efficiency improvement, namely the potential savings that can be achieved at a net positive economic effect, such as the benefits of the measures being greater than the costs. In practice, the definition of the economic potential may vary, based on the differences in assessment methods, assumptions, and system boundaries. Many studies have indeed shown that there is a further efficiency gap, even at current economic conditions, suggesting the existence of other barriers for implementing energy efficiency measures. The market potential tries to close this gap, and is defined as the potential energy savings that may be realised in practice, at current marker conditions.

The technical, economic and market potential of energy efficiency are amenable through interventions by stakeholders. Research and development activities by academia and industry affect the availability of technologies, as well as the costs of such technologies. The economic potential is not only influenced by the costs of technology, but also by energy prices and policies such as taxes and targeted subsidies. The market potential is a function of the economic attractiveness of a measure and of many barriers. The barriers may be removed or reduced in size by measures and policies at corporate, regional, national, and international levels.

In this section we focus on the economic potential for energy efficiency improvement and discuss the benefits of energy efficiency improvement measures. In the following sections we describe analytical tools to assess the potential in a specific situation, as well as policy opportunities for energy efficiency improvement.

5.2.2. The Potential for Energy Efficiency Improvement

Many studies have indicated that there is a sizeable potential for energy efficiency improvement. It is estimated that the United States uses its primary energy sources with only a 2.5 percent efficiency to fulfil its energy services. A 50 percent reduction in energy demand is technologically feasible, and in the long term even a 80 percent reduction is feasible. Other studies have also shown that there is considerable scope for energy efficiency improvement in different sectors and contexts. Energy efficiency improvement opportunities can be found in energy end uses and conversion, as well as in distribution and transmission. Transmission losses for power generation in developing countries can often be very high.

The potential for profitable and economic energy efficiency improvement in all sectors for the next 20 years is estimated at 25-35 percent in most industrialised and developing countries at today's energy prices. Implementing these improvements depends on the levels of industrialisation, economic structures, as well as many other issues. The potential for energy efficiency improvement may also vary by country and sector. Described below are estimates of the potential for energy efficiency improvement in different sectors.[1]

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[1] *Worrell, E., M. Levine, L. Price, N. Martin, R. van den Broek and K. Blok (1997), "Potentials and Policy Implications of Energy and Material Efficiency Improvement", Department for Policy Coordination and Sustainable Development, United Nations, New York, NY.*

Agriculture. Energy consumption in agriculture is divided into direct (on-farm) and indirect (e.g., fertilisers and pesticides) energy use. Direct commercial energy consumption varies significantly depending on agricultural practice and crop. In traditional agriculture, direct energy consumption can be solely non-commercial, including important sources such as animal and human labour. We focus on direct on-farm consumption of commercial energy.

Energy can be saved in tractor use by improved control of gears (estimated technical savings of 5-30 percent), maintenance and developments of diesel engines (10-35 percent), and reduced tillage (35-70 percent of energy use for tillage). High energy savings (25-85 percent) are possible through proper design, retrofit and maintenance of irrigation pumps and use of low-friction pipes. Energy savings of up to 60 percent in industrialised countries are also feasible in drying products, livestock production, and horticulture.

Industry. Significant potential exists in all industries to improve energy efficiency. A small number of energy-intensive industries are responsible for half of industrial energy use on a global level, and even more for developing countries. These sub-sectors are: iron and steel, chemicals, petroleum refining, pulp and paper, and cement.

- A large number of energy-efficient technologies are available in the *steel industry,* including continuous casting, energy recovery, and increased recycling, with the technical potential for energy efficiency improvement ranging from 25 to 50 percent, even in industrialised countries.
- A few bulk *chemicals*, such as ammonia and ethylene, represent a major portion of energy use in this sub-sector. The potential for energy savings in ammonia making is estimated at up to 35 percent in the European Union and at around 20-30 percent in Southeast Asia. Saving estimates for ethylene production are only available for industrialised countries and are estimated to be up to 12 percent (including feedstocks).
- Energy savings in *petroleum refining* are possible through improved process integration, cogeneration, and energy recovery. Compared to state-of-the-art technology, the savings in industrialised countries are estimated to be 20-30 percent, and estimated savings are higher for developing countries.
- *Paper* is produced in many countries, and the process consists of wood pulping and papermaking from the pulp (and waste paper). Large energy savings can be accrued in nearly all process stages, for instance, through improved dewatering technologies, energy and waste heat recovery and new pulping technologies. The technical savings potential is estimated to be as high as 40 percent, with estimates for long-term savings being even higher.
- Energy savings in *cement production* are possible through increased use of additives (replacing the energy-intensive clinker), use of dry process, and large numbers of energy efficiency measures (e.g., reducing heat losses and use of waste as fuel). Compared to today's best practice, potential savings are estimated at 15-40 percent in developing countries.
- In *other industries,* energy is used for a large variety of energy end uses. Steam and motive power are the major end uses of energy. In steam systems, energy savings of about 25 percent are typically possible—by improving the efficiency of steam boilers (process control, reduction of excess air, preparation of feedwater), steam distribution (leaks, steam traps), and use and recovery (process integration and heat exchangers). Motor systems are the largest electricity users in industry, but are often oversized (reducing the efficiency of operation), while inefficient throttles, used to control pressures and leaks, may lead to pressure losses. Many programmes have identified potential savings of up to 20-50 percent through motor system efficiency improvement.

Buildings. The buildings sector includes a wide variety of specific energy applications, such as cooking, space heating and cooling, lighting, food refrigeration and freezing, office equipment, and water heating. These applications are end-use services, emphasising that what is important is not the energy consumed but the service delivered, such as cooked food, a warm space, or a lit office. A wide variety of energy efficiency measures exist for all end uses, such as space conditioning (including changes in the building envelope), efficient appliances (in households and offices), improved lighting, motors in ventilation, and energy management systems. Studies estimate the technical potential savings of 25-50 percent up to the year 2000 in residential buildings for various industrialised countries. In commercial buildings, estimates vary from 25-55 percent in industrialised countries to 50-60 percent in developing countries

Transport. Transport energy use can be reduced by improving the efficiency of transportation technology (e.g., improving automobile fuel economy), shifting to less energy-intensive transport modes (e.g., substitution from passenger cars to mass transit), improving the quality or changing the mix of fuels used in the transportation system, and improving the quality of the transportation infrastructure. For all modes of transport, substantial opportunities exist to improve transportation equipment. The technical savings potential for passenger cars and trucks is estimated at 15-55 percent. Energy savings in railway traffic are estimated at 10-35 percent worldwide. Significant reductions in energy use can be achieved by encouraging shifts to less energy-intensive modes of transport and urban planning.

5.2.3. Benefits of Energy Efficiency Improvement

As discussed above and in other chapters, environmental, health, social, economic, and security issues are affected directly or indirectly by energy use. Hence, energy efficiency improvement may reduce the negative impacts on any or a number of these issues. The magnitude of the effect on each of the issues may depend on the specific energy efficiency measure, technology used, fuels saved or used, and local circumstances. The benefits may also vary for the different stakeholders.

On the national level, energy efficiency improvement is going to lead to reduced environmental impacts of energy use and reductions in the negative health effects of air pollution from combusting fuels or producing energy carriers. It is also going to affect the macro-economics, as well as vulnerability for imported fuels. For example, the effect of the latter depends heavily on the local circumstances. Replacement of charcoal by LPG as cooking fuel in Dakar, Senegal, results in a net fuel saving, as well as reduction of greenhouse gas emissions (due to the deforestation, transport and methane emissions from charcoal manufacture) and reduced indoor air pollution. However, the measure leads to increasing imports of LPG. Most energy efficiency measures can result in more efficient use of domestic and imported fuels, thus reducing the vulnerability for imported fuels.

For the private end user, energy efficiency benefits may vary, even if macro-economic effects on the environment and external debt are not reflected in energy prices. Since energy-efficient technology is generally modern and innovative, it not only reduces energy costs, but also can lead to increased productivity, reductions in material losses, maintenance, and labour costs, as well as reductions in air pollution (eliminating the need for expensive air pollution controls). Ultimately, these benefits improve the productivity of a firm, although they are insufficiently quantified, and hence not included in the cost-benefit analyses of many project assessments. These benefits need to be appraised in the development of energy efficiency projects. Box 1 shows an example of the benefits of energy efficiency projects in the steel industry.

5.2.4. Drivers for Energy Efficiency

The drivers for energy efficiency may vary over time and by country. Inefficient energy use contributes to many economic, social, environmental, health, and security issues, as discussed above. These adverse effects become drivers for improved efficiency, depending on the magnitude and urgency of the problems. In industrialised

BOX 1. NEAR NET SHAPE CASTING IN THE STEEL INDUSTRY

Advanced industrial technologies that show a number of inherent advantages are being developed. Such advantages include lower capital costs and environmental emissions, compared to state-of-the-art processes. The new technologies can "leapfrog" the problems associated with current production technologies in steel-making. The introduction of energy-efficient technologies in industry is dependent on a large number of factors. In the past, several new technological developments have shown rapid introduction in the steel industry, e.g., continuous casting, the demonstration of which, starting in 1947, has led to the eventual replacement of ingot casting in over 60% of the world steel production. Continuous casting dramatically reduces material losses in the casting stage, reduces production costs through lowered handling, and saves energy in ingot reheating due to the decreased material losses.

Near net shape casting implies the direct casting of the metal into (or near to) the final shape, e.g., strips or sections, replacing hot rolling. In conventional steel-making, steel is first cast and stored. The cast steel is reheated and treated in the rolling mills to be reshaped. Near net shape casting integrates casting and the first rolling steps. Originally, the technology has been proposed in the previous century by Bessemer. The current status of this technology is the so-called thin slab casting. Instead of slabs of 120-300 mm thickness, slabs of 30-60 mm thickness are produced. The cast thin slabs are directly reheated in a coupled furnace, and then directly rolled in a simplified hot strip mill. The technology is increasingly applied in developing countries (e.g., Korea and Mexico), showing that this medium scale technology suits the size of the often smaller steel plants in developing countries.

In the thin slab casters, energy used for casting and rolling is reduced with 75% relative to conventional technology. Capital cost of a new plant is 30-60% lower than conventional technology, depending on the capacity of the rolling mill. This results in sharp reductions in production costs. The application of thin slab casting technology by Nucor has led to successful entry and expansion of Nucor in this market in the USA.

countries, vulnerability to imported fuels and high energy prices have been the main driving force of energy efficiency improvement during the decade around the oil shocks. With the prices of oil declining after 1986, this factor has become less important. More recently, emerging environmental problems, such as local air pollution, and acid precipitation due to fossil fuel combustion, have become important environmental drivers. Today, potential climate change due to the emissions of greenhouse gases is the main environmental driver for increased energy efficiency in many industrialised countries.

High energy prices make energy efficiency improvement economically more attractive by reducing the payback period of a measure (see below). During periods of high energy prices (1973-1985), energy efficiency improvement rates were much higher than in periods with low energy prices (1986-today).[2] Similar variations can be found among countries which have alternating periods with high and low energy prices. Thus, energy efficiency levels in Europe and Japan tend to be higher than the US (which currently has low energy prices). Likewise, the reduction of subsidies for energy in China, initiated after energy price reforms of 1993, has contributed to increased interest in energy efficiency.

[2] *Schipper, L. and Meyers, S. with Howarth, R. and Steiner, R. (1992),* Energy Efficiency and Human Activity: Past Trends, Future Prospects, *Cambridge University Press, Cambridge, UK.*

Deregulation of the energy sector may lead to energy price increases or decreases. Many analysts have argued that the organisation of the energy market leads to unfavourable treatment of energy efficiency. The energy supply-side sector used typically much lower discount rates than energy consumers, who depend on commercial banks for capital availability. Deregulation of utilities reduces the state influence, and, therefore, the access to low-cost capital. Deregulation in some developing countries, e.g., in Latin-America (Colombia, Peru, Costa Rica) and Africa, has led to price increases for energy, and to subsequent increased interest in energy efficiency. The World Bank is a strong proponent of deregulation. However, deregulation and subsequent price increases may negatively affect the access of low-income households to energy services. These effects need to be taken into account when designing a framework for deregulation. Deregulation in industrialised countries is expected to result in lower energy prices, because of the competition, especially for large energy consumers and customers. Hence, this may result in reduced interest in energy efficiency, as has been observed in some states in the US, where the power sector is being deregulated.

Today, the local, regional, and global environments are major drivers for increased efficiency and clean use of energy. Currently, the debate around climate change is an important driver for energy efficiency improvement, which is a crucial "no-regret" opportunity to reduce the emission of greenhouse gases. While climate change is not a determining issue for energy policy in developing countries, a low-carbon energy development pattern is likely to have many benefits with respect to health, environmental, economic, and security issues. For example, in the cement industry, energy use typically accounts for 30 percent of the production costs. Hence, energy-efficient technologies stand to substantially reduce the production costs of cement, a material critical in the build-up of the infrastructure of the country. Many new cement plants in developing countries are among the most efficient in the world, leading to lower energy intensities in selected developing countries than in some industrialised countries.

5.3. STARTING AN ENERGY EFFICIENCY PROGRAMME

5.3.1. Introduction

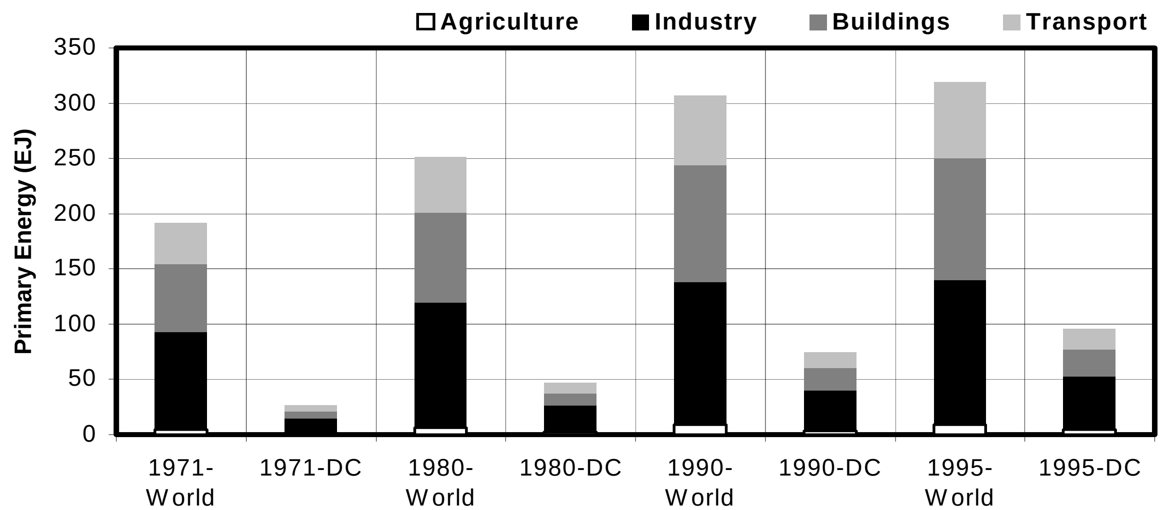
Energy intensity, services, and technologies vary widely by sector, as do the economic characteristics of the sectors. When designing an energy efficiency programme or project, the specific characteristics of the country need to be taken into account. A successful project is going to be sustainable in itself; it may also lead to replication by other stakeholders or in other sectors. In this section, we first discuss the different energy services typically found in each of the four sectors: agriculture, industry, buildings, and transport. Since the discussion is not expected to be complete, the bibliography provides further suggestions for more detailed studies. For each of the sectors, we discuss the general energy usage trends, energy uses and services, and, briefly, energy-efficient practices and technologies.

This section also providea a discussion of various tools needed for project assessment. This followa the discussion of trends. Tools include the means to assess opportunities for a specific project or sector and to appraise the opportunities that are identified. Financing of a project is important, and is often a bottleneck for project development in developing countries. We briefly discuss several project financing schemes. When implementing a project, sound project management is needed. It includes adaptation of technologies to local circumstances, training of personnel, and sufficient "after-care" to deduct lessons learned for future projects (including monitoring and evaluation).

5.3.2. Energy Use: Trends and Services in Developing Countries

Energy use is a function of population, economic activity, and the energy intensity of the activities. While increased demand due to population growth is a general driver for increased energy use, the demand of energy services may vary, and hence the economic activity mix and energy intensity of the mix. Energy intensity is defined as the amount of energy used to perform an activity. While on a high aggregation level, the activity is often defined as generating a unit of gross domestic product (GDP), on the lower aggregation levels, energy intensity is often expressed as the production of a tonne of steel, or the heating of a square meter of office space. Hence, energy intensity is directly linked to the type of activity and energy service performed. The economy of any country includes a huge variety of energy services, and the distribution or mix of these determines the overall energy intensity. This is called the structural effect. Energy savings can result by changing towards a less energy-intensive mix of energy services, or by improving the efficiency with which an energy service is provided. In this chapter, we concentrate on improving the energy efficiency, rather than macro-economic policies that may alter the mix of activities.

FIGURE 1. PRIMARY ENERGY CONSUMPTION IN THE WORLD AND IN DEVELOPING COUNTRIES, BY SECTOR.



Source: Price et al. *(1998). Note: Primary energy is expressed in exajoules (10^{18} J).*

Global primary energy demand has grown by 2.5 percent from 1971 to 307 EJ in 1990. After 1990, global growth has tapered off and increased to only 319 EJ, primarily due to large declines experienced in Central and Eastern Europe, because of the political and economic restructuring in many of these countries. Figure 1 provides an overview of the main energy use trends in developing countries. Below we discuss the main trends in the most important sectors, as well as the typical energy services that are found in each of the sectors. We discuss four sectors: agriculture, industry, buildings (including domestic energy use and office buildings), and transport. Industry is the largest energy consuming sector, followed by buildings, transport, and agriculture.

Agriculture. Increasing degrees of mechanisation lead to higher energy inputs per unit of product. Direct energy consumption per hectare of arable land in world agriculture increased 3.3 percent per year on average between 1980 and 1990, and per unit product only 1.1 percent per year. The difference can be explained by the increase in productivity per hectare. For developing countries, these figures are 4.2 and 1.4 percent per year, respectively. Energy use for agriculture in developing countries is estimated at 4.6 EJ, or half of the global energy consumption in this sector.

The major end uses of energy in agriculture are traction (tractors for mechanised agriculture) and irrigation. Tractors are, by far, the greatest consumers of fuel in field operations, accounting for 90-95 percent of the fuel used. Energy consumption in field operations is affected by many factors, including weather, soil type, depth of tillage operations, field size, speed, degree of mechanisation (manpower, animal power, and mechanical power), and management ability. Mechanisation is done for the purpose of increased labour productivity, improved quality of work, and overcoming time constraints or critical operations (e.g., land clearing). It may improve yields through better land preparation, more precise placement of seed and fertiliser and more efficient harvesting. In North America, tractors are used for nearly all crop production operations. In developing countries, they are often used only for tillage and transportation. It has been estimated that about 15 percent of the world's cropland is irrigated, and that this area produces about 30 percent of the world's food. We can distinguish between systems powered by gravity and systems in which water has to be lifted by pumps over a certain height. Other direct on-farm commercial energy input consists mainly of energy for drying, direct energy for animal production, and direct energy for horticulture, such as heating, cooling, ventilation, and lighting.

Energy efficiency improvement opportunities include more efficient use of tractors, use of more efficient diesel engines in tractors, and reduced tillage. No studies estimating the energy savings of these measures in developing countries are available. In developing countries, energy efficient irrigation technologies have been studied in more depth. Retrofitting inefficient pumps is estimated to save 20-50 percent on energy for irrigation, as found in studies in India and Africa.

Industry. In 1995, industry has accounted for 41 percent (131 EJ) of global energy use. Between 1971 and 1992, industrial energy use has grown at a rate of 1.9 percent per year, slightly less than the world energy demand growth of 2.3 percent per year. This growth rate has slowed in recent years, falling to an annual average growth of 0.2 percent between 1990 and 1995, primarily because of declines in industrial output of the economies in transition (EIT) in Central and Eastern Europe. Energy use in the industrial sector is dominated by OECD countries, which account for 45 percent of world industrial energy use. Developing countries and the EITs use 32 percent and 23 percent of world industrial energy, respectively. More efficient technologies exist for all industrial sectors.

Energy services in the industrial sector vary widely, due to the wide variety of products produced and processes used. These include the extraction of natural resources, conversion into raw materials, and manufacture of finished (consumer) products. A large part of energy is consumed by the energy-intensive raw material conversion industries, such as cement, steel, and petroleum refining industries. In these industries, energy is a considerable part of the production costs, often in the range of 20-30 percent, making energy efficiency an important cost-reduction strategy. Besides these energy-intensive industries, many small-scale industries exist in developing countries. These can be energy-intensive operations, such as sugar-making and brick-works, but also less energy-intensive processes, such as food processing or consumer products industries. These plants are often operated on a small scale, which may hinder the implementation of energy efficiency measures (see below). In the energy-intensive industries, most energy is used for the specific conversion processes, although large amounts of energy are used to produce steam (e.g., in the chemical and pulp and paper industries) or by motors. In less energy-intensive industries, energy is often used for utilities, steam production, drives, and motors. For a more thorough description of processes used in these industries and typical energy consumptions, see e.g., WEC (1995) and Worrell *et al.* (1997).

Energy efficiency opportunities can be found in all industries, including light and energy-intensive industries. While in energy-intensive industries major opportunities can be found in the processes used, these can be most economically implemented when constructing a new plant[3] or retrofitting an existing plant. Studies of many energy-intensive industries in developing countries have shown significant potential for energy efficiency improvement in the process industries. Estimates for energy efficiency improvement in the steel industry in developing countries can be up to 50 percent, while savings in the cement industry can vary from 5 to 40 percent. In the less energy-intensive industries, opportunities are found in the utilities. Often, old or badly maintained steam boilers can result in large energy losses, aggravated by badly insulated steam distribution networks and malfunctioning steam traps. Even in the US, energy savings in these systems can easily combine to an overall cost-effective potential of 25 percent. Savings in electricity use for motors (using over half of industrial electricity consumption) can be high, especially if a systems approach is used to

[3] *Most capacity expansion of energy intensive industries is currently found in developing countries. However, risk aversion and capital costs may often limit the implementation of innovative energy-efficient technologies. Trade in used industrial equipment from industrialised countries occurs in any sector, resulting in low-cost, but energy-inefficient, plants. This may ultimately result in increased costs for energy imports and negative impacts on trade balance and the environment.*

optimise the motor system to the energy service provided. Important measures include improved maintenance (e.g., pressurised air systems), sizing of the motor to the load, and adjustable speed drives. Table 1 outlines various energy efficiency measures in industry.

Buildings. Approximately 36 percent of world primary energy is consumed by commercial and residential buildings. Between 1971 and 1992, average growth in energy use for buildings has been 2.7 percent per year, faster than the global average energy use. Global buildings energy use has been 109 EJ (commercial fuels only) in 1995, with industrialised countries consuming 58 percent of the total, followed by developing countries (22 percent), and the EITs (20 percent). Energy use in residential buildings is about twice that of commercial buildings worldwide. However, energy demand in commercial buildings has grown about 50% more rapidly than demand in residential buildings for the past two decades. Buildings in developing countries use approximately 25 EJ, three quarters of which are accounted by residential buildings, although in the rest of the world, growth of energy use has been more pronounced in commercial buildings (including government services, schools, and hospitals). The share of electricity in buildings energy use is now estimated at around 20 percent in residential buildings and over 40 percent in commercial buildings.[4] This demonstrates the important growth of the use of appliances and office equipment.

Energy use in residential buildings is generally a function of the household size and income level. In developing countries, urban areas are generally associated with higher average incomes, and wealthier populaces exhibit consumption patterns similar to those in industrialised countries, where purchases of appliances and other energy-using equipment increase with greater disposable income. For example, the degree of penetration of refrigerators in urban China is

[4] *Price, L.K., L. Michaelis, E. Worrell, and M. Khrushch (1998), "Sectoral Trends and Driving Forces of Global Energy Use and Greenhouse Gas Emissions", in* Mitigation and Adaptation Strategies for Global Change, ***3,*** *pp.263-319.*

TABLE 1. EXAMPLES OF EFFICIENCY IMPROVEMENT MEASURES IN ENERGY-INTENSIVE INDUSTRY

IRON AND STEEL
Heat recovery for steam generation, pre-heating combustion air, high efficiency burners
Adjustable speed drives, coke oven gas compressors, heat recovery coke oven gases, and dry coke quenching
Efficient hot blast stove operation, waste heat recovery for hot blast stove, top gas power recovery turbines, direct coal injection
Recovery of gas and heat, optimised oxygen production, increase scrap use
Scrap pre-heating in the electric arc furnace, oxy-fuel injection in furnace
Heat recovery, recovery of inert gases, efficient ladle pre-heating
Continuous casting, thin slab casting, recuperative burners in reheating furnace
PETROCHEMICALS
Petrochemicals
Process management and thermal integration (e.g. optimisation of steam network).
Mechanical vapour recompression
Optimised compressor and pump systems, adjustable speed drives
Auto-thermal reforming
Cogeneration, combined heat and power production
PULP AND PAPER
Continuous digester, displacement heating/batch digesters
Black liquor gasification/gas turbine cogeneration
Falling film black liquid evaporation, lime kiln modifications
Improved boiler design/operation, cogeneration, and distributed control systems
Heat recovery in paper machine, long nip press
CEMENT
Improved grinding media, roller mills, high-efficiency classifiers
Dewatering with filter presses and slurry thinners
Optimise heat transfer in clinker cooler, use of waste fuels
Dry-suspension pre-heater and pre-calciner kilns, blended cements
OVERALL
Optimisation of boiler, boiler control systems
Maintenance of steam distribution system, steam traps, and process integration (pinch analysis)
Optimisation of motor systems, pumps and compressors, reduce air leakages, adjustable speed drives

Source: WEC, 1995

estimated at nearly 90 percent, while in rural China, it is estimated at less than 10 percent (1996). In comparison, refrigerators are only found in 22 percent of the urban households in India.

In industrialised countries, a large part of energy is used for space conditioning (heating, cooling, ventilation). In the US, space conditioning uses over half of the energy in residential buildings, and over a third in commercial buildings. Not many detailed studies have assessed energy use in buildings in developing countries. Space heating is not common in many developing countries, with the exception of countries (or regions) with colder climates, such as Argentina and China. However, with increasing income levels, air conditioning is increasing. Air conditioners have been found in 8 percent of urban households in China in 1995 (compared to 58 percent in Thailand in 1993), but have increased rapidly since then. In general, in developing countries, cooking and water heating dominate residential energy use, followed by lighting, small appliances, and refrigerators, although even the urban poor often have no access to electricity. For example, in many African countries, less than 10 percent of the households have access to electricity. Hence, energy uses in the residential sector depend strongly on local circumstances and development patterns.

In commercial buildings, appliances are the most important energy users, followed by space conditioning and lighting. Specific electricity use in commercial buildings (expressed in energy consumption per square meter) in industrialised countries shows a steady increase over time, while fuel use shows a decline over time in all countries. Unfortunately, not much is known about energy use in commercial buildings in developing countries.

Improved building practices can reduce the energy requirements, as well as increased efficiency of space conditioning equipment, and improved controls. Improved building practices include urban planning (e.g., proper orientation of buildings and tree planting), choice of building materials (e.g., light materials reflect more solar energy and need less cooling), adequate insulation levels, proper sealing, and energy saving window designs. Table 2 gives an overview of energy-efficient technologies in buildings.

TABLE 2. SUMMARY OF SELECTED ENERGY-EFFICIENT TECHNOLOGIES AND PRACTICES FOR BUILDINGS

SERVICE	TECHNOLOGY/PRACTICE
BUILDING ENVELOPE	**Energy-efficient windows** **Insulation (walls, roof, floor)** **Reduced air infiltration**
SPACE CONDI-TIONING	**Gas-fired, condensing furnaces** **High-efficiency heat pumps** **Air conditioner efficiency measures (e.g., thermal insulation, improved heat exchangers, advanced refrigerants, more efficient motors, see below)** **Centrifugal compressors, efficient fans and pumps, and variable air volume systems for large commercial buildings**
APPLIANCES	**Advanced compressors, evacuated panel insulation (refrigerators)** **Use of horizontal axis technology (clothes washers)** **Higher spin speeds in washing machine/spinner, heat pump dryers**
COOKING	**Improved efficiency of biomass stoves (developing countries)** **Efficient gas stoves (ignition, burners)**
LIGHTING	**Compact fluorescent lamps** **Improved phosphors** **Solid state electronic ballast technology** **Advanced lighting control systems (incl. daylighting and occupancy sensors)** **Task lighting**
MOTORS	**Variable speed drives** **Size optimisation** **Improvement of power quality** **Controls**
OTHER	**Building energy management systems** **Passive solar use** **Solar water heaters**

Source: WEC,1995.

Transport. Since 1971, global transport energy use has grown at a rate faster than total world primary energy use and has nearly doubled, jumping from 37 EJ to 69 EJ in 1995. The rate of growth in consumption for developing countries has been rapid over this time period (4.7 percent) while growth in industrialised countries and economies in transition has been more moderate (2.2 and 2.7 percent, respectively). Transport energy is divided between passenger and freight transport, both of which include several modes, such as automobile, truck, rail, ship, or air. Road transport, by passenger car and commercial trucks, accounts for the vast majority of total energy use (73 percent), followed by air (12 percent), rail (6 percent), and other modes (9 percent). The industrialised countries dominate transport energy use, accounting for two-thirds (43 EJ) of total world energy consumption in transport. Transport energy use has grown rapidly in developing countries and is estimated at 18 EJ (1995). Rapid economic growth has been accompanied by increased demand, resulting in a tremendous growth in road energy consumption, averaging 6 percent annually. Studies have found a strong relation between income levels and transport demand, both for passenger and freight transport. However, in addition to income level, important factors include changes in economic structure, the quality and density of infrastructure, and fuel prices. Hence, Asia has shown the fastest growth in energy consumption for transportation. It accounts for about half of the total transport energy use, followed by Latin America and Africa. The issue of the growth and demand for transport infrastructure is particularly salient for developing countries. The shift from labour-intensive to service-oriented economies has led to both increasing passenger transport and road freight transport intensities, reflecting the increased economic activity and demand for personal mobility. It may even be expected to be higher in the future, depending on increasing income levels. Car ownership in Bangkok, for example, has increased from 49.7 cars per 1000 persons in 1970 to 108.3 cars per 1000 persons in 1986, an average annual increase of 5 percent. Similar dramatic increases have occurred in other Asian countries as well. In developing countries, the share of energy use from road transport has increased to match industrialised countries levels (80 percent), while the share of rail has declined to about 8 percent of total energy use. Fuel intensities in developing countries are often much higher than industrialised countries, due to poor roads, infrastructure, and maintenance.

Transport energy use can be reduced by improving the efficiency of transportation technology (e.g., improving automobile fuel economy), shifting to less energy-intensive transport modes to achieve the same or similar transport service (e.g., substitution from passenger cars to mass transit), changing the mix of fuels used in the transportation system, and improving the quality of the transportation infrastructure (roads, railways). For nearly all modes of transport, substantial opportunities exist to improve transportation equipment. Measures that reduce energy use in conventional automobiles include improving engine technologies and the transmission, as well as reducing the load on the vehicle. Fuel intensities in developing countries are often much higher than in industrialised countries, and, therefore, hold even greater potential for improvement. In China, for example, recent estimates of fuel intensities for diesel and gasoline trucks in 1991 have been 36 and 37 litre/100km, respectively, or 25 percent higher than intensities in industrialised countries. These figures are also influenced by poor roads, infrastructure (see below), and maintenance, partly due to the wide variety and age of cars used.

Significant reductions in energy use can be achieved by encouraging shifts to less energy-intensive modes of transport. Shifting commuting from passenger cars to buses can result in a relative intensity drop of 200 percent. However, increasing the load factor (i.e., the number of passengers travelling) of the automobile through carpooling can have a similar effect. One study of the US estimates that 12 percent of inter-city truck-kilometres can shift to rail for the movement of goods, an important shift given the fact that road transport is four times as energy-intensive as rail. Transport

BOX 2. SUSTAINABLE URBAN TRANSPORT IN CURITIBA, BRAZIL

In almost every country, urbanisation is accompanied by more intensive use of motorised transportation. In many urban areas of developing countries, this development has occurred very rapidly, with negative consequences for urban planning, air quality, traffic congestion, energy consumption, and human health. Especially in many Asian cities, e.g., Bangkok and Jakarta, the increased transport demand has lead to uncontrolled growth of the number of motor vehicles. Combustion of fossil fuels in motor vehicles produces a number of pollutants that induce health risks. Automotive combustion engines are also major sources of greenhouse gases, i.e. CO_2 and nitrous oxides (N_2O).

The city of Curitiba, Brazil, is an excellent example of a sustainably managed transport system. In the 1960s, with a crippled transport system and burgeoning growth, the city has shown the characteristics of any large city in a developing country. Conventional wisdom may have led to the construction of more road capacity, which may have reduced travel time by personal car, but increased traffic loads and further aggravated the situation. However, starting in the 1960s, the local authorities in Curitiba have taken a path different from that of other cities, developing an integrated plan for transport, urban planning, infrastructure, business, and local community development. By planning and zoning residential and industrial development along so-called "arteries" in the proximity of public transport, transportation needs have been managed sustainably. The arteries are supplemented with a system of ring roads. Express buses on separate lanes are responsible for most of the transport load on the arteries and ring roads. Separate bus lines operate in close connection with the express buses and enter the residential areas. The public transport system now transports over 1 million people daily and accounts for over 70% of all weekday trips. Although Curitiba has the second highest per capita car ownership in Brazil (one car for every three people), Curitiba's gasoline use per capita is 30% lower than that of comparable Brazilian cities, and has lead to estimated annual fuel savings of 27 million litres (or 0.6 GJ/capita). The system has also reduced travel time and increased convenience. This systematic approach of integrating transport into urban planning has reduced space use, traffic congestion, as well as air pollution and energy use, making Curitiba one of the most attractive cities in Brazil, with downtown pedestrian areas and large green areas throughout the city. Curitiba is a successful example for many cities in developing and industrialised countries, where everyday traffic congestion leads to air pollution, health complaints, and economic damage.

infrastructure improvements can occur through increasing the availability or supply of infrastructure, or by reducing demand. Given the high costs of supply expansion, planners are beginning to examine methods to reduce the demand by transport vehicles, or to better optimise the use of existing infrastructure. Actions that can increase the load factor for any particular mode are also desirable, such as the construction of High Occupancy Vehicle lanes (HOVs) in passenger transport. Policies that encourage large shifts to public transit systems in densely populated areas, such as Singapore, Curitiba, and Manila, have been shown to reduce overall energy demand. Land use planning is an important tool to encourage shifts to mass transit. In Curitiba (see also Box 2), Brazil, the city's bus line accounts for 70 percent of total transport, and per-capita energy use is 30 percent lower than comparable Brazilian cities. This example and other studies indicate that land use planning and transportation system policies can reduce energy consumption in other developing countries.

5.3.3. Understanding Energy Efficiency Options

For successful implementation of an energy efficiency project, it is important to carefully assess opportunities technically and economically, including all of the investment costs and unintended consequences, as well as energy savings and productivity increases.

Information dissemination, through generalised campaigns and targeted energy audits, is essential to assisting energy consumers in understanding and employing technologies and practices leading to more efficient energy use. Residential energy audits performed in the US in the 1980s have been shown to have realised average net savings of 3-5 percent with benefit/cost ratios between 0.9 and 2.1. Commercial and industrial customers that received audits reduced their electricity use by an average of 2-8 percent, with the higher savings rates achieved when utilities have followed up their initial recommendations with strong marketing, repeated follow-up visits, and some financial incentives to implement the

BOX 3. INTERNATIONAL COOPERATION IN ENERGY AUDITING

Information and methods to identify and assess opportunities for energy efficiency are essential steps in the implementation of these practices and technologies. Energy audits for industries have been used as a tool to bridge the information gap. In India, energy audits for industry had a bad reputation, as historically these have been often subsided and provided at almost no cost. Often, the quality of the audits has been very low. In addition, the recommendations have been seldom implemented by the recipient. The cooperation between Tata Energy Research Institute (TERI), Bangalore, India, and the German organisation for Technical Cooperation (GTZ) aims to strengthen the capabilities of the TERI Bangalore Centre, provide energy audits for industry, and strengthen the capabilities of offering high-quality advice to industry. The Indo-German project provides various forms of training and improves measuring instruments for energy audits, as well as helps to establish south-south cooperation and to reorganise the institutions by building specialised teams for the various industrial sectors. The energy audit programme now has eight years of experience in providing energy audits to industry in Southern India, and has expanded from eight to 28 energy experts. This has provided the critical mass for the success of the project. It is planned to replicate this process in other parts of India and in other countries. Currently, the Jordan-German Rational Use of Energy Project is an attempt to replicate the good experiences from India by twinning the Jordan institute with TERI.

recommended measures. Energy audit programmes exist in numerous developing countries, and an evaluation of programmes in 11 different countries have found that, on average, 56 percent of the recommended measures have been implemented by audit recipients. The Industrial Assessment Centre (IAC) programme is a successful long-term project in the US. It is run jointly by 30 universities and provides free audits to small and medium-sized enterprises. Since 1976, over 7,700 audits with 53,000 recommendations have been done. Approximately 42 percent of the identified energy saving measures have actually been imple-mented. The programme has also resulted in auditing manuals and a database of audit results.[5] Box 3 describes a developing country audit programme to improve energy efficiency in industry.

The likely success of implementation for a given project depends on the full economic assessment of the found opportunities. A cost-benefit analysis includes, on one hand, an assessment of the costs (e.g., investments, costs for training, financing, and insurance), and, on the other hand, the cost-reductions due to implementation of the project (e.g., reduced energy purchasing costs, reduced operation and maintenance costs, financial assessment of productivity benefits, reduced material losses, and, potentially, reduced permitting and compliance costs due to reduced environmental emissions). It is important to assess the total life cycle costs (LCC) of a project, as the total energy costs over the life-time of energy-using equipment often exceed the initial investment costs. This helps to assess the overall economic impact of an investment, especially if future energy price changes are likely. A number of economic instruments are available to assess the probability of profit from an investment, e.g., the internal rate of return, the simple payback period (PBP), and the net present value. Economic handbooks discuss these methods in more depth. The PBP is often used in industrial practice to make preliminary evaluations, because it is simple to use and easy to calculate. It is calculated according to formula 1 (see below). Box 4 provides an example of a calculation for the implementation of a thin slab caster (see also Box 1).

Formula (1): PBP = I / (SEPC - OM)

where:
I: total investments
SEPC: saved energy purchase costs (energy savings by fuel multiplied by the purchasing costs)
OM: net change in operation and maintenance costs (including productivity benefits)

All measures with a payback period that satisfy a pre-set criterion are assumed to be financially attractive. However, the payback period criterion can vary largely, depending on the nature of the firm and the size of the investment. Thus, it is not clear beforehand what criterion one should use. A survey—carried out in the Netherlands in 1983/84 among a restricted number (16) of industrial companies in order to assess the

[5] *The publications and database can be found at http://oipea-www.rutgers.edu.*

BOX 4. CALCULATING THE SIMPLE PAYBACK PERIOD OF AN INVESTMENT

In the steel industry, a thin slab caster is an innovative technology that saves energy and production costs (see also Box 1). The typical investments are estimated at US$134/tonne steel capacity (I=134). Cost savings consist of energy savings and productivity benefits. Energy savings are estimated at GJ/tonne and kWh/tonne. Assuming US energy prices, this can amount to savings of US$10.5/tonne (SEPC=10.5). Productivity benefits consist of reduced capital costs, increased throughput, lower operation costs, and reduced material losses. Together, these amount to savings of US31/tonne (OM=- 31).

If we would only account for the energy savings in this project, the payback period would equal 134/10.5, or almost 13 years. This investment would not be attractive for a retrofit of an existing steel plant.

However, if we account for productivity benefits, the payback period amounta to 134/(10.5+31),or just over 3 years. This evaluation shows the real value of the project and makes thin slab casting an interesting energy efficiency option.

effectiveness of stimulating measures—has shown that the simple PBP is used in almost all companies to make a preliminary evaluation of investments. Although that survey has been carried out for another purpose and the number of companies is limited, we can use the results to obtain insight into the payback period used in industrial practice. The survey has shown that the payback criterion used varies widely and does not depend on the size of the firm. Only in some cases, a sharply defined criterion has been used. The weighted average is 3.8 years. This distribution has been more or less confirmed by a German study performed in 1989 among 500 industrial firms.[6] The average payback period criterion is 4.1 years. This distribution holds for general investments. For energy-saving investments, 69 percent of the firms require the same payback period as for other investments, 8 percent requiring a shorter payback period and 10 percent a longer one. A complicating factor in financial analyses may be high inflation rates, as historically have been found in Latin America and Africa. This basically reduces the financial attractiveness of any investment.

5.3.4. Financing Mechanisms: a Brief Introduction

The technical and economic information can be used to develop a business plan for the project or programme, in order to obtain financing. Various innovative financing mechanisms are available, including third-party financing, leasing, and through intermediaries, such as energy service companies (ESCOs). Financing is key to the success of a project. Private sector financing is becoming increasingly important in all sectors, as public or multilateral funding is reduced. Key factors are the scale of the investment and whether the investment is a project or a venture (i.e., the start of a new company). Four levels of financing can roughly be distinguished: micro (less than US$10,000), small (US$10,000-500,000), medium (over US$500,000), and large (over US$20M). Large lending institutions (e.g., multilateral development banks) are not able to deal with small-scale projects. Since most energy efficiency projects vary from micro to medium, they typically fall outside the scope of these institutions, unless special programmes have been developed.

Microcredit may be more important for small-scale projects (see also Chapter 7). Microcredit is based on traditional banking principles, but is designed to lend money to low-income groups. The concept can be very successful in countries with an underdeveloped financial infrastructure. The Grameen Bank in Bangladesh is a successful example of a microcredit institution for the rural poor. Established in 1974, the Grameen Bank now started provides funding for energy technologies in villages by developing solar energy systems. In addition, it is cooperating with international suppliers of energy services and energy-efficient equipment.

Leasing is a very common way of financing for all kinds of equipment, from photocopiers to airplanes. When equipment is leased, the user does not have to borrow funds for the capital

[6] *Gruber, E. and Brand, M. (1991), "Promoting Energy Conservation in Small and Medium-Sized Companies",* Energy Policy, ***19,*** *pp.279-287.*

investment. In energy efficiency leasing arrangements, the monthly lease payments are lower than the expected energy savings, while the technology leasing company is responsible for operation and maintenance (IEA, 1997). The International Financing Corporation (IFC) has been very active in promoting leasing companies. Leasing is proving to be an important way to finance the use of environmentally-sustainable and energy-efficient equipment. IEA (1997) provides an example of how a lease for energy-efficient heating equipment, put up by a Hungarian Bank, made it possible for an ESCO (see below) to guarantee energy savings in retrofitting municipal buildings.

Third-Party Financing is used to finance entire projects. A third party finances and carries out the work under its own responsibility and guarantees the work. The investment is recovered through operational savings over a pre-defined period of time. The risk is completely assumed by the third party. This financing mechanism is common in the construction of new power plants, such as build-own-operate-transfer (BOOT) agreements (David and Fernando, 1995). The contract negotiations may often be very difficult and time-consuming, as demonstrated by experiences in Malaysia and other developing countries (David and Fernando, 1995). Third-party financing may also be used to construct industrial cogeneration plants. In many countries, industrial cogeneration has attracted attention to reduce energy use and emissions (e.g., Denmark, Netherlands, and US). In these countries, joint ventures of energy supply or distribution companies with industrial (heat using) companies are set up to build new cogeneration power plants, where the steam is used by the industry, and part of the electricity is exported to the grid. Third-party financing is not yet common for many energy end use efficient technologies, although ESCOs can be viewed as a third party financier (IEA, 1997).

5.4. ENERGY SERVICE COMPANIES: ONE APPROACH IN DETAIL

Energy service companies (ESCOs) provide energy-saving services to consumers, either directly, or through utility demand-side management (DSM) programmes. ESCOs typically provide engineering and managerial expertise to help customers assess and implement energy efficiency improvements. These companies assume technical, financial, and operational risks, as well as arrange project financing. ESCOs then either receive a fee based on achieved energy savings, or sign a contract for the provision of energy savings at specified prices. An ESCO, or an Energy Service Company, is a business that develops, installs, and finances projects designed to improve the energy efficiency and maintenance costs for facilities over a set time period. ESCOs generally act as project developers for a wide range of tasks and assume the technical and performance risk associated with the project. Typically, they offer the following services: development, design, and financing energy efficiency projects; installation and maintenance of the energy-efficient equipment involved; measurement, monitoring, and verification of the project's energy savings; and assumption of the risk that the project will save the amount of energy guaranteed.[7]

These services are bundled into the project's cost and are repaid through the dollar savings generated. The ESCO employs a wide array of cost-effective measures to achieve energy savings. ESCOs often perform on the basis of performance-based contracting. When an ESCO undertakes a project, the company's compensation,

[7] *See, e.g., International Energy Agency (1997),* Energy Efficiency Initiative (Volume 1 and 2), *IEA/OECD, Paris, France; and, World Bank (1999), and* The Energy Service Industry, The Experience of the United States and Canada, *Energy Sector Unit, Energy, Mining and Telecommunications Department, The World Bank, Washington, DC.*

BOX 5. DESIGN AND IMPLEMENTATION OF A BIDDING PROGRAM

An example of a bidding programme is the PowerSaving Partners (PSP) programme of the Pacific Gas & Electric utility in California, US. In the programme, ESCOs have bid to provide 20 MW of power through various energy services. After a public announcement, 42 bids have been received, for a total of 130 MW. The bids have been evaluated on economics first, followed by an evaluation of six criteria: 1) measurement and evaluation; 2) programme development; 3) marketing plan; 4) compatibility; 5) comprehensiveness; and 6) location. The top 13 bids have been selected based on meeting the above criteria. Contract negotiations have been started with these 13 companies. Key issues in the negotiations have been the risk of project financing, compared to the avoided costs for the utility, measurement and verification protocols used, pricing structure over the contract period, contract administration by PG&E, time constraints for negotiations, complexity of the PSP programme design, and the disparity of professionalism and experience among bidders.

The final contract included a fixed payment price for the energy services, so that the risk of lower avoided costs would fall with the utility (on average the costs of the programmes were only 43% of the avoided costs of the utility). The risks of performance, however, were with the ESCO. ESCOs were paid on the basis of measured and verified savings. The PSP programme resulted in savings of 19.2 MW, and the total package was cost-effective and profitable.

and, often, the project's financing, are directly linked to the amount of energy that is actually saved. In the US, various utilities have organised bidding programmes in which ESCOs bid for a project through performance-based contracting. Experiences with these bidding programmes have shown that almost all cases have been cost-effective, compared to the costs of energy supply. Although the specific costs of energy savings of these bidding programmes have been slightly higher than that of utility DSM, the users bear significantly less risk in bidding programmes. Experiences with energy performance contracts can also be found in countries like Hungary, where international ESCOs, with the help of financial consortia, offer energy services based on performance contracts for building upgrades. The lack of knowledge on performance-based contracting and the perceived credibility have been obstacles in introducing ESCOs in these new markets. In Brazil a market for ESCOs is emerging. The current ESCOs in Brazil are technically competent, but the lack of experience, credibility, good measurement, and verification practices are barriers to market acceptance. Third-party financing has been very limited in Brazil, and needs to be expanded through investment banks to finance ESCO projects.

Typically, energy efficiency measures in ESCO projects require a large initial capital investment and offer a relatively long payback period. The customer's debt payments are tied to the energy savings offered under the project, so that the customer pays for the capital improvement with the money that comes out of the difference between pre-installation and post-installation energy use and other costs. For this reason, ESCOs verify, rather than estimate, energy savings. International metering and verification (M&V) protocols are being developed to provide a generally accepted standard procedure.[8] Most performance-based energy efficiency projects include the maintenance of all or some portion of the new equipment over the life of the contract, which compares to a BOOT-contract in energy supply. The cost of this ongoing maintenance is folded into the overall cost of the project. Box 5 showcases the procedures of a specific competitive bidding process from the utility's perspective. Despite the specific background of the project, general lessons can be learned on programme development and negotiations.

Historically, the energy service industry is relatively young. Most US ESCOs place the industry's origins in the late 1970s and early 1980s, when energy prices have risen. About 30 US utilities have used ESCOs as a component of their DSM programmes to reduce demand in resi-dential, commercial, and industrial facilities between 1987 and 1994.[9] The most recent review of the US market shows that independent

[8] *More information on the IPMVP can be found at http://www.ipmvp.org*

[9] *Goldman, C.A. and Kito, M.S. (1995), "Review of US Utility Demand Side Bidding Programs",* Utilities Policy, ***1****(5), pp.13-25.*

ESCOs are slowly declining, while utility-owned and retail ESCOs are increasing their market share within a deregulating environment for power supply. It also appears that performance contracting is being overtaken by other forms of energy service contracts, although this may be the effect of changing markets and also stands to be shaped by public policies.

If well-designed, public policies and deregulation of the power sector may provide an important role for ESCOs. Experiences with power market deregulation in six countries (Argentina, Chile, New Zealand, Norway, UK, and US) have shown that ESCOs are only interested in the largest commercial and industrial energy consumers. Energy service markets for small and medium energy users have failed to emerge in most countries, except for New Zealand, where regulation prescribes retail competition on the basis of service, not price. This shows that the success of ESCOs depends strongly on the policy framework in a specific country, underlining the important role of all parties, including policy-makers, utilities, and energy consumers.

5.5. ROLE OF INSTITUTIONS

Society is a complex organisation of relationships and activities (see also Chapter 6). This is also true for energy efficiency policy. A wide range of stakeholders is involved in all steps of an energy efficiency policy, from formulation to implementation. The stakeholders need to develop partnerships and nurture the relationships with each other, in order to develop and implement successful policies. These partnerships can take various forms. Voluntary agreements (see below) can be seen as a form of a private-government partnership. These partnerships are not a one-time effort, but rather a continuous development. Despite the importance of the partnerships, all partners do have distinct roles and responsibilities in the development process. For simplicity, we define three major stakeholders: governmental and quasi-governmental organisations, private sector (including NGOs), and academia (e.g., research institutes and universities).

The **government** may consist of the policy-making body, energy agencies, as well as state-owned utilities. Policy-makers' primary responsibility is to establish a legal and institutional framework for energy efficiency, as well as to establish the right conditions for energy efficiency and environment. In order to implement this effectively, the government needs to establish policies and tools for effective efforts to improve energy efficiency, specifically in the area of cost effectiveness. To improve the effectiveness over time and answer the changing conditions, the government needs to conduct policy evaluations (or outsource them to an independent third party). It can also lead by example, using its purchasing power to provide a market for new energy-efficient products. The US government Federal Energy Management Programme (FEMP) is an example of this. Quasi-governmental organisations, such as energy agencies and utilities, also have their distinct roles. An energy agency is primarily a clearinghouse for information, building relationships and partner-ships, as well as implementing programmes. For example, many European countries have an independent energy agency that plays a central role in programme implementation. State-owned utilities traditionally need to focus on improving the efficiency of generation and distribution of energy. However, utilities would need to consider least-cost planning strategies to energy services, through DSM programmes and rate structures that encourage energy efficiency.

The **private sector** encompasses a wide variety of stakeholders, such as industries, associations, private utilities, financing (banks), equipment manufacturers, and NGOs. Each of these has its own set of objectives. Industries and associations form primary partnerships for energy efficiency programmes. An association may serve as an information clearinghouse for their members and may support an infrastructure to implement innovative technologies. It is also the primary partner to participate in agreements and negotiations with the government, in order to achieve targeted results or implement policy objectives in the most effective way. By doing so, it promotes democratic decision-making processes. Technology suppliers and users play the most important role in the development, commercialisation, promotion, and marketing of energy-efficient technologies. This also stresses the role of innovative financing concepts and new organisations in the implementation of these technologies. Finally, NGOs play an important role in the public dissemination of information about the importance of energy efficiency, the participation and promotion of democratic decision-making processes, and the development of active partner networks.

Academia consists of research and teaching organisations. It plays an important role in the research and development of new technologies, technology assessment, and independent monitoring and evaluation of policies. Universities and research establishments develop science and technologies for energy efficiency and environmental sustainability, promote assessment capabilities for technology and policies, and monitor and evaluate policies. Universities and schools are also very important in developing a knowledge infrastructure for environmentally-sustainable practices.

5.6. BARRIERS

There are many barriers to the implementation of energy efficiency improvement measures. Empirical quantitative research on the size of the barriers, while limited, underlines the large diversity between individual investors (e.g., firms and consumers). More than one of the described measures apply, more or less, to an investor. The target group has large implications for policy formation aimed at increasing the implementation of energy-efficient measures and equipment. Although most of the empirical research has studied industrialised countries, similar barriers can be found in all countries. Developing countries suffer from all the factors that inhibit market acceptance of energy-efficient technologies in industrialised countries, plus a multitude of other institutional problems.[10]

[10] *Worrell, E., M. Levine, L. Price, N. Martin, R. van den Broek and K. Blok (1997),* Potentials and Policy Implications of Energy and Material Efficiency Improvement, *Department for Policy Coordination and Sustainable Development, United Nations, New York, NY.*

5.6.1.1. Unwillingness to Invest

The decision-making process to invest in energy efficiency improvement, like any investment, is shaped by the behaviour of individuals or of various actors within a firm. Decision-making processes in firms are a function of their rules of procedure, business climate, corporate culture, managers' personalities, and perception of the firm's energy efficiency. A study in the US determined nine "types" of managers, depending on industrial development type and management characteristics. A recent analysis of the Green Lights programme in the US has demonstrated the shortcomings in traditional decision-making processes, as investments in energy efficient lighting show much higher payback than other investments.[11] These analyses demonstrate the need for a better understanding of the decision-making process.

[11] *DeCanio, S.J. (1998). "The Efficiency Paradox: Bureaucratic and Organizational Barriers to Profitable Energy-Saving Investments",* Energy Policy*, **26**, pp.441-454*

In markets with strong growth and competition, efficiency, with respect to energy and other inputs, is necessary to survive. In contrast, stagnating markets are poor theatres for innovation and investment, and instead rely on already depreciated equipment to maintain low production costs. A favourable market expectation has been perceived as an important condition for investing in energy efficiency. Also, in markets where increased energy costs can still be recovered in the product price, firms do not have the incentive to invest in energy efficiency improvement. It appears that firms often perceive themselves as energy efficient, even though there exists significant potential for profitable energy efficiency improvement. Energy awareness as a means to reduce production costs does not seem to be a high priority in many firms, despite a number of excellent examples in industry worldwide.

5.6.1.2. Lack of Information and High Transaction Costs

Consumers often have no knowledge of energy efficiency. If they do have such knowledge, they often cannot afford even small increases in equipment costs or have other priorities. Reddy[12] makes the important point that the problem of this knowledge gap concerns not only consumers of end-use equipment, but all other actors in the market. Many producers of end-use equipment have little knowledge of ways to make their products energy efficient and little or no access to the technology for producing the improved products. End-use providers are often unacquainted with efficient technology.

In developing countries, financial institutions are hesitant to take risks in promoting new technology to an even greater degree than in industrialised countries. The government itself is little involved in providing the essential information necessary for consumers to make intelligent choices on energy efficiency. Indeed, in many developing countries, it is the government that owns and operates the energy supply companies; in these cases, the government often suffers from the same supply biases as the utilities that it runs. Energy supply companies (private or government-owned) often have significant political power, which often counteracts the efforts of agencies of government that promote energy efficiency. This presents a particularly vexing problem for energy efficiency in developing countries, as a governmental leadership role is essential to overcome the considerable imperfections in the markets of these countries.

Cost-effective energy efficiency measures are often not undertaken as a result of lack of information or knowledge on the part of the consumer, lack of confidence in the information, or high transaction costs for obtaining reliable information. Information collection and processing consumes time and resources, which is especially difficult for small firms and individual households.

Evaluations of electric utility demand-side management programmes showed that lighting retrofits resulting in large energy savings and short payback were rejected by the vast majority of building owners and managers, until the utility provided a programme with large incentive payments for the installation of the systems. In an evaluation of one of the utility programmes, more than 65 percent of the participants (all of whom had rejected the lighting retrofit without the utility program) stated that in the future they would invest in more efficient lighting systems without an incentive. Information in the broadest sense of the term was required to achieve market acceptance. The sceptical building managers needed to be convinced that the system would save energy, be cost-effective, could be installed without major disruptions, and would perform as well as the traditional lighting system.

Many individuals are quite ignorant of the possibilities for buying efficient equipment, because energy is just one of the many criteria in acquiring equipment. The information needs of the various actors are diverse and must lead to a diversified set of information sources. Public authorities and utilities play an important role in providing this information. However, in many

[12] *Reddy, A.K.N. (1991), "Barriers to Improvements in Energy Efficiency",* Energy Policy, ***19,*** *pp.953-961.*

developing countries, public capacity for information dissemination is lacking. Training is essential, especially in energy conservation planning and policy-making, because of the focus on energy supply in many developing countries.

5.6.1.3. Profitability Barriers

There is compelling evidence that residential consumers substantially under-invest in energy efficiency or, stated differently, exhibit high returns to make such investments. An analysis from a large number of consumer choices between two refrigerators differing only in the price and energy consumption has shown that consumers typically require a return on investment of 40 percent or more, in order to purchase the more efficient refrigerator.

A large number of standard accounting procedures is available for firms to determine the economic feasibility and profitability of an investment. Many investors use instruments, such as simple payback period, rate of return, or net present value to evaluate energy efficiency projects. When energy prices do not reflect the real costs of energy, consumers under-invest in energy efficiency. Energy prices, and hence the profitability of an investment, are also subject to large fluctuations. The uncertainty about energy price, especially in the short term, seems to be an important barrier. The uncertainties often lead to higher perceived risks, and, therefore, to more stringent investment criteria and a higher hurdle rate.

An important reason for high hurdle rates is capital availability. Capital rationing is often used within firms as an allocation means for investments. This leads to high hurdle rates, especially for small projects, from 35 to 60 percent, which is much higher than the cost of capital (approximately15 percent). On the supply side, the costs of capital are much lower, leading to imperfections of the capital market. Utilities and investors in power supply typically operate with payback periods of 20 years or longer. These capital market imperfections lead to bias against end-use investments vis-à-vis energy supply. This also seems to apply to international loans. From this perspective, energy efficiency investments in developing countries are put at a disadvantage.

5.6.1.4. Lack of Skilled Personnel

Especially for households and small and medium sized enterprises (SMEs), the difficulties installing new energy-efficient equipment, compared to the simplicity of buying energy, may be prohibitive. In many firms (especially with the current development toward *lean* firms), there is often a shortage of trained technical personnel, because most personnel are busy maintaining production. A survey in The Netherlands suggests that the availability of personnel is seen as a barrier to investing in energy-efficient equipment by about one-third of the surveyed firms. In the EITs, the disintegration of the industrial conglomerates may lead to loss of expertise and hence similar implementation problems. Outsiders (e.g., consultants and utilities) are not always welcome, especially if proprietary processes are involved. In developing countries there is hardly any knowledge infrastructure available that is easily accessible for SMEs. Such knowledge is important, because SMEs are often a large part of the economy in developing countries, and are often inefficient. In addition, the possible disruption of the production process is perceived as a barrier, leading to high *transition costs*. Transition costs may include the costs of not fully depreciated production equipment, although the investment in itself may be economically attractive. The size of the transition problems may be reduced by maintaining a good infrastructure for efficiency improvement. This seems especially true for small consumers (e.g., households and SMEs).

5.6.1.5. Other Market Barriers

In addition to the problems identified above, other important barriers include: (1) the "invisibility" of energy efficiency measures and the difficulty of demonstrating and quantifying their impacts; (2) lack of inclusion of external costs of energy production and use in the price of energy; and (3) slow diffusion of innovative technology into markets. A full discussion of these topics is beyond our scope. Many companies are risk-averse with regard to a possible effect on product quality, process reliability, maintenance needs, or the uncertainty about the performance of a new technology. Firms are, therefore, less likely to invest in new technology. Aversion of perceived risks seems to be a barrier, especially in SMEs.

There are other barriers to energy efficiency in residential markets. For dwellings that are rented, there are few incentives for the renter to improve the property that he/she does not own; similarly, the landlord is uncertain of recovering his/her investment, either in higher rents (as it is difficult to prove that improved thermal integrity saves the renter money in utility bills) or in the utility bills (as the bills depend on the behaviour of the renter). The same sort of problem can exist in commercial buildings between builders and owners. Builders are often required to minimise first costs in order to win bids, and many building owners do not have sufficient expertise to recognise the benefit of higher first costs to reduce building operating costs. Likewise, utilities have the incentive to promote greater energy use and not to promote greater efficiency by their customers, unless markets are transformed.

Gadgil and Sastry[13] stress that rigid hierarchical structure of organisations and the paucity of organisations occupying the few niches in a given area lead to strong and closed networks of decision-makers who are often strongly wedded to the benefits they receive from the status quo. They describe how the hierarchy in India leads to the discontinuation of an innovative programme for a utility to lease compact fluorescent lamps to its customers. Among the difficulties in adopting energy efficiency in India, at least ten major barriers have been found: lack of information about products; limited ability to pay even small increased first costs; very low electricity prices; limited foreign currency (which makes difficult the purchase of modern equipment from outside the country); poor power quality (which often interferes with the operation of the electronics needed for energy-efficient end-use devices); shortage of skilled staff to select, purchase, and install efficient equipment; a large used equipment market which keeps inefficient equipment operating long after its useful life; high taxes that increase the first cost differential between efficient and inefficient products; very high risk-aversion of the lending community; and many small and/or outdated industrial activities that do not have resources to produce efficient equipment.

13 *Gadgil, A. Sastry, A. (1994), "Stalled on the Road to Market: Lessons from a Project Promoting Lighting Efficiency in India,"* Energy Policy, ***22,*** *pp.151-162.*

5.7. POLICIES TO SUPPORT ENERGY EFFICIENCY

Many policies have been used to accelerate the implementation of energy efficiency improvement measures. Although most of the empirical research has studied industrialised countries, examples of successful policies can be found in all countries. Based on the literature and case studies, we present several examples of successful policies and programmes in developing countries.

5.7.1. Information Programmes

Information programmes are designed to assist energy consumers in understanding and employing technologies and practices to use energy more efficiently. These programmes aim to increase consumers' awareness, acceptance, and use of particular technologies or utility energy conservation programmes. Examples of information programmes include educational brochures, hotlines, videos, home energy rating systems, design-assistance programmes, audits, energy use feedback programmes, and labelling programmes. As noted before, the information needs are strongly determined by the situation of the actor. Therefore, successful programmes need to be tailored to meet these needs. Trade literature can be the most important source of information, followed by personal information from equipment manufacturer, as well as exchanges between colleagues is also an important information source.

Information programmes are often components of larger energy efficiency activities, so evaluations of their effectiveness are limited. Information programmes by themselves have been shown to result in energy savings of 0-2 percent. A US utility that launched a 2-year advertising promotional campaign for energy efficiency has found that participation rates in its programmes often doubled, but that savings have not necessarily been persistent for long periods. Developing countries, such as China, Brazil, Mexico, India, and Thailand, have developed large-scale information programmes to promote lighting and other residential technologies, although few detailed assessments exist on the effectiveness of these efforts. In general, information campaigns are most effective when the provider is a trusted organisation and when the information is provided face-to-face.

The Norwegian Industry Energy Efficiency Network (IEEN) was established in 1989. The main objectives are to improve energy efficiency in small and medium-sized enterprises and decision-making capabilities in industry. IEEN has built on previous experiences in Canada with the Canadian Industry Programme for Energy Conservation. Today, more than 500 companies among 13 different sectors, from dairies to the primary aluminium industry, and representing 70 percent of Norwegian industrial energy use, are organised in IEEN. Individual companies join voluntarily and are required to provide an annual statement on energy use and production volumes. Each year, the collected data is analysed and processed to produce a sector's benchmark. The benchmark provides information on how a specific firm is operating among the other company members. The benchmarks are shown in a bar diagram for various products of each industry sector. While the data points of competitors are confidential, each individual company knows its own status. The benchmark data is actively used to motivate companies to improve energy efficiency. A recent survey among IEEN members shows that a vast majority of the firms agree that participation in the network is important. The Norwegian programme has been already replicated in Poland and Croatia.

Energy audit programmes are a more targeted type of information transaction than simple advertising. Energy audit programmes exist in numerous developing countries, and an evaluation of programmes in 11 different countries has found that, on average, 56 percent of the recommended measures have been implemented by audit recipients. Audits have been discussed in more detail in section 3.3.

Education and training ,both for customers and for industrial energy managers, offer perhaps the greatest potential for achieving long-term energy efficiency savings. The importance of training for developing countries is highlighted below. For industrialised countries, training often has proven to be a highly cost-effective option for achieving savings. One US utility has measured the effect of energy efficiency education for low-income customers and found annual savings 8 percent higher than for customers who have not received the information and training.

These examples point to the fact that better information, training, and audits have a role to play in energy efficiency policies. However, information alone has not been very effective in getting consumers to actually commit to purchasing energy-efficient products. Analyses of consumer information programmes in the US has found that these programmes alone generally result in much lower energy savings than expected. However, information programmes, combined with various other approaches, can be very effective. People are much more likely to pay close attention to information, if they are likely to use it; incentive programmes which get the attention of consumers, when combined with the provision of high-quality information, have proven to be successful in many utilities. Information programmes (e.g., labels for appliances and other information derived from test procedures) provide the necessary underpinnings for other energy efficiency policies.

5.7.2. Market Transformation Programmes

Market transformation programmes are basically a collection of the instruments discussed in this section. These are organised in a way to bring about a change in a specific market. Examples can be found in many countries, where targeted approaches using various incentives have been used to introduce compact fluorescent lighting (i.e., Brazil) or efficient motors in the market (i.e., Canada). We discuss several approaches that have been used in practice. The role of ESCOs has been discussed in section 5.4.

Utility **Integrated Resource Planning (IRP),** which has been applied primarily in industrialised countries, is used to assess all options for meeting energy service needs, including utility-sponsored end-use efficiency programmes. The novel feature of IRP is that it requires utilities to look beyond the utility meter and into the ways that electricity is used, in order to find the least-cost way of providing energy service. IRP programmes in the US have shown a wide variety of end-use efficiency measures that are less costly than energy supply additions. Two major problems occur: 1) inducing the utility to carry out end-use efficiency programmes; and 2) designing these programmes so that they are, in fact, cost-effective. In the US, utilities traditionally have been subject to rate of return regulation, i.e. the utility obtains profit from its "rate base", consisting of its investment in generation, transmission, and distribution. This results in a strong disincentive for end-use efficiency programmes. This is a dilemma. While the end-use efficiency is desirable from an individual consumer and a social perspective, the utility has strong incentives to increase supply and disincentives to reduce demand under rate of return regulation. In the early 1980s, a new approach provided incentives to utilities for promoting end-use efficiency programmes. These incentives consisted of: 1) recovery of all costs of carrying out the programmes; 2) increased profits for demonstrated successful end-use efficiency programmes; and 3) recovery of foregone profits resulting from reduced sales. This represents a transfer of financial resources from the ratepayer to the utility—increasing the utility profitability—and has been extremely successful in promoting utility end-use efficiency programmes. Certain types of regulatory reforms that remove the financial disincentives could lead to increased utility energy efficiency investments in the US. US utility expenditures on demand-side management (DSM) programmes tripled in 5 years to US$3 billion in 1994. The 25 utilities with the largest estimated energy savings resulting from these programmes, representing 25 percent of the total electricity sales, spent an average of 2.1 percent of revenues on these programmes.[14] Perhaps most remarkably, utility expenditures on DSM in the early 1990s were between 7 and 10 percent of expenditures on all supply, transmission, and distribution.

There have been many evaluations of individual utility DSM programmes, and most have been shown to be more cost-effective than energy supply. It is, nonetheless, difficult to accurately measure the performance of these programmes. Electricity used is a measurable quantity. Electricity saved is much more elusive. The relative invisibility of energy savings acts as a disincentive to consumer investment. It is not easy to overcome consumer scepticism, even of energy efficiency measures that perform extremely well, when evidence for success is uncertain in the absence of extensive statistical studies. One study, which has evaluated US$190 million of commercial lighting programmes in 20 utilities including all costs and energy savings of the programmes, has shown an average cost of energy savings to be 3.9 cents per kWh. This is considerably less than the marginal cost of new power at the time the programmes have been implemented.

There has been interest in IRP and the establishment of DSM programmes in many developing countries. Thailand has launched a

[14] *Hadley, S. and Hirst, E. (1995),* Utility DSM Programs from 1989 Through 1998: Continuation or Cross Roads? *Oak Ridge National Laboratory, Oak Ridge, USA.*

multi-sectoral DSM programme to invest US$180 million over five years. It is aimed at saving 225 MW of peak demand and 1,000 GWh annually. This is estimated to be half the cost of new supply. The programme includes design assistance for new commercial buildings, as well as lighting retrofits in existing buildings. China has also shown considerable interest in IRP, with several utilities developing plans. Utilities in Mexico and Brazil have been active in DSM programmes. Brazil's national electricity conservation programme (PROCEL) is estimated to have saved the equivalent of a 250 MW power plant. The cost-benefit ratio has been estimated to be more than ten to one, with savings of US$500 million and programme costs of US$35 million.

Experiences with deregulation of power production in Europe and the US have demonstrated a declining interest in DSM programmes. New innovative programs are being developed to ensure energy efficiency programmes. For example, in many states in the US, the so-called public-benefit charges are applied to electricity sales. These charges are used to fund research and development (R&D) activities, as well as energy efficiency promotion programmes. Several private utilities have entered the ESCO market as a way to retain large energy-consuming customers.

An innovative policy mechanism, designed to transform the market towards the production and consumption of more efficient products, is **"market aggregation",** or the organised use of buyer demand to stimulate new supplies of a product or service. If a significant share of buyers of a given type of product demand a more efficient product, then this can "pull" the market to a more efficient product mix. Government agencies can play a key role in aggregating the buyers to reduce risk for the producer, and in providing incentives for the production of more efficient products. Market pull activities are now gaining greater interest in industrialised countries, and eventually may become a model for developing countries. NUTEK, the Swedish National Board for Industrial and Technical Development, has successfully undertaken several technology procurement projects for more efficient refrigerator-freezers, laundry equipment, high-performance windows, computer monitors, office lighting, electronic ballasts, and other products. In the US, recent activities include a federal procurement program (FEMP), which directs all federal agencies to purchase energy-efficient products that are in the top 25 percent of the market. Other voluntary programmes are the so-called "Golden Carrot" programmes, applied in Sweden and the US and involving subsidies to design and produce a refrigerator more efficient than the level set by the appliance standards. The winning design has become the basis for the next generation of refrigerators. Golden Carrot programmes have been launched for other appliances.

BOX 6. INTRODUCING CFLs THROUGH MARKET TRANSFORMATION STRATEGIES

Compact fluorescent lamps (CFLs) are thin fluorescent tubes that are bent several times to fit in a small space. CFLs can be used in many applications, have a long life-time (on average 6 years), and result in electricity savings of approximately 60-80% compared to incandescent lamps. CFLs have been developed in the 1970s and first marketed in 1978. In 1988, nearly 10 million CFLs have been sold in the US, representing about 1% of the incandescent lamp market. By 1992, CFL sales have reached 35-40 million, or 4-5% of the market, equivalent to an annual market growth of 33%/year, but because of their relatively long lifetime, the market share of CFLs is, in fact, higher.

The success of CFLs in penetrating the US market can be attributed to several factors. The main incentives that had a large impact have been product improvements (i.e., size reduction, improved shape, instant on lamps), cost reductions, utility incentives through DSM programmes, and energy and maintenance cost savings in the commercial sector. It is estimated that in 1991 utility incentives have been involved in half of the CFL sales in the US. In other countries, the introduction of CFLs has also been rapidly. In The Netherlands, the penetration of CFLs in households is now among the highest in the world. The utilities have pursued DSM programmes since the early 1990s to reduce the emissions of CO_2 and NO_x and reduce energy use. The DSM programmes aim at sales of 15 million CFLs in a period of five years, with an average penetration goal of 3.5 lamps per household. By 1995, a penetration of 2.15 CFLs per household has been achieved, saving approximately 64 GWh annually. Several utilities have provided rebates of 25% on CFL purchases by clients, as well as information campaigns. Other very successful CFLs market transformation programs can be found in Brazil (Procel) and Mexico (Ilumex).

5.7.3. Energy Price Reform

Markets are a powerful and fundamental force in wide-scale implementation of energy efficiency. Subsidies that depress prices of energy provide a significant disincentive for energy efficiency. The removal of this barrier (low energy prices) is an important step toward creating an investment climate in which energy efficiency can prosper.

Worldwide, consumer energy prices typically do not reflect the full costs of energy production, transmission, and distribution because these prices are often subsidised. Furthermore, the energy prices do not include environmental costs. In 1991, world fossil fuel subsidies reduced consumer energy prices by 20-25 percent. Energy subsidies have been most significant in the developing countries and in Eastern Europe and the former Soviet Union. Between 1979 and 1991, electricity prices in developing countries were on average 40 percent lower than electricity prices in OECD countries. A survey of electricity prices of over 60 developing countries found that electricity subsidies grew during the 1980s. In 1991, the average electricity price in developing countries was 4 cents/kWh while the marginal costs were about 10 cents/kWh. Subsidies have decreased during the 1990s, but are still considerable in many countries.

Energy prices in some areas are beginning to more closely reflect costs in response to commercialisation of the electricity industry and investment by independent power producers. For example, Thailand has essentially eliminated across-the-board subsidies, electricity prices in Korea have reached the level of costs, and energy prices in Poland are being adjusted to reflect full economic costs. In Chile, energy prices have risen following power sector privatisation and reforms that eliminated government inter-vention in setting prices. In Colombia, Peru, Jamaica, Costa Rica, and Bolivia privatisation of part or all of the energy supply industry is currently taking place, and is expected to lead to deregulation of electricity prices. After many years of trying, the Chinese government initiated significant energy price reforms in 1993. As of 1994, 90 percent of all coal was no longer subject to price regulations, and the price of this coal reflected most of the supply costs. In 1993, electricity price reforms in China led to prices for new power projects being based on the cost of generation plus a return on capital. This change, combined with higher prices for power from existing power plants, means that electricity prices may, in time, approach deregulated marginal costs.

International lending organisations, led by the World Bank, have been strong proponents of energy price deregulation in developing countries. The largest hurdle to such price increases involves the impact on low-income consumers. This is a serious problem in many developing countries, as low-income urban families often spend a substantial portion of their income on energy. Recent surveys in urban areas of developing countries show the poorest 20 percent of the population spending 20 percent of their income on energy. It should be noted that, very often, in developing countries, the poorest have no access to commercial energy at all. The impacts of higher energy prices on the urban poor can be mitigated in several ways. A low tariff for the lowest consumption block can be instituted, or subsidies for energy efficiency improvements can be targeted at low-income urban dwellers.

5.7.4. Financial Incentives

Direct subsidies, tax credits, or other favourable tax treatments have been a traditional approach to promoting activities that are thought to be socially desirable. Incentive programmes need to be carefully justified to assure that social benefits exceed costs. Direct subsidies might also suffer from the "free rider" problem, where subsidies are used for invest-ments that would be made anyway. Estimates of the share of "free riders" in Europe range from 50 to 80 percent, although evaluation is often difficult. However, other subsidy programmes, e.g., the federal grants in the US, for improving insulation and making other changes to reduce heat from houses of low-income families, show relatively few free riders. An interesting type of subsidy has been the provision of low-interest loan funds for energy efficiency projects, with the government absorbing the difference in interest payments. In some European countries, there have been promising results from experiments with the so-called "green" funds that provide low-interest loans from private funds.

An example of a financial incentive programme that has had a very large impact on energy efficiency is the energy conservation loan programme that China has instituted in 1980. This loan programme is the largest energy efficiency investment programme ever undertaken by any developing country, and currently commits 7-8 percent of total energy investment to efficiency, primarily in heavy industry. The programme not only funded projects whose average cost of conserved energy was well below the cost of new supply, it also stimulated widespread adoption of efficient technologies beyond the relatively small pool of project fund recipients. The programme has contributed to the remarkable decline in the energy intensity of China's economy. Since 1980 energy consumption has grown at an average rate of 4.8 percent per year (compared to 7.5 percent in the 1970s) while GDP has grown twice as fast (9.5 percent per year), mainly due to falling industrial sector energy intensity. Of the apparent intensity drop in industry in the 1980s, about 10 percent can be attributed directly to the efficiency investment programme,[15] and the rest comes from unsub-sidised efficiency investments, efficiency improve-ments incidental to other investments and housekeeping measures.

5.7.5. Regulations and Guidelines

Regulatory programmes have proven effective in promoting energy efficiency gains. Examples include appliance energy efficiency regulations, automobile fuel economy standards, and commercial and residential building standards programmes. In such programmes, the government passes a requirement that all products (or an average of all products sold) meet some minimum energy efficiency level. Energy efficiency standards are applied in many countries for various energy uses. Standards can be performance-based, i.e., they do not mandate how the manufacturer is to meet them (i.e., what technologies or design options to use) and are used for appliances or cars, e.g., the CAFE standards in the US (Corporate Average Fleet Efficiency, see below).

Appliance energy efficiency standards have been aggressively pursued in the US. Since the passage of the National Appliance Energy Conservation Act (NAECA) by the US Congress in 1987, the federal government has mandated standards for such products as refrigerators, water heaters, furnaces and boilers, central air conditioners and heat pumps, room air conditioners, clothes washers, dryers and dishwashers, ovens, and lighting ballasts. NAECA requires a periodic update on all standards, with the timing of new standards differing among different products. The standards in the US are currently being revised. From the viewpoint of economic and energy savings, these standards have been a major success. The standards already in effect are expected to reduce primary energy consumption in the US by 1.1 EJ/year by the year 2000, and 2.75 EJ/year by 2015, avoiding the equivalent of 31 500 MW power plants by the year 2000.

The auto fuel economy standards were promulgated in the US at a time (1975) when its autos consumed about 80 percent more fuel per vehicle mile than European or Japanese autos. By 1992, the average U.S. fuel consumption had declined from 18 litres/100km to 12 litres/100km, while the European and Japanese fuel intensities changed very little. Much of this reduction in fuel intensity was a result of the standards. Estimates of the impact of the standards by themselves varied between 15 and 50 percent out of the total savings gained for new automobiles.

Building energy standards may be performance or component-based standards. While most residential standards specify the measures to be

[15] *Sinton, J.E. and Levine, M.D. (1994), "Changing Energy Intensity in Chinese Industry",* Energy Policy, ***22,*** *pp.239-255.*

included in the building, some also have an alternative or performance pathway, allowing the builder to choose different combinations of measures to meet a specified performance level. The actual energy savings from building energy standards are more difficult to estimate than for appliances and automobiles, as buildings are not mass-produced.[16] Where performance standards are used, the standard is a design standard, meaning that the design, rather than the building itself, needs to meet the code. Faulty construction practice is not dealt with, and is typically responsible for a significant share of poor energy performance of buildings. The operation of a building, which is not affected by building energy codes, plays a major role of the actual performance of buildings. Building commissioning, where systems are tested and maintenance personnel are trained to ensure correct performance of systems, can help deal with this problem for new buildings. In spite of these limitations on energy standards for buildings, they are important policy tools. Because buildings are long-lived, consume large quantities of energy, and can be made more energy efficient at much lower cost when new than after they have been built and occupied, even energy standards that in their implementation are far from perfect can still yield significant economic and energy benefits. Building energy standards are in use or proposed in a large number of countries. A survey of energy standards that received replies from 57 countries, more than half of which do not belong to the OECD, found that 27 had mandatory standards (of which four were residential only and two were commercial only), 11 had voluntary or mixed standards, 6 had proposed standards, and only 13 (all developing countries) had no standard.[17]

[16] *To assure performance every individual building has to be tested. In practice, buildings are not tested, and the degree to which post-standards buildings meet the standards has been established through a small number of experiments.*

[17] *Janda, K.B. and Busch, J.F. (1993),* Worldwide Status of Energy Standards for Buildings, *Lawrence Berkeley Laboratory, Berkeley, USA.*

5.7.6. Voluntary Agreements

Generally, a voluntary agreement is a contract between the government (or another regulating agency) and a private company, association of companies, or other institution. The content of the agreement may vary. The private partners may promise to attain a certain energy efficiency improvement, meet an emission reduction target, or, at least, attempt to do so. In turn, the government partner may promise to support this endeavour financially or to refrain from other regulating activities.

- Some examples of voluntary agreements directed at energy efficiency improvement are discussed.[18] Agreements have been reached between The Netherlands' government and associations of *industrial companies* to improve the energy efficiency in the year 2000 by 20 percent, compared to the 1990 situation. In Denmark, agreements can be closed between the government and industrial companies. Companies that enter into such an agreement are exempted from paying the Danish carbon tax. Also, in other countries, such as Finland, Germany, and Japan, agreements have been reached.
- The US Environmental Protection Agency (EPA) has created voluntary programmes to reduce greenhouse gas emissions in *buildings*. These programmes are known as EPA's Energy Star programmes. The Green Lights program, launched in 1990, involves an agreement between the EPA and corporations, in which the corporation commits to all cost-effective lighting retrofits and the EPA commits to providing technical support. By 1994, Green Lights has had 1682 participants, including 37 percent of the *Fortune 500* firms, representing 130 million m² of floor space. EPA estimates that the programme saved 1 TWh of electricity in 1994. Other green programmes include Energy Star Computers, which has achieved agreement of the major

[18] *International Energy Agency (1996),* Voluntary Actions for Energy-Related CO_2 Abatement in IEA Member Countries, *IEA/OECD, Paris, France.*

manufacturers to provide energy-saving features on their computers, and Energy Star Buildings.
- German car manufacturers have given a voluntary statement to reduce the specific fuel consumption of cars they make and sell in the year 2005 by 25 percent, compared to the year 1990.

Experiences with early environmental voluntary agreements (VAs) varied strongly—from successful actions to failures. The first evaluation of the Dutch Long-Term Agreement, halfway the program period, shows promising results, in that most sectors stand to achieve their targets. Voluntary agreements can have some apparent advantages over regulation, in that they may be easier and faster to implement, and may lead to more cost-effective solutions. The Global Semiconductor Partnership is an example of an international voluntary agreement to reduce PFC emissions, while avoiding regulation.

5.8. CONCLUSIONS

Energy efficiency improvement reduces air pollution (global warming, acid precipitation, and smog in the urban and industrial environment), waste production (ashes), and water and thermal pollution. Efficiency improvement is a cheap energy source. Economic benefits are the reduced costs of energy transformation and generation, reduced fuel imports, and increased energy security. Technologies do not now, nor stand to in the foreseeable future, provide a limitation on continuing energy efficiency improvements. Significant potential exists for energy savings through energy efficiency improvement in all sectors of society, and these savings can change current unsustainable consumption patterns. Three factors have played a major role in the considerable energy efficiency improvements in the past decades: increasing energy prices (except for the past five to ten years), energy policies aimed at bringing energy efficiency into the market, and technological development.

Barriers to efficiency improvement can include: unwillingness to invest, lack of available and accessible information, economic disincentives, and organisational barriers. The degree to which a barrier limits efficiency improvement is strongly dependent on the situation of the stakeholder. Specific implementation barriers may apply to selected stakeholders and/or technologies. This means that no single instrument can "do the job", and policies need to tailor activities to the specific barriers for a target group of stakeholders. A range of policy instruments is available, and innovative approaches or combinations have been tried in some countries. Successful policies can contain regulation and guidelines, economic instruments and incentives, voluntary agreements and actions, information, education and training, as well as research, development, and demonstration policies. Successful policies with proven track records in several sectors include efficiency standards and codes, technology development, as well as utility/government programmes and partnerships.

A policy aimed at sustainable development places energy efficiency improvement in the middle of the economic and environmental policy field. Energy efficiency facilitates the introduction of renewables and "buys time" for the development of low-cost renewable energy sources. However, energy efficiency does not receive attention appropriate for the important role it needs to play in development of an environmentally-sustainable society. Regulatory frameworks typically do not recognise energy efficiency improvement as an energy source. A balanced approach is required to place supply and demand on an equal footing. Changes are needed to fulfil the promise of energy efficiency and to fulfil energy needs more sustainably, accounting for social, economic, and environmental issues.

6

ENABLING FRAMEWORKS
FOR SUSTAINABLE ENERGY

PROMOTING INSTITUTIONAL CHANGE FOR SUSTAINABLE ENERGY

6.1. INTRODUCTION

Energy is an essential component of development. Society needs not energy *per se,* but rather the services that energy can provide, such as heating, cooling, manufacturing goods, pumping or purifying water, etc. The widespread availability of *energy services* is needed for sustainable development.

The main features of a sustainable energy system are well known: high efficiency in energy transformation and final uses; much greater utilisation of renewable energy sources; and clean and effective utilisation of fossil fuels.

The introduction of these changes faces both barriers and opportunities. Some of these are of a technical nature: for instance, some of the technologies for renewable sources of energy or for improved energy efficiency are less mature than conventional technologies, have not been adapted to the specific conditions of the place, or their cost may still compare unfavourably with those of more traditional solutions.

However, the widespread adoption of more sustainable energy systems is also influenced by non-technical factors, particularly the institutional environment, such as norms, regulations, incentives, taxation, etc. In many countries, these factors have evolved and become consolidated over a long period during which the role of energy has not been sufficiently understood and the concept of sustainability has been unknown. As a consequence, these factors often represent powerful barriers against the introduction and diffusion of the energy systems required for sustainable development. The energy policies of many developing countries—when such policies are explicitly stated—often do not take into due account the possibilities offered by new technology, and, sometimes, with the best of intentions, actually discourage their adoption.

In the following sections, we consider all the non-technical factors that depend on the action of governments (both central and local), including legislation.

It should be noted from the start that technical and non-technical factors are only formally independent, since they actually interact with each other. Legislation may orient technology one way or the other. Many examples are known, for instance, of well-meant laws or norms which have slowed down the development of technologies or turned them towards less effective solutions. Positive examples can also be found. Conversely, new technical solutions open opportunities that can be taken up by the legislator. Therefore, discussion of institutional problems cannot be entirely separated from technological considerations.

6.2. LIBERALISING THE ENERGY SECTOR

6.2.1. Introduction

In the past, governments played a direct and prevailing role in the energy field in most countries (and certainly not only the so-called Centrally Planned Economies). Energy was seen as a strategic sector crucial to international competitiveness, economic and social development, and national security, in which the most important decisions were to be taken by the government. State utilities for electricity, gas, and, sometimes, also coal and oil products were instruments for implementing energy policies in many Western countries, such as the United Kingdom, France, and Italy. Similar solutions were adopted in most developing countries.

This concept has been gradually abandoned in many countries, as they have recognised that market mechanisms could perform the same tasks with better efficiency. In the last decade or so, the entire world has been moving toward increased reliance on private sector, competition, and free initiative. The introduction of elements of competition even in those sectors which were previously considered as natural monopolies, such as electricity and gas, already present in the United States and in the United Kingdom, is now required by the directives of the European Union, and is being gradually implemented in the EU countries. Prices of oil products have been deregulated in most industrialised countries. Exploration and exploitation of oil and gas deposits are open to competition. The process of liberalisation in this field also has made great progress in the economies in transition, as well as in China.

The process is slower in many of the developing countries. Reservations about foreign interference through investments, preoccupation about the fragility of their economic systems, reluctance to abandon instruments of control, and lack of local capital to start energy enterprises have all contributed to delay of the transition to free market mechanisms in most developing countries.

Financing institutions consider that the development of sustainable energy can greatly benefit from market and competition. For instance, the World Bank states that “one of the most powerful ways to improve energy supply is to ensure that the energy market is determined by consumers’ choices. This means both that the price of energy should reflect its cost and that regulation of energy industries should encourage competition and choice".[1]

The European Union also encourages the introduction of market elements in all fields in its programme of aid to African, Caribbean and Pacific (ACP) countries. This includes support to structural adjustment (including structural reforms and sectoral policies), and the creation of an environment more favourable to the success of projects.[2]

However, free market is not everything. Effective as market forces are in optimising the allocation of resources for short and medium-term objectives, the market is known to be short-sighted, not to respond spontaneously to long-term signals. As the World Bank puts it, "liberalising energy markets, however important, may not be the complete answer... private companies have shown little interest in extending electricity supplies to rural areas (industrial and urban customers are more lucrative)". Long-term and social signals can be introduced by governments (e.g., through introduction in the prices of the cost of externalities), thus promoting sustainability in the energy field, while using market mechanisms to the best of their potential.

In other words, while "deregulation" is needed to allow space for private initiative and competition, "re-regulation" is needed to establish a set of rules that allow the market to function properly by correcting its imperfections and by accounting for the social costs of the energy system.

6.2.2. The Organisation of Government in the Energy Field and Energy Planning

Within central and local governments, many solutions are possible to deal with energy matters. There can be a dedicated ministry, or the task can be assigned to a ministry with wider competencies (e.g., industry, or environment, or finance, etc.). The best solution depends on local circumstances.

In some cases, an inter-ministry, or inter-department committee at minister level, has the final responsibility. This reflects the fact that energy problems are not confined to the "energy sector", but permeate all sectors of economic, environmental, and social development. Some form of cooperation and coordination of energy aspects in the various ministries is certainly useful. For instance, regular workshops to bring together all these departments and allow for the exchange of information, experiences, and ideas have been suggested (in the case of Barbados).

Apart from the political responsibility, such a policy is implemented by the operative structure of the government departments. Unfortunately, ministries of energy in the South are generally known to be chronically understaffed and under-resourced. Governments may also consider establishing independent high-profile agencies to promote, support, or overview sustainable energy

[1] *World Bank, 1996,* Rural Energy and Development: Improving Energy Supplies for Two Billion People

[2] *European Commission, 1996, Green Paper on relations between* the European Union and the ACP countries on the eve of the 21st century—Challenges and options for a new partnership, *Chapter VI, Brussels, European Commission (also on Internet at http://www.oneworld.org/euforic/greenpap/chap6.htm)*

BOX 1. SUSTAINABLE ENERGY GOVERNANCE IN INDIA

One particular case worth mentioning is that of India, where a Ministry of Non-Conventional Energy Sources (MNES) exists since 1992, having replaced the former Department of Non-Conventional Energy.[3] MNES is responsible for the overall planning and programme formulation, as well as overseeing implementation. MNES works at the state level, through "nodal agencies" which have been set up to promote renewable energy programmes in their respective states; it also involves the state-level utilities (State Electricity Boards) for grid-interactive power generation projects, while NGOs are generally cooperating to ensure connections with the local (village) level. While the creation of a Ministry to renewable is seen by some as a positive sign, others underline that its lack of links with the much more powerful Ministry of Power relegates renewable energy to a marginal position that is not given enough attention in the overall country's energy plans.

[3] *Svaran Singh Boparai, 1998, "India and Renewable Energy: a Future Challenge",* Renewable Energy, ***15,*** *pp.16-21, Pergamon*

development. Such an agency may have fewer staff requirements than a ministry and, potentially, can address the limitations and rigidity of government bureaucracy. Setting up such agencies has, sometimes, been possible in the frame of development cooperation projects.

Another important element to be considered is the level at which energy policies should be formulated, specified and implemented. In the past, just one level was considered in most countries—the national level. Energy policies were the responsibility of the central government, and other levels of government (e.g., regional, provincial, or local) were called in occasionally, only at the executive stage.

Recent trends, in both industrialised and developing countries, point toward a much more decentralised approach. This is exemplified by the so-called "subsidiarity principle" adopted by the European Union, which states that all decisions need to be taken and implemented at the lowest (most decentralised) level that is possible or practical. Central governments often retain only the powers of setting the guidelines, orientating and coordinating energy policies, as well as looking after the part of the legislation that must be common to all the country, while progressively more decisions are taken at the local level. This sharing of responsibilities has the double advantage of better adaptation to the local conditions and of involving stakeholders more directly in the process. Of course, the degree of decentralisation depends on the size of the country and on its general organisation, but there is hardly a small country today that does not find it effective to delegate some of the powers in the energy field (and obviously in others) to smaller units, down to individual villages.

Generally, the main reference to the energy policy of a country in the past was a national energy plan, setting objectives and targets, specifying the actions that would be implemented to reach them, and (at least ideally) assigning the resources necessary for these actions. Such prescriptive national energy plans of the command/control type are seldom considered nowadays, both because of the realisation that, in the past, they have often remained on paper, and because of the aforementioned trend towards market mechanisms.

This obviously does not mean that governments do not have an energy policy, but rather that the instruments of this policy have changed. Since the main instruments are those that influence the market and, hopefully, direct it towards the desired results, the outcome of policy decisions is less deterministic. For instance, a tax on a polluting fuel is expected to help decrease the consumption of that fuel; but the degree to which this happens (specifically, the elasticity of demand with respect to price) is often not known, especially in countries that have relied less on market mechanisms in the past.

Therefore, such instruments have to be calibrated on experience. The approach must include a degree of flexibility, and it is necessary to set up a system to monitor, frequently and accurately, the results of policy measures, in order to correct them in a timely fashion.

Often, energy plans of the past assumed energy demand as an external condition, determined by economic growth, population size, industrialisation, etc., thus concentrating their attention on the supply side (i.e., how best to satisfy this demand). There is now a general realisation that it is possible to influence demand by improving the efficiency of energy utilisation, and that the action on demand may be just as important as the action on supply, and often economically more rewarding.

A first useful step for a government in the energy field is to set clear goals for its action and to identify realistic quantitative targets. If all concerned parties are convinced that the government is serious and determined to reach its objectives, they stand to act accordingly and this is to be reflected by the market. Such target settings are useful in order to select the best range of policy instruments and to discuss them with stakeholders.

Regulatory boards and commissions (discussed again in Section 6.2.4) are important actors in the governance of the energy structure of many countries. Although in many cases such boards and comissions are independent from government, their role increases with the degree of liberalisation of the energy market. They have become major players in many countries, including the United States, United Kingdom and, among the developing countries, e.g., Argentina.

6.2.3. Levelling the Playing Field

6.2.3.1. Eliminating Subsidies

Energy prices have been (and in many cases still are) imposed by governments on the basis of general policy objectives, such as promoting development or social equity, protecting national industry etc.. Having recognised the significance of energy for development, many governments subsidise electricity or various fuels, so that their price to the final consumer is lower than the cost of production and delivery. In many developing countries, energy prices and tariffs are much lower than in industrialised countries, although the cost of producing and delivering energy is by no means lower. For instance, it has been evaluated that the average OECD tariff for electricity is about 50 percent higher than the corresponding tariff averaged over all developing countries.

For the developing countries (DCs), this has the double effect of discouraging energy conservation (by making interventions to increase efficiency artificially more expensive than the energy which is saved) and of creating a barrier to the introduction of new forms of energy, renewable in particular, which are not equally subsidised. Moreover, it has been observed that generalised subsidies (i.e., not limited to the poorer strata of the population), although originally meant to alleviate poverty, actually favour the richer layers of the population. Only the rich can afford consuming substantial quantities of energy; thus, they have little incentive to spare energy or to use it more effectively, and the resulting general costs are spread among the entire population. Poor people often have no access to commercial energy anyway, and political prices of energy as a whole discourage private business entrepreneurs from extending energy services.

In substance, there are two main problems with imposed energy prices. The first is that they do not allow the market to function. They make no place for competition and, therefore, either the final user pays a higher price than necessary, or public finance spends more money, or both. The second problem is that imposed energy prices are generally not instruments of an *energy* policy, but rather of other policies (social, industrial. or others). As a result, they distort the energy market and orient it towards undesired solutions. Specifically, subsidised energy prices will diminish or cancel the advantage of increasing the efficiency of energy utilisation and encourage waste. Since such subsidies are generally applied to traditional fuels or energy forms, they are going to act as disincentives for new energy sources, renewable in particular, and for new ways of producing energy, such as decentralised power production or cogeneration of heat and power. As a result, with very few exceptions, imposed energy prices are an obstacle to the introduction of sustainable energy systems.

Prices of conventional fuels and electricity need to achieve marginal-cost pricing, i.e., the cost of producing the last kWh added to the grid, or of acquiring the last tonne of coal or oil. In this way, the consumer is faced directly with the least-cost alternative between consuming more energy or using it more efficiently. Prices also need to allow for the eroding effects of inflation. If economic support has to be given to industry, farmers, the poorer strata of the population, other instruments need to be used rather than "political" energy prices. (For the special cases of temporary support to sustainable energy, see Section 6.3.1.1.)

Although the necessity of eliminating energy subsidies has been recognised in principle in many countries, its application often meets with severe difficulties. Increasing prices of largely used commodities is always unpopular and often politically sensitive. People used to paying little for the fuel they use are likely to consider a sharp rise of its price unacceptable. Political crises have been triggered in the recent past by increases in the prices of energy. Recent increases of the tariffs of electricity in Ghana generated a wave of protests, resulting in their prompt suspension by the government. Previous attempts to raise the tariffs had been rapidly absorbed by inflation.

A technical difficulty connected with correct pricing of energy should be mentioned here. Individual energy consumption is not always measured. In most countries, the heat provided for space heating from central building boilers or from district heating is not metered, and is charged according to some prefixed criteria, such as floor area. In some cases, there are no meters for electricity, gas, and, frequently, water. This has been a major problem for introducing pricing reforms and energy saving measures in the economies in transition in Eastern Europe, but it is also applicable to a number of developing countries and (for space heating) in some industrialised countries as well.

However, even when the market operates fully, the price paid by the final consumer also includes taxes, that, in some cases (e.g., petrol in European countries), constitute a large fraction of the final price. It is quite common that different mechanisms are present for different energy sources (e.g., free market prices plus taxes for petroleum products and coal; regulated maximum prices plus some market elements for electricity and gas, see Sections 6.2.4.1 and 6.2.4.2).

BOX 2. CROSS-SUBSIDIES

Sometimes, subsidies allocated to one form or one utilisation of energy extend to others. For instance, diesel is used both as a fuel for diesel engines and for heating purposes. In some European countries, for instance, taxes on gasoil are less heavy than on petrol, in order not to burden truck drivers excessively; however, the same lower tax is inevitable for diesel-powered private cars and for heating. In India, subsidies have been given until recently to kerosene, considered as a need for poor people that use it for lighting; however, since kerosene can easily be added to diesel fuel, gasoil price has been levelled with that of kerosene. In some countries, fuel for farmers (especially diesel fuel) is subject to a lower tax, but it is difficult to assess where and for what purpose it is eventually used.

6.2.3.2. Internalising Externalities

While energy taxes have been used in the past mostly as instruments to ensure revenues for the national budget, there is the possibility of using the fiscal system coherently, in order to charge to the user the costs which are borne by the society as a consequence of the use of energy. environmental costs, health costs, and, more recently, costs connected with climate change, or the so-called “externalities”.

Externalities are defined as “the costs and benefits originating when the economic or social activities of a group of people have consequences on another group of people, and when the first group does not take adequately into account these consequences”. For instance, the production of electricity from coal affects, through acid rain, farmers or fishermen who do not use electricity, or use little of it.

Among others, externalities include damage to health and the environment, effect on employment and on energy security, depletion of finite resources, etc. Ordinarily, these are not reflected in the price of energy and have to be borne by society as a whole, or by some groups of the population, such as the less privileged ones.

The economic evaluation of externalities is a prerequisite, if a government decides to introduce external costs in the price of energy, in order to have users pay for the full cost of what they consume. However, this is not the only possible use for such an evaluation. Many other kinds of policy decisions can be taken in a more informed and effective way, if one has a guidance to the “hidden” costs which are avoided by improving environmental conditions. For instance, respective externalities for various fuels may orient policy decisions which stand to favour one against another. The same applies to different energy systems. Evaluating the costs and benefits of more (or less) stringent environmental standards also requires a comprehensive approach as the one we outline above. In general, the evaluation of externalities is valuable for anyone who wants to pay greater attention to economic instruments for environmental policies, develop comprehensive indicators of environmental performance of different technologies, and compare different approaches to encourage competition and market mechanisms.

Not adding externalities to the price of energy corresponds to giving a subsidy to that form of energy, equal to the "hidden costs" which are not charged and, eventually, are paid by society as a whole, or by some particular group not coinciding with the users. These "virtual" subsidies are even more difficult to remove than actual direct subsidies. The price of petrol in the United States, which is much lower than in most industrialised countries because it takes no account of externalities, is an extremely sensitive political issue and constitutional barriers are claimed to exist against the introduction of the hidden costs in the price.

Economic theory shows that there are no relevant externalities, if the emissions (or other causes of impact) are reduced to an optimal level, which is the level where the marginal cost of further reducing them is equal to, or greater than, the marginal cost of this pollution or impact. In other words, once this level is reached, the cost of reducing it further is greater than the benefit gained by society or by the affected groups, and, therefore, it is not justified.

The full inclusion of externalities in the energy prices can greatly facilitate the diffusion of sustainable energy schemes, since for renewable energy sources and efficiency interventions, externalities are much less negative than for conventional energy sources, and, in some cases, are even positive.

BOX 3. EVALUATING EXTERNALITIES

Although its principles are quite clear, the evaluation of externalities is far from simple. Aggregate, top-down methods, starting from national statistics on emissions and damages, although useful for a first orientation, do not yield marginal costs, nor can take into account local and time variations. More useful, but correspondingly more difficult, are bottom-up methods, using an approach based on the damage functions and the impact pathway. They are based on the specific emission data for a given technology and for specific sites. The main problems concern the uncertainties on the causes and nature of impacts, as well as the lack of adequate studies on the economic evaluation of damage.

The most complete way to calculate externalities for a given energy technology takes into account the whole life cycle. For instance, the production of electricity from coal starts from coal mining, coal beneficiacion, its transportation to the power plant, its burning and the relative exhausts at the stack, the generation of power, the final disposal or utilisation of the ashes, and the cost of recovering the site of the mine once this is exhausted. Some evaluations also include indirect impacts, such as those associated to the manufacture of the equipment used to extract, transport, or burn coal, and the construction of the power plant. Not surprisingly, on the example just mentioned, the largest impacts are those on the health of the coal miners, those associated with coal transportation, and those deriving from the acid emissions of the plant. Of course, positive externalities, such as the creation of jobs along the whole cycle, are also taken into account.

Long-term effects are difficult to express in monetary terms, since this involves the choice of a discount rate extending over several generations—a very sensitive choice, which is not so much an economic, but a political or ethical dilemma.

Various attempts to calculate externalities, both in general terms and for specific situations, have been carried out in the last decade. Almost all of them originate in OECD countries.[4] One of the most exhaustive is the recent (1995 and on-going) ExternE programme promoted by the European Commission.[5] Developing countries have so far put little effort into this kind of exercise, but this can probably be useful for them to evaluate long-term strategies and to assess market mechanisms to control emissions. Evaluations made elsewhere have little applicability to developing countries, because of the large variations in the value of parameters; however, the methodology can be very much the same.

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[4] *See, for instance, L.A. Cifuentes and L.B. Lave, 1993, "Economic Evaluation of Air Pollution Abatement: Benefits from Health Effects",* Ann. Rev. Energy Environ.*, **18,** pp. 319-342; and N. Rajah and S. Smith, "Using Taxes to Price Externalities: Experiences in Western Europe",* Ann. Rev. Energy Environ., ***19,** pp. 475-504*

[5] *European Commission, 1995, DG-XII,* ExternE, Externalities of Energy *, EUR 16520 EN, Brussels-Luxembourg*

The evaluation of externalities is a first step toward adopting market measures in place of command/control mechanisms. The traditional route for governments in the past has been to impose, through norms and regulationss maximum values for emissions and other performance criteria. Often, this also included mandating certain technological solutions rather than others. This approach is simple, but not always effective; the costs of reducing negative impacts on the environment have been estimated to be generally much greater than what can be achieved by market forces. Moreover, by imposing particular technologies to be adopted, technological development and innovation have been discouraged or impeded. By substituting economic measures for regulations, the market is stimulated to work out the best solutions in economic terms, and R&D is encouraged to progress in the desired direction. However, the type of market instrument employed to take externalities into account may differ. In Europe, the prevailing trend is to introduce externalities into prices by means of taxes. In the United States, the preferred system is to fix a maximum value for cumulated emissions (generally decreasing with time), distribute this value among potential polluters by assigning emission credits, and allow these credits to be traded in exchanges, as if they were bonds. This results in assigning (negative) market values for the emissions, and, therefore, leads to choosing the most economical solutions to reach the targeted result.

In industrialised countries, attempts to address externalities through taxes and tradable emission rights have had a very large impact when applied to the most common pollutants emitted by large-scale plants, particularly sulphur oxides and nitrogen oxides. In these instances, the penalty is typically greater than the cost of reducing the emissions, or of purchasing emission share at a reasonably low-value, so that any reasonable entrepreneur is able to intervene. The result has been a very steep alleviation of the phenomenon of acid precipitation in Europe and North America, as well as a general improvement of air quality. Emission taxes for these pollutants have also been introduced in developing countries (for instance, in China), but for the time being they are generally too low to reach the desired result.

The same applies to the "carbon tax" (meant to include the externalities deriving from the effect of carbon dioxide emission on the stability of global climate) in the few countries where this has already been applied (mostly Northern European countries). Uncertainty in the evaluation of externalities, doubts about the magnitude of the phenomenon, the very long time horizon involved, and the worldwide effects expected from global warming have prompted, for the moment, relatively low values of the carbon tax. The tax itself, or more probably the expectation of substantial increases in the future, has already contributed to an acceleration of the shift toward less carbon-intensive fuels (from coal to natural gas), even if it has had only marginal effects on the overall level of energy consumption.

In some countries, there is another mechanism that makes taxation based on externalities more effective. The institution of the tax foresees that its revenues (or a part thereof) are devoted to specific actions aimed at reducing pollution, for instance, promotion of demonstration projects, support to the diffusion of renewable energy technologies, or increased energy efficiency. Although many economists frown at this concept of "targeted taxes" on sound theoretical grounds (If there is good reason for a public expenditure, why not charge it to the general budget?), the mechanism has proven effective on the ground, implying, perhaps, additional psychological and information motivations.

Examples of taxes on externalities used to finance sustainable energy schemes are fairly common in industrialised countries, but some examples can also be found in developing countries. For instance, since the middle 1980s the Government of Ghana is imposing a small levy (originally equal to 0.3 percent of the pump price) on petroleum products, the revenue from which is used to finance sustainable energy projects.

6.2.4. Restructuring the Energy Sector

6.2.4.1. The Electric Power Sector

The introduction of market mechanisms and competition in the power sector has been—and still is—one of the most important factors of transformation of the energy sector in many countries, both industrialised and, more recently, also developing countries.

A distinction should be made between privatisation and liberalisation of public services, which do not necessarily go together and which belong to different decision levels. The choice to change the ownership aspects of a public enterprise is a decision of economic policy which has different motivations in different contexts, including improvement of management, efficiency of financial markets, reduction of public deficit, etc. Liberalisation is a choice dictated by technical-economic considerations and drawn by the evolution of technology; its main purpose is decreasing the cost of energy and improving the quality of the service by introducing competition and by optimising the allocation of resources. Various countries have adopted privatisation and liberalisation measures in different proportions. Since privatisation does not directly influence technological choices and sustainability, here we focus on liberalisation.

In 1996, following the experience of the United Kingdom and elsewhere, the European Union issued a directive requiring all member states to introduce market mechanisms in the electricity market (and, sometime later, in the gas market), also giving guidelines and minimum quotas for market opening. The solutions adopted for introducing liberalisation into the electric power sector vary widely, although most models incorporate a formal separation production, transmission, and distribution into district entities. Different companies are responsible for each of the three functions, or, in some cases, at least temporarily, the three sectors are distinguished within the same company, with separate budgets and management. There is generally only one company in charge of transporting electricity (more than one long-distance electric network in a country is hardly justified); there are many distribution companies over the country, but generally only one in each geographical location (although a few exceptions do exist); and there is generally a multiplicity of power producers. The aim of the liberalisation procedure is to allow the maximum share of the users (at the limit, all users) to choose among different producers, based on price and quality of service, and to have the electricity convoyed from the production site to the consumption side through the transport system. The price to be paid for transport is regulated, generally on a cost-plus-fee basis. At the beginning, only large-scale consumers (typically large and medium industries) are going to be able to choose among producers, but most countries aim at a progressive enlargement of the basis of these "eligible customers", eventually arriving at the totality of electricity users. Since it is impractical for isolated customers to contact many prospective producers (or vice versa), the figure of the "provider" is emerging, establishing links between the producer and the client and actually introducing the element of competition at all scales (this figure is already common in the field of telecommunications). In the various countries, the degree of choice given to the final consumer, the actual level of competition, the uniformity of prices, and the balance between public and private enterprises are very variable and are rapidly changing with time.

In order to function properly, the electricity market has to be regulated. Rules have to be set, in order to guarantee that the market functions properly, the interests of the consumers are protected, and some social objectives of public interest find their fulfilment. Examples are the extension of the grid to locations not yet served, an upper limit to tariffs, the assurance of service for essential or strategic usage, and the promotion of environmental protection and renewable sources of energy. While some of the basic guidelines need to be set by the government and established by law, setting the actual rules and monitoring of the functioning of the system is increasingly committed to a specific authority, which is generally a high-level body independent of the government.

Such authorities have been pioneered by the United States since 1987 by the creation of the Public Utility Commissions at the state level (with a corresponding electricity regulatory commission at the federal level). Anglo-Saxon, North European and South American countries have followed: the UK since 1989, Argentina and Norway since 1990, and so on, until the system has been adopted by most—not all—OECD countries. Independent regulatory Authorities are still rare among developing countries. In the latter, in most cases, deregulation of the electricity sector has been introduced and regulatory powers remain within the government, as in the case of Jamaica, where an Office of Utility Regulation has been established.

Developing countries, however, have particular problems to take into account. In many developing countries, the size of each grid (many not interconnected) is still too small to justify more than one large-scale electricity producer. The problem concerns the access to the grid of very small independent power producers, often based on renewable energy or operating diesel generators. Moreover, the quality of the service is often very poor, with frequent interruptions, and improving this aspect is a major concern. The importance of rural electrification is also much greater than in the case of industrialised countries, and solutions have to be weighted against these problems. It would probably be unwise for most developing countries to adopt the regulation of the electricity market schemes from industrialised countries, without introducing major changes to account for their own particular conditions. However, there is a general consensus that introduction of elements of liberalisation of the market at an early stage, if tailored to their actual conditions, would generally be beneficial. In particular, it is recommended to liberalise the sale of energy from renewable energy sources (RES), independently of eligibility rules in general.

In other words, developing countries must make the most of exploiting the potential of the market in reducing costs, allocating resources, and finding innovative solutions, but at the same time they must orient the market decidedly towards their outstanding priorities, such as poverty alleviation, rebalancing of rural and urban areas, and promotion of social, as well as economic development. There is no fixed formula to do this, and each country must consider its own specific situation. Some examples can be found in the next sections.

It may be worth mentioning that, among the provisions regulating the electricity market in some of the industrialised countries, a levee is applied, generally on the tariffs for the transportation of electricity, in order to support some goals of public utility, such as the financing of research and development in the field of electricity, or the promotion of RES.

6.2.4.2. Other Energy Sectors: Gas And Petroleum

The gas sector has problems similar to those of the electric sector, due to the need of infrastructures for transport and distribution. The deregulation of the gas sector in industrialised countries is proceeding more or less in parallel with that of the electric sector—in some cases preceding it, in others lagging behind. In some countries (e.g., Italy and UK since 1999), the same regulating authority oversees both sectors. Liberalisation of the gas market has little significance in most developing countries, since there is typically no infrastructures for natural gas.

Petroleum products and, to a large extent, coal are more easily amenable to market mechanisms (apart, of course, from the regulation of their environmental performance, which is open to a number of options, as exemplified by the various approaches to the reduction of SOx emissions).

The prices of petroleum products have been deregulated in most industrialised countries. State-owned oil companies often have been privatised, and where they have not, they have no longer monopoly positions, and are required to operate as private ones in a competitive environment.

Exploration and exploitation of oil (and gas) fields is also generally open to national and international competition, through a system of concessions subject to competitive bidding.

In developing, oil-producing countries, state-owned national companies are still the rule. They have responsibilities for the exploitation of national reserves, which is generally carried out by means of joint ventures with foreign (or multinational) petroleum companies. This is understandable, in view of the prevalent weight of oil on their economies, and, in particular, on the balance of payments. This situation is not expected to change in the foreseeable future.

This system can be—and is being—used, in some cases, to the advantage of sustainability. Some far-sighted governments actually bind the concession of oil exploration and exploitation to some forms of introduction and diffusion of sustainable energy systems, so that they are better prepared for the time when petroleum reserves run off. Some of the major oil companies have responded positively to this challenge, putting substantial investments in the development of advanced energy systems, such as renewables (particularly biomass and solar photovoltaics) and distributed generation and cogeneration.

6.2.5. Barriers and Opportunities

6.2.5.1. Legislative Issues

The trend towards deregulation and market mechanisms indicates that it may often be more important to eliminate legislation that constitutes an obstacle to the diffusion of sustainable energy systems, rather than to create new laws. However, new laws and norms are still necessary to regulate the market, impose certain minimum standards, and set up incentives (see Section 6.3.1.).

A clear indication that has emerged from past experience is that technical norms should not be included in legislation. Examples abound of technical norms that represented the best choice expressed by the scientific and industrial communities at the time they were included in the legislation, but which have become rapidly obsolete because of technological progress or change in the external conditions. The fact that they have been included in laws has made the process of amending and updating them extremely cumbersome and lengthy, with norms made with the best possible intentiond finally representing obstacles to the progress of technology and diffusion of improved solutions. If technical specifications are necessary, they must be subject to periodic revisions, with the possibility of having them issued and updated rapidly. However, in most cases, it is better to specify the targets one wants to reach rather than the technology to reach them. At most, a technical annex can show that at least one technology exists capable of obtaining the desired results, but if other (and perhaps better) options are available, people should be allowed to use them.

Looking for laws and norms that impede the development of sustainable energy systems is not an easy task, since such legislation may not be addressed specifically to energy and may be equally or more relevant to other fields. For instance, taxation on energy technology and equipment discourages some efficient energy technologies. Similarly, renewable energy technology products (such as solar photovoltaic and heat panels) or materials to manufacture them locally are often subject to high import duties that increase their market price, relative to conventional energy.

The process of generating electricity in a dispersed or decentralised way (often by RES) is often discouraged by the difficulties of obtaining the required permits, which may have to follow the same procedures as permits for plants that are a thousand times larger. Sometimes, this also applies to energy generated to be consumed on-site, while selling electricity to other customers is often illegal, and provisions to sell it to the grid are technically difficult, bureaucratically cumbersome, and economically unrewarding. Legislation allowing equipment owners to connect and sell power to neighbours is under discussion in Uganda. If implemented, the resulting microgrids could bring about dramatic improvements.

Setting up solar panels on the roof or facade may be in contrast with local building codes. Passive solar architecture includes a number of features (such as orientable sunshades, greenhouses providing and storing solar heat, or wind towers for cooling) that, even if not prohibited, are discouraged by local legislation (for instance, by calculating and taxing greenhouse space as part of the residence).

Labelling and minimum standards are well-known and proven instruments to improve the efficiency of energy consumption (for instance, in appliances). Setting the right values is a difficult problem of compromise between contrasting needs. Overly low standards risk the failure of projects, because of poor quality of the equipment, with consequent loss of confidence by the business and financial worlds, as well as by consumers. Overly high standards risk involving excessive (and unnecessary) costs, limiting consumers' choices and endangering projects for another reason. Efforts to reach reasonable standards are underway in a number of initiatives, such as the PV Global Accreditation Programme (PV-GAP) for photovoltaics.

Positive examples of standard-setting at the level of a single country are beginning to emerge. Policies and programmes for appliance labelling and standards, as well as for improving thermal efficiency of new housing projects have started (e.g., South Africa), but have yet to be implemented on a large scale. Energy standards for commercial buildings have been adopted in Côte d'Ivoire. However, better results may be obtained by setting up common standards agreed upon, at least at the regional level, thus facilitating commercial exchanges, joint initiatives, and exchange of experience.

6.2.5.2. Technology-Specific Issues

Energy is interlaced with every facet of productive and social life; this is particularly true for the more sustainable energy systems, which are mostly distributed, local, and integrated into everyday life. Therefore, it is not only institutions, legislation, and norms explicitly concerning the energy sector that are relevant in terms of barriers, as well as of opportunities, for the development of new energy structures. We briefly discuss two examples here.

The first concerns energy from biomass, be it residues, forestry products, or dedicated plantations. In most developing countries (and not only in those), the largest fraction of agricultural residues today are burnt in the fields. Although this practice does return to the earth a part of the minerals and of the nitrogen content, it is by no means the most effective, it wastes large quantities of stored heat and it creates potentially severe environmental problems. Repeated shut-downs of airports because of the smoke, for instance, have induced the Chinese government to ban the practice of burning, at least in certain areas. Although the residues can be tilled back into the ground, only about one-third of the residues is estimated necessary with this technique to supply the required fertilisation. Large quantities of biomass are thus made available for energy use.

Agricultural, land use, and forestry policies often present institutional difficulties for the energy exploitation of biomass. The state ownership of forests in many countries (as opposed to village ownership or private concessions) does not encourage sustainable forestry practices and rational exploitation. Forest departments typically lack the resources to manage forests and woodlands, or even to guard them against public exploitation as a free good. Returning this land to ownership and management by local communities (a form of privatisation) can be a sound way of turning depredation into good management. Tenure laws, forestry codes, management plans, rural wood markets, and price regulations must be developed and implemented. The World Bank, together with UNDP, ESMAP, and the Regional Programme for the Traditional Energy Sector (RPTES), are conducting pioneering efforts along these lines in 12 countries of Sub-Saharan Africa.

Another example of a sustainable energy system that often meets with institutional difficulties is the combined production of heat and power (CHP), which is an energy-saving technology meeting increased favour in both industrialised and developing countries. Here, the difficulties are more internal to the energy sector, but derive from the fact that CHP puts together two sub-sectors which are regulated with different rules and logics: two markets, two types of technology.

The techniques used until recently for CHP put emphasis on heat production. The CHP plant generally operated following the demand for heat; the ratio of electricity to heat produced was rather rigidly fixed and relatively low, so that the electricity produced was all consumed on the site and complemented with inputs from the grid. The result was relatively easy to manage from the institutional point of view, but the overall efficiency was low and hardly justified the recourse to this technique. The fact that the plant followed the heat load implied its partial utilisation and, therefore, increased financial loads.

New techniques, in particular gas turbines and combined cycles, have completely changed the situation. The overall efficiency has become much higher, and the electricity to heat ratio has become much more flexible, but also much higher. In these conditions, it becomes convenient to operate the plant at full power all the time, extracting at each moment only the quantity of heat that is required. The power produced is generally much more than what is needed locally, and, therefore, it has to be fed into the grid. In these conditions, rules have to be set to distribute the cost of the overall production between heat and electricity. If (as it is often the case with district heating) the plant belongs to the electrical utility, then taking up electricity is an internal problem, but setting the price for heat is more complicated. In the case of industrial CHP, where the plant is owned and operated by the industry or (in some cases) by a third party, either the sale of electricity or of both electricity and heat involves specific regulations. Incentives for CHP plants, originally set for older technology, often require a *maximum* electricity over heat ratio (to make sure that it really is CHP), which is absolutely in contrast with maximum efficiency and modern technology trends.

6.3. MAKING IT HAPPEN

6.3.1. Creating enabling conditions

6.3.1.1. Encouraging Renewable Energy Technologies

Renewable energy technologies (and, to a lesser extent, some energy efficiency measures) necessitate some degree of public support to take off. There are good reasons to provide temporary financial support to these technologies, despite the general principle that subsidies to energy need to be avoided. The first reason is that this support is meant to overcome the inadequate functioning of the market, which discriminates against renewable energy in many ways: because externalities are not yet reflected in the price of energy; financing systems favour conventional solutions and large-scale supply-side interventions; and there are still barriers of knowledge and capacity. The second reason is that, in the past, conventional sources have received subsidies and support that have enabled them to buy down costs by rapidly following the learning curve.

It is, however, clear that if some of these technologies need to be subsidised to gain a footing, then such subsidies must be open, universal, and time-bound. Decisions need to be regulated and made in common with the private sector. Subsidies should never be given to technologies that do not have the capability of eventually (and predictably) becoming competitive and surviving by themselves in the marketplace.

In the past, many governments in both industrialised and developing countries have planned, financed, and, often, directly implemented projects using renewable energy. Alternatively, they have supplied capital incentives for any such projects with little discrimination. These approaches have proven to be inadequate in scale, and, often, conducive to supporting uneconomical technologies, because they have not adequately considered market conditions.

Fiscal incentives for sustainable energy systems should, therefore, be carefully designed and targeted to buy down initial cost, risks, and other implementation barriers; subsidies for running costs are much harder to justify and often have been the principal cause of project failure.

Many countries have set up ambitious targets for the penetration of RES in their economy, as well as set up incentives and regulations in order to reach these goals. The Commission of the European Union, for instance, has approved a "white paper", indicating the objective of doubling the share of renewable energy sources in the energy budget of the Union. Member countries are requested to adopt consistent policies to reach this collective objective, and several countries have already complied with appropriate legislation.

Examples from industrialised countries include the Non-Fossil Fuel Obligation (NFFO) in the UK, the Renewable Portfolio Standard in the US, a number of methods of dispatching and price incentives for electricity generated by renewable sources in various European countries, and several types of intervention for energy-saving measures. Experience has shown that these interventions are most effective when they make use of market mechanisms (such as through competitive bidding), and when they actually promote technology improvement (through planned decrease of subsidies with time).

NFFO derives from the 1989 Electricity Act, empowering the UK Secretary of State to order the Regional Electric Companies (RECs) to contract for specified amounts of electricity sourced from non-fossil fuels. The RECs are compensated for the extra cost of electricity by means of a levee on electricity consumers (the Fossil Fuel Levee). NFFO is operating since 1993, by means of competitive bidding (five until the last in 1998). The competitive mechanism has allowed the highest prices paid for the kWh from each of the technologies considered (wind, hydro, landfill gas, waste, and biomass) to decrease substantially from each call for tenders to the next. The total capacity expected to be commissioned by the year 2000 amounts to 1500 MW. Similar bidding systems have been introduced in France and Ireland.

On the other hand, other countries offer fixed prices for the acquisition of energy from RES to the grid, namely Germany, Denmark, Spain, and Italy. These prices are calculated on some prescribed bases (such as avoided marginal costs plus decreasing incentives) and, therefore, do not depend on competition; however, the results obtained so far do not seem to be worse than with the bidding system.

Additional incentives are often offered to the developer, such as accelerated depreciation allowances, tax exemptions, lower import duties, government-guaranteed special lines of credit, or even direct subsidies.

India, in its Ninth Five-Year Plan, has set a number of ambitious detailed targets for renewable energy, sub-divided by technology and application.

In India, there is a host of benefits available to both manufacturers and users of renewable energy systems.[6] These include: (i) 100 percent depreciation for tax purposes in the first year of the installation of the systems (recently reduced to 50 percent); (ii) no excise duty on manufacture of most of the finished products; (iii) low import tariffs for capital equipment and most materials and components; (iv) soft loans (2.5-10.3 percent)

[6] *Svaran Singh Boparai, 1998, "India and Renewable Energy: a Future Challenge",* Renewable Energy, ***15,*** *pp.16-21, Pergamon*

to manufacturers and users; (v) 5-year tax holiday for power generation projects; (vi) remunerative price for the power generated through renewable energy systems fed to the grid; and (vii) third-party sale of renewable power.

Innovative approaches are possible. One receiving attention at the moment is the "concession approach" to renewable energy resources (starting from wind), which applies, with the necessary changes, the same criteria used for oil and gas field concession, through the exploration phases, setting up of joint ventures, and exploitation phase. The main advantage of this approach resides in contracting the concessions in fairly large blocks that justify launching of joint ventures and the effective transfer of technologies, as well as allow the process of buying down costs to effectively take place. At the moment, this approach is being considered, in particular, for wind projects in China.

Successful approaches include bundling consumer demand (to capture economies of scale) and financial capacities through community association, and delegation of public sector responsibility to private sector concessionaires.

New renewable energy technologies are already contributing to improving the quality of life, especially in rural communities of developing countries. Their social contribution is, in a way, much greater than their share in national energy budgets. Examples vary from the biogas family plants in China to those at village scale in India, the small wind generators or PV systems feeding TV and communication systems in Mongolia, and the PV-fed refrigerators for vaccines in Africa. However, we are just now experiencing the first results of policies designed to encourage the diffusion of renewable energy technologies (RETs), not by direct subsidies (or not only by them), but by creating a favourable institutional environment for their diffusion through market forces and private initiative. Effects can already be observed, for instance, in Zimbabwe, India, or in some provinces of China.

6.3.1.2. Supporting Appropriate Financial Mechanisms

One of the main difficulties to be overcome for the diffusion of sustainable energy systems is the dispersion of financing into a myriad of small projects. Lending institutions are used to large-scale loans, such as generally required by supply-side conventional plants. The cost of assessing each single proposal of renewable energy or improvement of energy efficiency is often far too high to be justified by the amount requested. This applies to project financing (where the loan is assessed on the basis of the techno-economical soundness of the proposal) but it also applies to the more conventional loans based on the solvability of the requester. Now, credit is an essential need for the diffusion of sustainable energy schemes at the individual level, where there is often the possibility of paying for the energy services, but not of anticipating the money for downpayments.

The solution to this problem relies on aggregating together many similar projects, so that the technical analysis is done once for all and transaction costs are sensibly reduced. Bundling these projects is also convenient from the technical point of view, as it allows to supply adequate answers to the problems of installation, operation, maintenance, availability of spare parts, etc. However, from the financial point of view, it is an absolute necessity.

Governments are not expected to provide financial services directly, but they can greatly facilitate the development of appropriate financial mechanisms by creating the right legislative environment, supplying guarantees, making the initial investment available for rotating funds, etc.

In India, the central government has set up a financing company, Indian Renewable Energy Development Agency (IREDA), which is exclusively devoted to development and financing of RE projects. IREDA has developed state-level institutional linkages with technical consultancy organisations in various states. IREDA provides soft loans and technical assistance to manufacturers, suppliers, financial intermediaries, and the actual users of RE systems. A programme on wind energy, small hydropower, and photovoltaic market development in India has been taken up by IREDA, with assistance from the

World Bank and other international agencies. IREDA has financed projects of about 625 MW capacity and sanctioned loans of about Rs14,000 million (US$400 million).

FINESSE (Financing Energy Services for Small-Scale Energy users) is a programme set up by the World Bank and UNDP with the help of some bilateral donors. It draws on the concepts of:

- bundling small projects into appropriate financing packages;
- incorporating them into national energy planning;
- selecting appropriate intermediary solutions; and
- providing technical assistance and training as needed.

Since 1991, these concepts have been applied to Indonesia, the Philippines, Malaysia, Thailand, and Sri Lanka.

SADC (Southern Africa Development Community) has applied, since 1996, the same concepts in Angola, Lesotho, Malawi, Namibia, South Africa, and Zimbabwe.

Where these methods have been applied, results have, in most cases, been encouraging. It is probably too early to draw any conclusion, but the impression shared by the majority of operators in this field is that the potential is greater than is generally assumed. The key factor is to involve and stimulate local business initiatives, so that the community can express its needs more easily. Aggregation of demand then becomes a powerful factor of cost reduction, both in terms of financing and in technical terms. When these terms can be addressed together (as, for instance, for the ESCO case), the results are probably easier to come home.

6.3.1.3. The Instrument of Voluntary Agreements

In the transition from top-down command and control mechanisms to economic participatory market mechanisms, the instrument of voluntary agreements (VAs) is meeting increasing favour and finding more frequent application in the fields of environment and energy policy. VAs in this sense are a relatively new instrument, which complements—rather than replaces—other instruments. Is is also especially potentially effective under two points of view: the implementation of objectives incorporated in existing policies (as concerns the definition of the ways to reach such objectives) and the definition of innovative policies (as an instrument for identifying and implementing new types of objectives).

The definition we adopt of VA is "an agreement between at least one public subject and one economic subject aimed at reaching objectives of public policies".[7] Formally, VAs are contracts, which may have a variety of forms, but which have some common characters:

- they are finalised to public interests, with objectives of improving the quality of environment, use of natural resources, quality of energy services, and other social objectives;
- there is at least one non-economic public entity and one economic, generally private, entity among the signatories; and
- for the public subject, the agreements constitute an instrument of environmental and energy policy.

VAs are the result of negotiations; the parties agree on the objectives and on the way to reach them; however, the most distinctive element of VAs, with respect to other voluntary instruments, is the voluntary exchange of engagements.

The economic subject(s) engage themselves to reach certain targets or implement certain standards which are *not* required by the present legislation; the public subject(s) take some corresponding engagement, which can range from a simple public recognition of the engagement of the enterprise to the destination of resources, implementation of normative and administrative measures that facilitate or expedite the action of the private parties, and realisation of particular infrastructures of interest to the economic parties.

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[7] *P. Amadei, E. Croci and G. Pesaro, 1998,* New Instruments of Environmental Policy: Voluntary Agreements*, Franco Angeli, Milano*

In the case of VAs, enterprises can introduce new schemes for the management of environmental and energy variables in the process of industrial production, assuming a direct and primary role in the direction of the innovation, which is to be based on its own technological, organisational, and market strategies.

In order to be effective, a VA needs to be controlled and monitored, so instruments to do that have to be clearly defined in the text of the agreement and implemented at an early stage. It has to be binding—it is voluntary in the sense that the parties have negotiated it and entered into it by their choice, but once it is signed, it is mandatory for the signatories. For this reason, sanctions have to be foreseen, if one of the parties does not fulfil its engagements. In the simplest case, the sanction may be that the other party does not comply with its own obligations, but other types of sanctions are possible. In some cases of large-scale VAs, the government may clear that, if the stated objectives is not reached by the implementation of the agreement, it has to fall back on some forms of command and control.

Voluntary agreements with environmental objectives, some regarding the energy sector, have been operating in many OECD countries. The Netherlands has been at the forefront of the adoption of such instruments in Europe. Chemical industries, the energy sector, and, later, the transport sector have had a major role. Among the specific topic considered are the reduction of waste production, its reuse and recycling, elimination of chlorofluorocarbons (CFCs), reduction of packaging, etc.

Evidence of VAs in the environment and energy sector is scarce for developing countries. There is no special reason why this instrument can not be as effective in developing countries as it appears to be in industrialised countries.

BOX 4. EXAMPLES OF VOLUNTARY AGREEMENTS

A scheme of voluntary agreement adopted or considered in several European countries involves Government on one side and manufacturers of appliances on the other, in order to promote the increase in energy efficiency of refrigerators and the elimination of CFCs from discarded refrigerators without release to the atmosphere. Manufacturers engage in improving the average efficiency of their product, according to an agreed schedule, and to take responsibility for the disposal of the old refrigerators, and the government facilitates this process by modulating value-added taxes, according to class of efficiency, and by supplying contributions for the controlled recycle or disposal of each old machine replaced by a high-efficiency model. Another well-studied VA in a province of France concerns the engagement of a large segment of industrial companies in the region to reduce the production and maximise recycling of wastes, while the government provides technical and financial support. In the United States, the "Green Light" initiative, started several years ago, now sees more than two thousand companies introducing high-efficiency lighting in all their areas, again with technical support from the government (the Environmental Protection Agency) in evaluating different alternatives. Another important initiative has been the agreement between the government and the three major auto producers for the development of zero or very low emission vehicles, by which the manufacturers have engaged in producing and commercialising such vehicles in a given time frame, and the government participates with very substantial funding to the R&D effort necessary to reach this goal.

The European Union has put out a recommendation to the member states that the instrument of VAs be used for environmental purposes whenever possible, and it has issued a number of guidelines for such agreements.

A voluntary agreement involving the government and the representative organisations of all economic and social parties has been the backbone of the new Italian sustainable energy policy formulated at the end of 1998. The basic agreement is a covenant, signed by the central and local governments, the associations representing industry commerce and other business, the workers' unions, associations of cooperatives and farmers, the banking system, environmental associationsm and consumers' representatives. The parties agree on a certain number of guidelines in the energy field (including international cooperation, opening of the energy markets, social cohesion, competitiveness, quality of the services, etc.), a certain number of specific environmental targets, and on the type of actions to be carried out to reach these targets. The agreement is actually a general framework, which is presently being articulated in sectoral and local agreements, which are much more specific and include verifiable objectves, monitoring mechanisms, and penalties.

Evidence of VAs in the environment and energy sector is scarce for developing countries. There is no special reason why this instrument can not be as effective in developing countires as it appears to be in industrialised countries.

6.3.2. Facilitating Sustainable Energy Initiatives in Rural Areas

As we have mentioned at the beginning, the recourse to market forces and private entrepreneurship must be adequately steered, so as to avoid the danger that socially important but economically less rewarding tasks are left behind. Particularly, this is the case for rural electrification and provision of energy for the poor. The main guideline to do this is by promoting and inducing independent and autonomous agencies at the local level, to pursue rural electrification and decentralised energy systems.

For a limited period, development assistance is generally needed to underwrite (by credit guarantees, etc.) obligations in the public interest (such as rural electrification) that are imposed on new (or newly-privatised) companies where these lose money. Governments must thus nurture a capable, motivated, and vigorous local sustainable energy sector, until it becomes self-sustaining. Actors include manufacturers of renewable energy and energy-efficiency equipment, assemblers, importers, distributors, retailers, equipment installers and operators, such as renewable-based independent power producers (IPP) and Energy Service Companies (ESCOs), energy managers, consultants for the industrial and commercial sectors, technical support service providers for small users of renewable energy technologies and energy efficient devices, and NGOs that help to implement these policies. Maintenance is important (including the procurement of spare parts) and needs up-front financing and aggregation of microprojects.

Several different approaches are possible, most relatively new and untested:

- **Public/private sector joint ventures:** Public utilities supply know-how and share financing, risk, and management functions with private sector enterprises. For instance, in Tanzania, the public utility Tanesco has worked with the town of Urambo to establish and operate a diesel-based electricity cooperative.[8] In India's West Bengal state, a local NGO, the Ramakrishna Mission, and the state Nodal Agency have come together to form the West Bengal Renewable Energy Development Association (WBREDA).
- **Energy Service Companies:** ESCO-based PV deliveries have been implemented in the Dominican Republic, Morocco, Indonesia, and Bolivia, and are currently being tested in Zambia. ESCOs own the equipment and are paid a monthly fee for the energy services provided. ESCOs are also active in the field of energy efficiency: a small grant GEF/World Bank project is now attempting to nurture the ESCO market in the Ivory Coast. Few, if any, ESCOs in the rural areas recover their cost; they depend on some form of grants. A grass-roots energy service company has been set up in Karnataka, India. Called the Solar Electric Light Company (SELCO), it has been successfully marketing and installing solar home systems and water pumps in several districts of the states of Karnataka and Andhra Pradesh, through innovative rural credit support schemes.[9]
- **Project-led capacity building:** Good project design can force private sector developers to build up comprehensive energy delivery services. A good example is supplied by the Regional Solar Pumping Programme of the European Commission in Sahel.
- **Community Associations and Cooperatives:** Cooperatives have played a major role in the rural electrification of the United States and in several European countries. This route is presently being actively pursued in Bangladesh. Community associations and cooperatives can greatly contribute to aggregate political voice, technical and managerial know-how, and financial credit-worthiness. They may also open the door to larger-scale solutions, such as minigrids and medium to large scale biomass production. Examples can be found in Morocco (where the management is supplied by an NGO), the Philippines (sponsored by

[8] *UNDP/CE DG-VIII, 1999,* Energy as a Tool for Sustainable Development for ACP countries, *Brussels*

[9] *See ref. S.S. Boparai, above*

the Asian Development Bank), and the state of Minas Gerais in Brazil (started by a concession funding by the government to a local company for the installation of photovoltaic systems in schools, etc.). In India, a group of farmers in Tamil Nadu have purchased and installed solar pumps with government support. In Cape Verde, a World Bank solar electrification and wind power loan is helping to lead the reform process by introducing the private provision of energy services in rural areas.

We have clearly indicated that the ability to provide modern energy services in rural areas and to the poorer strata of the population is, perhaps, the most critical test of the energy policy of developing countries. Liberalisation without the appropriate regulating instruments risks concentrating the attention of entrepreneurs where the task is easier and more rewarding—in cities and on the more affluent people. However, experience in facilitating market mechanisms to deal with the more difficult tasks has been positive so far. The examples are numerous, and many of them are cited in the preceding paragraphs on the types of instruments which have been tested. The ability of the rural population to spend money to utilise modern energy systems is higher than generally believed, if nothing else, because they are already spending excessive amounts of money for very inefficient systems like candles, kerosene lamps, or carrying batteries for recharging to the nearest city. The economic value of the productive activities that can be based on the availability of even small quantities of energy is also fairly high, and local people can readily appreciate that when they are given the correct information and the possibility of taking the initiative upon themselves.

6.3.3. Introducing Integrated Resource Planning and Demand-Side Management

Often, the more sustainable energy solutions are also the most convenient economically. These opportunities often are not captured, because of lack of information, institutional barriers, or lack of organisational structures needed to implement them.

One relevant example is the way in which utilities plan their investments. In the traditional utility of the industrialised countries, this planning proceeds in separate steps from power generation to transport and distribution. Assuming a certain growth of demand, the planning of the generation capacity to respond to it is carried out in steps of at least 100 MW each. The choice of the plants and of their siting is mostly determined by minimising the cost of this step. The following step is to design the enlargement of the transport system required to carry the electricity from the production to the consumption site, and this is optimised separately. The final step concerns distribution in a similar way.

Such a procedure does not allow taking into account the interactions among the different steps. For instance, small generators located close to the site of utilisation generally have a higher specific cost for generating electricity, but incur savings in the transport and distribution (e.g., transformers). The resulting distributed generation may well lead to lower overall costs than the planned centralised production. The way to evaluate this is readily available through the methods of Integrated Resource Planning (IRP),[10] which have already been adopted by a number of utilities in the last decade, and which are also being diffused in developing countries. For instance, a number of workshops on the subject have been organised in China, with a considerable measure of success, by the Working

[10] *D. Berry,* Least Cost Planning and Utility Regulation, *Public Utilities Fortnightly, March 17, 1988; Electric Power Research Institute,* Moving Toward Integrated Resource Planning: Understanding the Theory and Practice of Least Cost Planning and Demand-Side Management, *EPRI, Palo Alto, CA, EM-5065, February 1987; D. Bauer and J.H. Eto,* Future Directions: Integrated Resource Planning, *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, 1992*

Group on Energy Strategies and Technologies of the China Council for International Cooperation on Environment and Development. IRP is actually a much broader concept, and it applies to all types of energy systems, not only electricity. IRP takes into considerations the complete energy chain, including the extraction and collection of primary energy, its conversion into carriers suitable for transportation, distribution, and end use, as well as the provision of desired energy services. IRP also includes life cycle considerations, while traditional planning is generally limited to a relatively shorter time horizon.

IRP has proven to be an effective, powerful analytical method, providing useful answers whenever resources are limited. IRP analysis is based on the chain as a whole, and it must include the potential for efficiency improvement of all realistic supply and demand side alternatives. These alternatives are then ranked according to cost (including social and environmental costs), in order to find the true least-cost option. A prerequisite is a transparent and rational energy pricing system.

In some cases, utilities are required by regulations to employ IRP methods. IRP methods, however, can be applied to set priorities for investment to be cost-effective and establish performance standards for all energy-intensive investments, for instance, commercial buildings.

The next step derives from the consideration that it is often less expensive to use energy more efficiently, than to produce more energy to obtain the same service. From a societal point of view, it is convenient to put on the same footing the options of production and consumption, by comparing the marginal costs of increased generation and those of increased efficiency. The main barrier found in the past to the implementation of this principle was that the utility, which had the strictest relationship with the users, based its revenues on selling electricity and would not look favourably to schemes reducing such revenues. In some particular cases, utilities whose generating capacity was completely saturated had some benefits from reducing or delaying demand growth, because installing additional capacity would involve marginal costs higher than the tariff they could apply. In California, many utilities provided, free of cost, high-efficiency lights to their customers to obtain this goal.

The application of economically convenient measures to increase the efficiency of energy use is called Demand-Side Management (DSM).[11]

While, until the recent past, the main trend was to devise methods to require, or at least encourage utilities to offer DSM services to their clients, the present market approach to this sector indicates that a better solution may be to promote or stimulate the setting-up of specialised companies called Energy Service Companies (ESCOs). Although DSM originates with electricity, it is by no means limited to it. ESCOs offering services to reduce fuel consumption for space heating, for example, are relatively common in European countries.

Some cases of successful application of DSM come from developing countries. In Jamaica, for instance, the public electric utility has started a DSM project, sharing the costs and benefits of energy efficiency measures with the customer. SADC (Southern Africa Development Cooperation) Energy Management Programme targets low-cost and housekeeping industrial measures, through audit and training programmes for industry managers and technicians.

It is important to keep these considerations of IRP and DSM present, while designing the rules of the liberalised market, so that these rules encourage rather than discourage, energy efficiency and energy service companies. In some cases in the

[11] *E. Hirst and J. Reed (ed.s),* Handbook of Evaluation of Utility DSM Programs, *Oak Ridge National Laboratory, December 1991; C.W. Gellings and W.M. Smith,* Integrating Demand-Side Management into Utility Planning, *Proceedings of the IEEE, June 1989; Reddy, A.K.N., A. d'Sa, G. Sumithra, and P. Balachandra (1995). Integrated Energy Planning, Part I and II,* Energy for Sustainable Development *Volume II(3 and 4).*

past, the emphasis on cost reduction and competition among generators has monopolised the attention of the regulators and created some negative bias, which is presently being removed.

National agencies with responsibilities for energy saving (and often also for renewable energy) may have an important role in the diffusion and application of demand side management and energy efficiency. Such agencies, set up by governments, exist in most industrialised countries and in many developing countries. There are also regional associations of these national agencies, such as EnR in Europe and more recently (1997), MEDENER for the Mediterranean countries (including, on the South shore, Morocco, Algeria, Tunisia, Egypt, the Palestinian authority, and Lebanon). These associations are supporting joint programmes and technology transfer.

6.3.4. Additional Policy Considerations

6.3.4.1. Removing the Information Barrier

The "information barrier" works in two directions: toward the people and toward the government. Most people do not know what possibilities are offered by alternative energy sources and more efficient devices, not necessarily only those made possible by advanced technology, but also the equipment that has been on the market for some time somewhere else. People do not know they have different options in the energy field; they do not have adequate information on their performance, limitations, and costs. Therefore, they tend to maintain their traditional systems even when new, more convenient ones, are available.

In order to overcome this barrier, government can support promotional campaigns, based on good and objective information, so as to make people aware of sustainable energy alternatives, which also have economic and other advantages. The targets of these campaigns should be business, finance, and small-scale service sectors, as well as ordinary households. Examples of similar campaigns exist. For instance, in Morocco, the government, through the Centre for Renewable Energy Development (CDER), together with an NGO and with German technical cooperation, has launched an educational project on the options offered by renewable energy technology and their environmental aspects. Targeted in a first phase to about 550 students of secondary schools in a rural environment, the project is a means of reaching a larger strata of the population.

Demonstration is also needed; people are going to want to be shown the alternatives in actual operation, in the reality of the local environment, and are likely to imitate a neighbour who has acquired a more advanced energy system when this proves to be successful and profitable. Therefore, governments need to promote demonstration projects as a means to disseminate information, as part of a scheme to create the appropriate conditions for diffusion of sustainable energy systems carried on by market forces, and not as a repetitive intervention that replaces the spontaneous diffusion process.

The other type of information barrier is the insufficient base of knowledge available to governments and other decision-makers in the field of energy. Often, they have to make decisions in the absence of enough hard data. Much of what is missing is physical data, for instance, data relating to the availability of energy sources. While exploration for fossil fuels, although far from being complete and satisfactory, enjoys a well-recognised status and is actively being pursued and promoted in many countries, the evaluation of the reserves of renewable energy sources is mostly lacking. Solar (direct and indirect) radiation maps, time and space distribution of wind regimes, quantities of biomass residues available for energy production, potential for energy from forestry and for energy crops, geothermal anomalies that can lead to exploitation, and, where applicable, evaluation of opportunities for the utilisation of currents, tides, waves, and ocean thermal gradients are rare, occasional, and, when they exist, generally inadequate.

The lack of this information is likely to discourage programmes for the exploitation of renewable energy resources, which are generally underestimated. For instance, it is now common lore that wind charts are initially based, most of the time, on measurements taken at airports, but the sites for airports are generally chosen just where there is little wind. A recent detailed survey of the energy potential of biomass residues in China (carried out in the frame of a US-supported project) has shown possibilities much beyond what was commonly estimated before, and has indicated both the areas and types of residues on which attention should be concentrated.

Many other types of information are needed and very often do not exist. Even rather basic data is often not available, such as how much energy is consumed in a village or in a certain area, what type of energy, for what purposes, and at what prices (if commercial). Even less is known about what is necessary to assess a market's potential: how ready people are to pay for energy services, what their priorities are, who takes the decisions at the various levels (including the household) on the implementation of new energy schemes, and what the availability is of certain items on the market, etc.

For instance, a survey, conducted in Uganda on the priorities assigned by families to different energy services, showed a reality which was quite different from what was previously expected.

Market assessment for particular items of equipment is also useful before launching certain diffusion projects, and the private sector involved (often small-scale or informal business) does not always have the means and capability to carry it out.

A logical step beyond information is involvement. Rural energy projects have shown to have more possibilities of success, when participatory appraisal methods are included as integral parts of energy programmes and women are directly involved in the decision-making process. Community ownership and management, as well as partnerships with local and regional organisations and NGOs are essential.

6.3.4.2. Promoting Research and Development

A typical role of governments in the energy field, at least in industrialised countries, is to promote, support, and carry out research and development (R&D) activities. In these countries, the private sector contributes substantially (generally more than 50 percent) to financing and carrying out these activities. However, support is still needed from governments for a number of reasons. First of all, proprietary as the results of R&D may be, they are always, at least partially, shared by those who have not paid for the activity, and, therefore, constitute a common good. Secondly, and partly for the same reason, the private sector tends to concentrate on applied R&D close to production problems. Fundamental and basic R&D (which is often the motor of deep innovation and breakthroughs) is mostly left to government initiative, often through the universities, and long-term programmes are generally led by government institutions, as well as some of the larger-scale projects.

There is a fair amount of discussion, and possibly of disagreement, on how much and what type of R&D of developing countries need to support or carry out directly. In this context, consideration has to be given to the fact that the private sector is unlikely to contribute, at least financially, to R&D, in a measure comparable to that of industrialised countries.

Some think that R&D on advanced energy technologies is better left to industrialised countries. Others argue that concentrated high-level R&D, even of a rather basic type, is possible with limited financial effort in the field of sustainable energy, and this "centre of excellence" can give a developing country (or region) a much better understanding of the field and constitute a point of strength for cooperation in the application of the advanced technologies. One example which is frequently quoted is the very high quality of the results obtained in the field of agriculture by the Conssultative Group on International Agricultural Research (CGIAR) centres, most of which are located in developing countries.

Without entering into this debate, it must be noted that the situation varies greatly from one country to another. Developing countries with a tradition in basic sciences have already greatly contributed to the worldwide development of sustainable energy technologies. For instance, results obtained in China, India, and Brazil, among others, have been part of the foundation for important developments in photovoltaics and biomass utilisation.

However, there is also a huge scope and need for less basic R&D activities. Technology adaptation to meet local conditions is one example, i.e., how to make equipment more reliable, resistant to local environment, of lower cost, amenable to fabrication with local skills, instruments, and materials, adapted to the specific requirements and habits of the users, etc. All of these requirements are specific to a region, a country, or even a particular area, and the corresponding R&D has to be carried out locally. One example is the success in the development of two innovative types of cookstoves in Ethiopia, carried out by a team of local professionals (with the support of a British NGO). This has been carried out through a repeated assessment of needs, design, product trials, redesign, and performance monitoring. Cooperation with manufacturers, installers, merchants, and individual households has been the key to success.

R&D institutions strictly connected with local realities are also precious instruments of education, training, follow-up of projects, etc.

In India, the Ministry of Non-conventional Energy Sources (MNES) has set up the Solar Energy Centre (SEC) responsible for testing solar energy systems; it intends to become an autonomous body. MNES is also setting up new centres of excellence in renewable energy. The National Institute for Renewable Energy (NIRE) is being set up as an autonomous institution to deal with development, testing, and promotion of various renewable energy rechnologies. A separate Centre for Wind Energy Technologies is being set up.

Promoting Regional Cooperation

Every country can benefit from regional cooperation in the energy field. This is particularly true for small countries, or for the less developed ones.

The regional trade of energy is often a necessary condition to carry out large-scale projects, such as a hydroelectric plant. Interconnection among small electricity grids of neighbouring countries can allow new larger plants, but it can also allow a more rational and cost-effective utilisation of the plants which are already available and provide increased grid stability. Connecting the grid of Burkina Faso to that of Ghana or the Ivory Coast can avoid most of the use of low-efficiency diesel generators or oil-fired plants. Using untapped hydro resources in Nepal to supply electricity to India can be of mutual advantage. In general, large-scale hydro potential sites are located far away from consumption centres, and can often not be exploited without transnational interconnections and regional trade.

Exploitation of natural gas resources is another example. Transporting gas from deposits in one developing country, not only overseas to industrialised countries, but also to the neighbouring countries, may constitute a common ground for development, and allow further expansion in the use of a flexible, efficient, and clean fuel. The gas fields of Nigeria and of the Ivory Coast supply an example.

Countries of the same region often share the same climatic, geographic, environmental conditions, and cultural background. They may profit by putting together their efforts in R&D, adaptation of technologies, and experience in diffusion of sustainable energy system. Several regional research centres already exist, one example being the Regional Solar Energy Centre in Bamako, Mali.

Standards and norms often differ from one country to another in the same region, thus making exchanges difficult and reducing the single markets to uneconomical dimensions. Trivial examples, such as the bottles for LPG, show the importance of the relatively simple exercise in unification. By creating a greater market for energy products, however, one can stimulate the development of specific products of regional interest and create new opportunities for local business.

The case of the small developing island states is paradigmatic; their dimension is generally so small that, if left separate, they are unlikely to attract marketing effort, and the penalty on the scale-factor of many goods is severe. Only by putting together their efforts on a regional basis can they reach economic dimensions.

Similar considerations apply to the financial markets; here, too, the aggregation of the demand of several small countries can be the necessary condition for accessing investment capital at reasonable conditions.

Although regional and international cooperation can be started by private enterprises and NGOs, the initiative of governments is essential in this domain.

6.3.4.3. Capacity Building

Another barrier to the diffusion of sustainable energy systems, which governments can help to remove, is the lack of adequate skills. This weakness is well known and understood, and the efforts to overcome it by "capacity building" are already at the top of priorities for both governments of developing countries and for cooperation programmes in the energy and other fields.

However, the majority of the efforts of capacity building have concentrated on the technical aspects connected with the construction, assembling, and installation of the devices; less attention has perhaps been devoted to operation and, especially, to maintenance. Well-known are many cases of projects financed by donor agencies which, while technically and economically sound, have been unsuccessful or even counter-productive because they have been soon left abandoned for lack of appropriate maintenance, unavailability of spare parts, or even ignorance about operational procedures.

But what requires an even much greater effort in the future concerns the replication and diffusion of these projects. This necessitates not only technical, but other skills as well: market analysis (in order to identify and qualify the demand for energy services and energy devices), marketing capabilities, organisational and managerial capacities, and business training for would-be entrepreneurs.

Another area requiring capacity building is within the government itself. Energy policy analysis, energy economics, in addition to the necessary technical background, are required in order to evaluate, choose, and implement programmes both centrally and locally. Still more sophisticated training would be required for technology forecast (i.e. trying to identify which new technologies are going to be important in the future in a given context) and for technology assessment (i.e. evaluating all the consequences and implications of the introduction and diffusion of a new technology from the economic, social, environmental point of view, and, again, for the particular situation of a given country).

The aforementioned FINESSE programme has addressed the issues related to providing education and training in business management, project identification, and preparation of "bankable" project proposals.

Finally, it is important to train teachers, and especially those who are going to build capacities at the local level, such as training communities to operate and maintain equipment themselves.

Workshops for the private sector, aimed at providing training and basic technical assistance, have been organised, for instance, through the Pacific Regional Energy Programme (PREP).

6.4. CONCLUSIONS

As it may have become clear from all the preceding considerations, there is no unique or best way, applicable to every country and situation, to proceed in regulating the energy sector. Each country or group of countries in a region needs to find what instruments are more likely to have success in their particular conditions.

A few general conclusions can, however, be attempted.

Market instruments and stimulation of private initiative are too effective to be ignored in any circumstance. The important role of the government is to use these instruments so as to reach its goals of economic and social development, with special emphasis on providing modern energy services to the rural areas and to the poorer strata of the population, as well as to protect the environment.

One of the first steps towards the use of market-based instruments is to reduce or eliminate the subsidies which are given to various forms of energy (except in a transitional phase to compensate for market failures and accelerate the introduction of environmentally-friendly technologies), to let the market determine the prices through competition when this is feasible, and to introduce taxation that reflects at least a part of the externalities.

Liberalisation of the power sector (and, when applicable of the natural gas sector) needs to aim at allowing a number of independent producers to enter the market and compete. In particular, it should favour distributed generation, renewable sources of energy, high efficiency, combined heat, and power production. Privatisation may be under certain circumstances, an instrument for increasing managerial efficiency and competitiveness, but it ought not to be considered a goal in itself. High-level regulating authorities, essentially those independent from government and political powers, have proven to be a good solution, but the main guidelines of their ruling and the priorities of their objectives have to be set by governments.

Market rules in the energy sector should, in any case, put on an equal footing supply and demand of energy, and aim at increasing the efficiency of energy use through integrated resource planning and demand-side management.

Identifying barriers in legislation, norms of implementation, and diffusion of more sustainable energy systems is by no means simple, and needs to be done at various levels of governments. Private business, NGOs, and various types of associations can help in this analysis.

Special measures are advisable to facilitate the initial diffusion on the market of renewable energy technologies and advanced methods for energy efficiency; however, such measures have to be transparent, limited in time and possibly decreasing in a programmed way, and in no case should promote technologies that have no prospects of eventually competing in a free market.

Aggregating demand for financing is essential for the promotion of small interventions, which are prevalent for renewable energies and for efficiency improvement. The same aggregation is going to have positive results on technical issues, like installation, operation, maintenance, availability of spare parts, etc.

Several different options are available for facilitating sustainable energy initiatives at the local level and in rural environments. The ones which are most adapted to the particular conditions of a country need to be identified and selected. The involvement of local communities, as well as encouragement to small business, cooperatives and the like, is an essential condition for success. Collecting and providing correct and adequate information is of the greatest importance, while training and capacity building is required in both technical and non-technical domains.

Research and development should be encouraged, with emphasis on testing and adaptation of technologies, determination of standards, and contribution to training.

Regional cooperation is a positive asset, and, in some cases, it becomes an absolute necessity. It concerns free energy trading, exchange of experience, pooling of R&D, setting up of common standards and norms, etc.

In conclusion, institutional conditions, as derive from the actions of governments at all levels, are of great importance in determining the evolution of energy systems. An active, targeted initiative is necessary in order to direct this evolution in a more sustainable way.

It is important to devote more attention to projects aimed at creating an environment favourable to the diffusion of sustainable energy solutions by market forces and private initiative. Such projects may concern the identification and removal of institutional barriers, creation of local structures to supply energy services or market improved equipment both in urban and in rural areas, capacity building at all levels, etc.

Experimentation of innovative organisational, institutional, financial, or normative solutions is at least just as important as the testing of new technologies, and possibly more useful. More projects in this direction need to be encouraged.

7

ENABLING FRAMEWORKS
FOR SUSTAINABLE ENERGY

FINANCING FOR SUSTAINABLE ENERGY

7.1. FINANCING RENEWABLE ENERGY FOR SUSTAINABLE DEVELOPMENT

There is an unmistakable relationship between energy and sustainable development. While energy is not an end in itself, it is an essential tool to facilitate social and economic activities. Thus, the lack of available energy services correlates closely with many issues of sustainable development, such as poverty alleviation, advancement of women, and the environment. The creation of opportunities for people living in poverty to improve the level and quality of their energy services is going to allow them to enjoy both short-term and self-reinforcing long-term improvements in their standard of living and environmental quality.

Thus far, many efforts have been undertaken to increase provision of energy services for people in rural areas of developing countries. According to a World Bank report, grid-based rural electrification programmes have benefited about 800 million people over the last decades, whereas about 1.5 billion people still have no access to electricity. It is, however, generally recognised that the rural-urban disparity in access to modern energy services is likely to remain unchanged, if we continue to rely on grid-based conventional electrification, as the costs of grid extension to rural areas can be prohibitive.

There is a variety of different decentralised energy technologies that can serve to complement grid extension efforts. In many circumstances, in rural areas of developing countries, decentralised electrification can offer more cost-effective means to provide needed energy services. In particular, renewable energy-based decentralisation holds promising opportunities for its less adverse impact on environment and human health, as well as cost-effectiveness in a number of applications.

Nonetheless, renewable energy-based technologies are yet to gain wide market acceptance and face barriers against widespread diffusion. These barriers can be institutional, technical, and financial. On the financing side, there are two major barriers. The first and foremost barrier is the initial cost, which is higher, compared with conventional means. Although amortised costs over the life-time of the technologies are much less than those of conventional means, the initial cost barrier often effectively makes renewables out of reach for most users in the low/middle income bracket. Second, for villagers living in poverty, not only are modern energy services not affordable, they also compete with a host of other health, sanitation, and survival needs for a share of the household's resources. Unless the energy system can be used to alleviate poverty, it cannot compete with other, more urgent needs.

At the level of end users, availability of accessible financing is the key to overcoming the initial cost barriers. Affordability stands to be dramatically increased with credit facilities made available to the population. This is particularly important for people living in poverty, because they think primarily in terms of the first cost, rather than the life cycle cost, which ultimately results in lower energy prices and improved energy services. In order to bring the costs within the reach of many end users, it is necessary to spread the high initial costs over a period of time. For this to happen, certain financial arrangements need to be made and this is where microcredit can play a key role.

Microcredit is the provision of small amounts of credit to clients who are underserved by traditional, formal banking institutions, because of their lack of assets. To bring financial services to the poor, microfinance institutions (MFIs) have developed lending mechanisms that do not depend on the collateral, credit history and loan guarantees required by the formal banking sector. Microfinance is characterised by small loan amounts given for short-term working capital, repayment in small, frequent intervals, and a focus on women. In general, MFIs strive to attain sustainability through charging an interest rate sufficient to cover their costs. This is often higher than the commercial rate, but lower than the rates of alternative sources of credit available to their customers.

The term MFI is used in this document to refer to a range of formal and informal financial intermediaries that cater to clients underserved by traditional institutions. These include:

- microcredit banks, who offer primarily banking services;
- multifaceted non-governmental ogranisations (NGOs) which offer microcredit in addition to a number of other services which support micro-entrepreneurs and/or development objectives;
- village banks that give loans to all members of their village, for communal village projects, as well as individuals; and
- small and mini-credit banks which offer loans on a scale larger than microcredit, often requiring some forms of collateral and guarantees.

The obstacles to rural business development are familiar territory to microfinance institutions (MFIs) worldwide. In addition, experienced MFIs have found it beneficial to offer services, which bolster their client micro-enterprises through the enhancement of skills, marketing and supply channels or appropriate technologies. Through its ability to target income-generating enterprises, support the needs of entrepreneurs, and mobilise the finances of the rural population, microcredit may be able to play a crucial role in promoting productive uses of energy for sustainable economic development.

This briefing report is intended to provide an overview of the issues relating to design and implementation of financing schemes for renewable energy and their application for promoting productive uses of energy for income-generating purposes.

7.2.1. The Need for Rural Energy Services

In itself, energy is of little interest to most people. However, it is an essential ingredient of socio-economic development and economic growth. The objective of the energy system is to provide energy services necessary for all sectors of the economy (residential, commercial, service, industrial, construction, mining, agriculture, and so on). Energy services are the desired and useful products, processes, or services that result from the use of energy, for instance, illumination, comfortable indoor climate, refrigerated storage, transportation, appropriate temperatures for cooking, materials, etc.

Emphasis on energy services is particularly important in developing countries, where the current levels of energy services are low. With modern technologies, energy requirements often can be reduced, even while the levels of energy services provided are increased. One study[1] estimates that with wide adoption of modern energy carriers (i.e., electricity, liquid, and gaseous fuels) and the introduction of efficient energy conversion and end-use technologies, energy service levels equivalent to those in Western Europe in the mid-1970s can be realised in developing countries with primary energy requirements per capita just 20 percent higher than the actual level in 1990. Energy technologies that improve energy efficiency, reduce pollutant emissions, and reduce emissions of greenhouse gases can make significant contributions to sustainable development. The energy services for households, small business enterprises, and community services are varied and can be provided using any combination of energy options including electric power, thermal energy, liquid, and gaseous fuels.

7.2.2. Household Energy Needs

Household electrical energy needs commonly include lighting, ventilation, television, radio, and water supply. To meet their lighting needs, households often rely on candles, kerosene lamps or pumped gas lanterns. Dry cell batteries are commonly used for radios and flashlights. Wealthier households may charge 12 volt automobile batteries from grid-connected charging stations to power black and white televisions and even small fans. Cooking and water heating are primary household thermal loads, and these tasks are usually done using traditional fuels such as wood and dung. Gathering wood, dung or other biomass for cooking is a time-consuming and cumbersome process for rural households. The gathering process can comprise many hours of daily drudgery, particularly for women. In addition, the smoke from burning matter compromises the living quality of indoor spaces and may cause damage to the structure of the house. Wood gathering can be a cause of deforestation in some ecosystems. An illustrative example of the impact that increasing the level of energy services can have in a community is provided by the switch from kerosene wick-lamps to fluorescent tubelights that has taken place in Pura village in South India. When this was carried out, the energy input decreased to one-ninth, compared to the kerosene originally used. The household expenditure for lighting has been cut in half, despite the fact that illumination has increased by a factor of about 19 (Reddy, 1994).

7.2.3. Micro-Enterprise Energy Needs

Micro-enterprises often require greater energy inputs than households to run electric tools or machinery. Lighting for micro-enterprises increases working hours in workshops and small

[1] *Reported in* Energy for a Sustainable World, *J. Goldemberg, T.B.Johansson, A.K.N. Reddy, and R.H. Williams, (New Delhi: Wiley-Eastern, 1988) and in* Ambio, *"Basic Needs and Much More with One Kilowatt Per Capita", J. Goldemberg, T.B. Johansson, A.K.N. Reddy and R.H.Williams, Vol 14, No. 4-5 (1985).*

industries, as well as selling hours in shops or restaurants. Communications are useful to inquire about market conditions in a nearby city, or can be micro-enterprises in and of themselves. Motive power is needed for a number of machines including mills, lathes, and rice huskers. Refrigerators and freezers are used for cold drinks, fish, and produce preservation. Process heat assists a number of industries and is especially important in crop processing. Rural entrepreneurs that can afford them usually buy diesel-powered machinery. However, this option creates a dependence on diesel fuel, which is expensive and causes air pollution, immediately impacting the local inhabitants.

Erratic or limited service may be of particularly crucial importance for micro-enterprises that depend on electricity for their livelihood. For example, in Bangladesh, where the electric supply is erratic in both rural and urban areas, most of the independent tailors use manual sewing machines, even though electric ones are available and several times more efficient. In this case, the electric supply is not reliable enough.

7.2.4. Community Energy Needs

Community energy needs include health clinics, schools, street lighting, community and/or religious centres, and offices for local governments, non-governmental organisations, and financial institutions. Each of these community services has a matrix of needs, which depend on energy resources. The energy technologies and their application to the variety of rural needs are demonstrated in Table 1.

TABLE 1. SECTORAL APPLICATIONS OF RENEWABLE ENERGY TECHNOLOGY

	SECTORS					
TECHNOLOGY	DOMESTIC	SMALL BUSINESS	AGRI-CULTURE	HEALTH	COMMUNITY	OTHER
SOLAR ENERGY						
PV	●	●	●	●	●	●
solar thermal electric		●			●	●
solar water heating	●	●		●	●	●
solar cookers	●	●			●	
BIOMASS						
improved cookstoves	●					
briquetting	●	●				●
district heating					●	●
electricity generation						●
BIOGAS						
electricity generation	●	●		●	●	●
transport fuels		●				●
MICRO/SMALL HYDRO		●			●	●
WIND						
turbines	●	●		●	●	●
pumps	●		●	●	●	

Source: Gregory, J. et al., Financing Renewable Energy Projects, *IT Publications, UK, 1997.*

7.3. RENEWABLE ENERGY TECHNOLOGIES FOR RURAL ENERGY SERVICES

Renewable energy options tend to have high initial costs and low operating costs, compared to conventional technologies. There can also be a wide variation in the service provided by different renewable energy technologies. In addition, the quality of grid or diesel mini-grid service can vary. Remote reaches of electric grids are often the first to be shut off when generation capacity is overwhelmed. Likewise, diesel mini-grids often offer only 4-6 hours of service per day. For these reasons, quality of service needs to be taken into consideration when weighing electrification options.

Several renewable energy technologies (RETs) provide cost effective energy alternatives to grid extension or isolated diesel mini-grids in rural areas. This section outlines some of the most common electric and thermal renewable energy technologies, explaining their resource requirements, quality of service, typical costs, and relevant issues.

7.3.1. Renewable Energy for Electricity Generation

In comparing a range of options and applications for electric power, it is evident that each technology has a certain range of sizes and power outputs (Table 2 and Table 3). It is critical to accurately characterise the energy end uses, the current and projected power demands, and the costs, when making decisions for either the household or the village.

7.3.1.1. Small Photovoltaic (PV) and Wind Systems

Simple, robust, and modular, small PV and wind energy systems provide basic lighting, television, and radio service. These systems are often referred to as Solar Home Systems (SHS) or Wind Home Systems (WHS), but this label does a disservice to the many micro-enterprise and office applications of the electric service provided. Where the wind resource is above 5 m/s, wind home systems may be more economical than PV. PV works in a variety of climates, but is particularly efficient in areas with direct sunlight and few clouds. The system consists of a generator, either a PV panel or wind generator, a battery (usually 12 V deep cycle or automobile battery), and a charge controller. It is usually sized to power 2-4 fluorescent lights, a radio, and/or a black and white television for 3-5 hours per day. It can also be used for small motors such as fans, sewing machines and blenders, as well as small resistive loads, such as a soldering iron, and communications equipment to recharge cellular phones. The system provides direct current (DC) electricity. For alternating current (AC) applications, a small inverter may be used. The system is installed directly on the edifice in which the electricity is to be used. Because these systems are completely modular, they can be deployed independently to the customers that buy them. Systems usually cost between US$400-700, depending on the size and local conditions.

7.3.1.2. Wind/PV/Diesel Hybrid Systems

Community scale hybrid systems are able to offer 24-hour AC power, without grid extension. Consisting of a mix of generators including Wind, PV, and/or Diesel, these systems benefit from the local natural resource (solar or wind) and the reliable back-up of a diesel generator. These systems can be more cost effective than diesel-only mini-grids, particularly when fuel is expensive and difficult to transport. Moreover, these systems are cost-effective to operate all day long, unlike diesels, which are usually used 4-6 hours/day. Hybrid systems can be the center of a village mini-grid, or can power specific loads in a centralised area. Wind systems generally become more economical than PV panels at 4 m/s annual average wind speed. The availability of a wind resource study, preferably at least one year of may have an initial cost between US$10,000 for a 3 kW system and US$35,000 for a 10 kW system.

7.3.1.3. Micro-hydropower Plants

Micro-hydropower systems utilise a turbine to convert the energy of falling water to electrical power. Micro-hydropower systems require a falling stream or river that provides sufficient head and flow rate. The water resource may vary seasonally, due to water freezing, draught, or spring runoff. Micro-hydropower generators range from 200 W (enough for a few house-

data, is very important for estimating the power output of wind hybrid systems. A hybrid system holds) to 300 kW (a community mini-grid). The system provides a constant availability of AC electric power throughout the day. Thus, the more users that are involved, the cheaper the energy becomes per user. The natural resource, however, is the ultimate limiting factor of the available power. Thus, as energy consumption increases, the system can only be expanded a certain amount to meet the increased load. Micro-hydropower systems can be highly cost-competitive, where the resource is available. A typical 15 kW micro-hydropower system may cost between US$20,000 and US$30,000.

TABLE 2. ELECTRICAL APPLICATIONS OF RENEWABLE ENERGY

SYSTEM	CENTRALISED?	KEY ISSUES	TYPICAL SYSTEM SIZE	TYPICAL SYSTEM COST (US$)	# OF END-USERS SERVED
PV SOLAR HOME SYSTEM	**Totally decentralised**	**DC power, Limited energy/day**	**50 W**	**$400-700**	**1**
WIND/ DIESEL HYBRID	**Community centre or mini-grid**	**AC power, Energy usage per day limited by fuel usage**	**1.5-20 kW**	**$10,000-50,000**	**1-20**
MICRO-HYDROPOWER	**Community centre or mini-grid**	**AC power, Limited instantaneous power at all times**	**10-50 kW**	**$15,000-80,000**	**10-100**

TABLE 3. APPROPRIATE TECHNOLOGIES FOR A VARIETY OF POWER RANGES

CONTINUOUS POWER	1 W	10 W	100 W	1 kW	1O kW
Primary Cells	●	●	●	●	●
PV - battery		●		●	●
Wind - battery	●	●	●	●	●
Hydro-electric turbine	●	●		●	
Diesel Generator with battery	●				
Diesel Generator	●	●			●
Grid Extension				●	●

Source: Gregory, J, et al., Financing Renewable Energy Projects*, IT Publications, UK, 1997.*

7.3.2. Thermal Energy Sources

7.3.2.1. Biogas Digesters

Biogas digesters use an anaerobic process to extract methane from animal and/or human wastes. The methane can then be used for cooking and/or lighting. Biogas digesters can be implemented on a household or community level, although the household level is most common. Biogas digesters can be built from locally-available materials. A household-sized system may cost between US$300 and US$500. Such a system requires at least two cows, or one cow and an input from the household latrine.

7.3.2.2. Solar Cookers

Solar cookers utilise reflectors and heat-absorbing materials to focus the sun's energy as a cooking source. Solar cookers can be made from a variety of materials and in a wide range of designs. A household solar cooker may cost between US$15 and US$100. One of the cultural challenges of solar cookers is that they require the household to modify its cooking habits to accommodate a cooking process which is slower and more gradual than a wood or gas fire. Like photovoltaics, solar cookers are most appropriate in areas that have clear, direct sunlight, and will be less effective in cloudy areas or during rainy seasons.

7.3.2.3. Solar Thermal Water Heaters

Solar thermal water heaters collect the sun's energy to heat water. The technology uses flat-plate solar collectors to transfer heat to tubes through which the water passes. Simpler, less efficient technologies also exist and may be more economical in developing countries. As with all solar technologies, solar thermal water heaters are most effective in clear sunlight. Hot water can be useful in households, health clinics, or educational boarding facilities. In addition, hot water may enable many productive uses including tourism. Solar water heaters may cost between US$200 and US$500 for a single household, depending on the technology.

TABLE 4. THERMAL APPLICATIONS OF RENEWABLE ENERGY

SYSTEM	CENTRALISED?	KEY ISSUES	TYPICAL COST (US$)	NUMBER OF END USERS
SOLAR THERMAL WATER HEATER	**Decentralised**		**$200-500**	**One household or housing unit**
BIOGAS DIGESTER	**Decentralised or Centralised**	**Requires sufficient biomass inputs**	**$300-500**	**One household or housing unit (dormitory)**
SOLAR COOKER	**Decentralised**	**May require altered cooking practices**	**$15-100**	**One household**

7.4. MICROCREDIT SCHEMES FOR RENEWABLE ENERGY

7.4.1. Rationale for Microcredit

Most renewable energy technologies have higher initial costs than their conventional alternatives, although the life cycle cost may be much less. For example, small solar home systems have a purchase price greater than one year's income for many middle and lower-income households. Other technologies, such as solar cookers, may cost less, but appear costly compared to the traditional cooking methods.

While the wealthiest members of rural society are able to afford cash sales, the ability for the important in rural areas, where financing for energy services is largely unavailable. Rural financing is typically only available for agricultural inputs (agriculture banks) and industrial activities (development banks). Microcredit may be able to play a crucial role in facilitating the provision of energy services in rural areas, by providing small-scale loans to rural populations, with an emphasis on income-generating micro-enterprise activities.

Smaller loans, tailored to borrowers with limited ability to pay, are essential in making renewable energy systems affordable and available. Microcredit is an effective way to provide households and small businesses with access to capital, via

majority to gain access to energy services depends on the availability and terms of financing suited to those with moderate to low incomes. Availability of credit is particularly

loans that typically include flexible repayment schemes, fee schedules that match customer income streams, and longer loan repayment terms. Because of the high initial cost of renewable energy systems, loan terms need to be long enough to render the periodic payments affordable to the end user. In addition, downpayment for the loan must be a manageable amount, as this can be a major obstacle to households with little disposable income. Many potential customers do not have the cash on hand to be able to afford a high downpayment, even though they may have a monthly cashflow that allows them to be able to pay back a loan.

AFFORDABILITY OF ENERGY SERVICES

While many renewable energy technologies require a large initial investment, most traditional fuels require small frequent payments. For example, a user of kerosene may spend US$5 a month in US$1 increments. Payment is made both when cash is available and need is imminent. Such a user may see a US$5 fee per month as inordinate, and a US$60 yearly payment as absurd, even though they are spending the same amount over the course of a year.

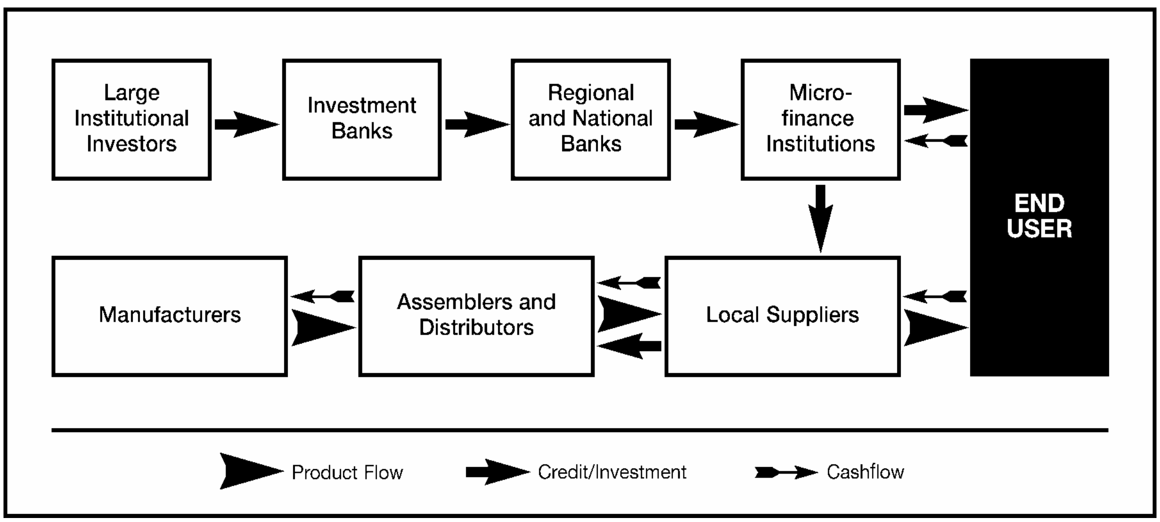
Efforts can be made to match payments for energy services from renewable energy systems to payments made for traditional fuels. One option is a centralised renewable energy battery charging station, in which the end user charges a battery on an as-needed basis. Some experiences have shown that this is a good “entry-level” energy service. The end users become accustomed to the quality of the energy service without modifying their payment habits. Then they move up to having their own household renewable energy system for little extra cost. Another innovation is “pre-pay” meters for renewable energy customers, which are being developed for applications in South Africa and Indonesia. This approach allows the end user to purchase an “electricity card” from a local vendor. They then insert the card in the meter in their home, which releases energy for the purchased number of hours. This type of infrastructure adds the price of the meter and associated services to the cost of the energy service.

7.4.2. Potential for Microcredit

The access to microcredit for financing the delivery of energy services surely depends on the availability of suitable financing mechanisms and institutions that are willing to provide capital. As the awareness of both microcredit and renewable energy technologies grows, financial institutions are going to be able to better channel capital into loans for energy services. Microfinance institutions may be in the unique position to be able to tap philanthropic, donor and government funds to access and leverage funds targeted at microfinance intermediaries, renewable energy providers, and rural electrification purveyors. Debt instruments can also be used in the form of on-lending from an upstream bank, renewable energy lines of credit, renewable energy funds, non- or limited recourse lending, and asset-based lending. Equity instruments for microcredit applications can potentially include joint ventures, individual investors, investment funds, green funds, or venture capital funds. Other mechanisms include risk mitigation measures, loan guarantees, and supplier credits.

A useful tool for understanding the role microfinance can play in providing energy services is a delivery chain analysis. Figure 1 shows the many players, from the financial services side to the renewable energy product side, involved in bringing energy services to the end users. This spectrum ranges from large institutional investors who are interested in investment-grade products with high rates of return, all the way to smaller financial intermediaries, such as microfinance institutions that may be able to work with smaller margins or leverage their funds with other types of funding. There are several entry points along the chain for investors, depending on the scale and focus of their investment. On the renewable energy product side, the energy services delivery chain includes the sales and support network, the equipment suppliers, and manufacturers. These two delivery chains are linked together, in order to provide the energy services to the end user, whose main concern is affordability, reliability, service, and expanded energy services. The primary linkage with the end user is through financial intermediaries (i.e., microfinance institutions) and local retailers, who both require capital in order to provide capital to end users. Microcredit is an important part of the chain, because it can be the most important factor in a successful on-the-ground project that is also sustainable. Working with non-government organisations, equipment suppliers, and microfinance institutions can be effective in reaching out to the rural areas, so that sales and support can be enhanced.

FIGURE 1. ENERGY SERVICES DELIVERY CHAIN



Source: Sustainable Energy Solutions, 1998 (adapted from Figure 3, Pocantico Paper No. 2, Selling Solar Financing: Solar Energy in the Developing World, *1996)*

There are a number of different modes of microfinance that can be considered for the end user. The type of financing depends on the size and type of the system, who is the owner of the system (e.g., individual or small utility), the income stream of the borrower, and the type of financial institution that is involved. A few types of common microfinance models are presented in the next section, as well as in the case studies.

7.5. FINANCING MODELS

7.5.1. Financing Directly for the End User

Providing loans for the purchase of renewable energy systems puts the ownership of the system directly in the hands of the end users, encouraging their responsible management of system care and maintenance. In this scenario, ownership transfers to the end user at the point of sale. The end user is bound to repay the loan, according to the guarantees and recourse measures stipulated in the loan contract. Financing to the end user can be issued by the renewable energy supplier, a financial intermediary, or a bank.

A renewable energy supplier may find it beneficial to provide financing to the end user to increase their sales potential. The supplier can finance this loan programme through supplier credits or a revolving credit fund capitalised by a third party, typically a bank. This arrangement has both advantages and disadvantages for the customer. As the vendor takes the risk as the final guarantor of the loan, he will usually seek customers who are clearly good credit risks. He may also require a high downpayment, as customers who have already made a substantial investment are less likely to default on later payments. In addition, the dealer typically charges an additional fee for managing the credit service. This increases the transaction cost of the financing, which is passed on to the customer.

All of the above procedures may limit the target population, excluding those individuals in lower/middle income level. These factors ill-position the commercial supplier to provide rural credit services; however, the benefits financing can endow on a supplier's sales volume may cause some suppliers to overcome these hurdles. The advantage of this system is that payments are made to the supplier directly. This motivates the supplier to ensure that the system performance is good, at least for the duration of the loan. Suppliers have a strong incentive to operate their business efficiently and, therefore, can provide far less cumbersome loan processing procedures.

Another approach is to utilise a financial intermediary to provide the end user financing. This can potentially be a local microfinance institution or an non-governmental organisation (NGO) that operates revolving loan funds. In this case, when the renewable energy supplier finds a potential customer, he brings him/her to the MFI to process the loan. The MFI then provides a loan, which can be accounted as a cash sale by the supplier. This improves the supplier's cash-flow, and thus, the likelihood that the supplier is able to stay in business. The customer then has the responsibility to repay the loan according to the loan terms set out by the MFI. These practices may include an initial training session, participation in a solidarity group, weekly meetings, or other practices which bolster the repayment capacity of rural MFIs. Many of these have been described in the previous section entitled "Potential for Microcredit".

An example of a third party approach (i.e., using a financial intermediary) is given in the case study on ITDG Peru's fund for micro-hydropower. In this case, ITDG, an NGO, takes on the technical responsibilities assigned to the supplier in this section. It finds the potential customer and does the technical design of the system. ITDG also does much of the loan application processing itself, passing on the approved loan form to the Inter-American Development Bank, which has capitalised the fund. When the loan is approved, ITDG plays an integral role in the construction and implementation of micro-hydropower system. For additional details on this project, see Case Study #4 at the end of this chapter.

The third-party approach allows each of the participating organisations to concentrate on the activity in which it specialises. In addition to the technical capabilities of the system supplier, it benefits from the rural finance capacity of the MFI, including its rural banking network, client base, field staff, rural finance expertise, and access to financing resources, among others. Whereas many renewable energy rural electrification programmes have had difficulty in the cost-recovery phase of their programme, the third party financing scheme relies on an established microfinance institution. By taking advantage of well-established micro-credit practices, which have been developed to target the issues of income generation and risk mitigation in poor rural communities the micro-finance-led approach can, hopefully, side-step the cost recovery problems that past renewable energy programmes have encountered.

DEDICATED FINANCING: THE RENEWABLE ENERGY AND ENERGY EFFICIENCY FUND

The Renewable Energy and Energy Efficiency Fund (REEF) is a specialised fund of the International Finance Corporation (IFC), focused on investment in private sector projects in the renewable energy and energy efficiency sectors in emerging markets. The fund is targeted to be capitalised by the Global Environment Facility (US$30 million), IFC, and a group of large investors (US$210 million) which stand to be able to leverage projects with total costs of US$300-800 million. REEF consists of an equity fund with capitalisation of US$110 million and a debt facility with a loan portfolio of US$100 million. The GEF funds are intended to be used for grants to finance incremental costs and/or mitigate risks of investing in projects that may not be acceptable to commercial investment funds, because of their inadequate risk-adjusted rate of return. One of the challenges for the REEF is securing a significant amount of external funding from the project sponsor. It is planned for REEF to invest its resources over a five-year time period and to liquidate the portfolio 10-13 years after the first closing date.

The primary objective of the REEF is to generate a competitive rate of return from diversified equity and debt portfolios, containing renewable energy and energy efficiency investments. REEF will never serve as the principal investor on a project, investing only in projects when the sponsor holds a significant financial stake. The underlying goal of the REEF is that it is to catalyse further investment in these types of projects by increasing awareness about the technologies and project structures that have been proven in the market, supporting new types of projects, and developing and accessing new sources of commercial financing.

Because the IFC sees the possibility of rapid expansion of the renewable energy and energy efficiency markets in developing countries, they have targeted the REEF at on-grid and off-grid renewable energy projects and energy efficiency businesses. This is to be done by making investments in:

- **grid-connected renewable energy power projects;**
- **small-scale off-grid power systems that use renewable energy technologies (e.g., small distributed mini-grids);**
- **energy service companies and individual end users that invest in energy efficiency technologies; and**
- **local manufacturing companies and financial intermediaries involved in the renewable energy and energy efficiency sector.**

Both the debt and equity components of the REEF are able to invest primarily in projects with total costs less than US$50 million. However, the equity fund seeks to allocate at least 20% of its resources to smaller projects (less than US$5 million). In order to ensure a balanced portfolio, the REEF guidelines specify that neither the equity fund, nor the debt facility, is to invest more than 80% of its funds in one of the three target themes (e.g., on-grid renewables, off-grid renewables, and energy efficiency). In terms of geographic focus, the guidelines also specify that not more than 60% of the funds can go to one particular region. The regions are defined as Asia, Latin America and the Caribbean, Africa and the Middle East, Central and Eastern Europe, and the Newly Independent States.

All countries that are eligible for GEF funds will be able to submit proposals to REEF. The intended recipients of REEF financing are private sector renewable energy and energy efficiency project developers, energy service companies, independent power producers, energy end-users, and financial intermediaries.

However, the added expertise of a third party carries a disadvantage. As the holder of the loan agreement, the MFI takes the risk for non-repayment. If the system experiences a technical failure, the MFI, rather than the equipment supplier, suffers the consequence. The supplier has an incentive to provide service, in order to maintain its reputation; however, the risk of non-repayment remains with the MFI. Such risk inequity can be mitigated through service agreements and contractual relationships between the supplier and the MFI.

Finance for purchase of RETs is the most widespread of the financing modalities discussed in this section. Because of its simplicity, it is likely to continue to be employed in new programmes. However, it suffers from shortcomings, such as the relatively weak link between system provision and maintenance, the relatively steep credit terms, and its reliance on distributed rather than centralised systems. These weaknesses encourage further development of the other modalities in future programs.

7.5.2. Leasing

For long-term loans, some programmes implement a leasing contract, in which the RET remains the property of the lease agent, until the full cost of the system is repaid. A lease agent may be an MFI, an NGO, a renewable energy equipment supplier, a utility, or a cooperative. Leasing mitigates risk and can enable the program to provide more lenient credit terms to the end user. The end user is able to make small, regular payments, until the system is repaid. At that time, ownership of the system passes to the end user.

Self-collateral does not always work. In regulatory environments, where the right to repossess property is not enforced, the contract specifying ownership of the system is worthless, and the possessor of the system may keep it, whether he has paid or not. In some political climates, repossession may adversely impact a lender's reputation by portraying them as unsympathetic to the poor. Where self-collateral is not effective, other risk mitigation mechanisms can be implemented, such as peer-group based social collateral.

Leasing creates a strong incentive for the lease agent to maintain the system, while the customer is still paying off the lease. Thus, end users benefit from increased system reliability. However, a lease contract does not always include a service contract, and many leases will stipulate specific repair and maintenance activities that are the responsibility of the end user. In the case of a renewable energy supplier who is providing the lease, a service contract can be a straightforward component of the lease. However, if a small or mini-credit provider is providing the lease, it is unlikely that they will have the resources to provide a service contract, unless it is contracted through a third party.

Leasing is common among many small and mini-credit providers. It is often used in developing countries as a lending mechanism for agricultural machinery and small business equipment. Because of its prevalence among small and mini-credit providers, leasing may be an acceptable modality for introducing RETs into the existing loan portfolios of these financial intermediaries. In countries where the laws regulating repayment of loans are not strong, the lease arrangement offers a secondary assurance of redress in case of non-payment. Moreover, in a regulatory environment, where there are other lease arrangements already in place, the contractual legitimacy of RET leases should be equally straightforward.

offers the advantage of leveraging the self-collateral of the RETs that have them. (Solar and wind home systems, hybrid systems, and some solar cookers and crop dryers have self-collateral; micro-hydropower systems and biogas digesters are essentially based on civil works and cannot be used as self-collateral.) If the end user fails to provide the loan repayments, the lease agent has the option to repossess the system. Self-collateral, as any other form of collateral,

Leasing programs are often able to offer more lenient credit terms than purchase programmes because of their ability to utilise the self-collateral of renewable energy systems. In addition, they may have a larger scale programme than entities that sell for purchase only, and, therefore, may be able to take advantage of bulk discounts.

Like purchase arrangements, lease programmes are limited to decentralised technologies. In addition, they often do not have as low a monthly fee as service programmes. They are essentially a centre-ground, sharing the advantages and disadvantages of the purchasing and fee-for-service modalities. Like finance-for-purchase, lease programmes are also widespread. Many of the programmes, which appear to be finance-for-purchase programmes, are actually leases. They include a contractual clause, which transfers system ownership only after the final payment has been received. This is the case with the Grameen Shakti loan programme, which is described in the case studies.

7.5.3. Fee-for-Service Using Energy

Service Companies (ESCOs)

Energy service companies, or ESCOs, provide energy services rather than equipment sales. An ESCO can utilise either centralised or decentralised RETs, but the most common usage of the term is for decentralised technologies that are installed at the end user's location. An ESCO may be a private company, a cooperative, a utility, or an NGO. The defining characteristic of methods. In addition, an ESCO may be able to aggregate demand, leading to favourable financing terms. However, this model requires that maintenance, repair, and component replacement be incorporated into the regular payment. These costs are not always included in the other two modalities and may be left to the customer.

The ESCO model benefits the end user by eliminating both the financial and technical risk to the end user, transferring them to the ESCO. The end users never have to fear that their entire investment is going to be lost, if the system breaks down, or that they are going to be faced with large payments for repairs or maintenance in the future. The end user pays for this advantage through slightly higher regular payments. As the ESCO model provides little incentive for the end user to conduct proper care and maintenance of the system, the lifetime of the system may be shortened, another cost which the ESCO has to pass on to the end user. However, the ESCO can provide the maintenance necessary to ensure that its equipment remains in good condition, in case it ever needs to re-deploy the system to another end-user.

The ESCO model depends on the existence of a service network that can collect payments and provide service in all of the areas that the ESCO operates. Developing such a network economically requires building sufficient economy of scale. Very few renewable energy programmes have been able to develop the scale necessary to implement a sustainable ESCO, although pioneering efforts are taking place in the Dominican Republic, Honduras, and Sri Lanka. The model from the Dominican Republic is presented in the case studies.

the ESCO model is that the ESCO retains ownership of the renewable energy system indefinitely. In addition, ESCOs take responsibility for all maintenance, repair, and replacement tasks. The end-user pays the ESCO on a fee-for-service basis.

The ESCO can establish the fees such that equipment costs are recovered over the whole lifetime of the equipment. This can lead to lower regular payments than with the other While the ESCO model has many advantages, the scale that it requires and the inherent inefficiencies it takes on to provide uninterrupted service remain obstacles to its implementation.

7.5.4. Concessions for Renewable Energy Development

Resource development concessions have been used by the oil and gas industry over the last several years to explore and develop new projects. The concept involves the government delineating a region for prospective resource development. Then, exploration and development rights are bid upon by interested parties. Concessions can be a way to achieve economies of scale and offset transaction costs associated with purchasing individual renewable energy systems. Resource concessions for rural energy development have already been initiated in Argentina, and there is a wind resource concession programme being developed in China.

The Argentine government has initiated a programme with the provincial government to develop rural energy systems, using a concession approach. The programme gives priority to photovoltaic panels, small windmills, micro-hydro power, and diesel-driven generators. Through this programme, competitive concessions with exclusive development rights in a delineated region are granted to one or more private sector enterprises, on the basis of the lowest subsidy required per supplied user, technical qualifications, and financial qualifications.[2] In exchange, the supplier must meet

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[2] *Kozloff, K., "Electricity Sector Reform in Developing Countries: Implications for Renewable Energy",* Renewable Energy Policy Project Research Report, *Number 2, March, (1998).*

certain requirements of the provincial government. The types of business entities that participate in the concessions are established utilities elsewhere that are seeking entry into the rural markets.

Granting concessions as a way of developing large, high-quality wind resources in remote areas is being considered in China.[3] The plan is to develop a wind resource with very large wind farms (greater than 50-100 MW) and transmit the power over long distances. By focusing on large-scale wind power development, the government hopes to attract large companies to the project and encourage joint ventures with local companies. The concept involves the government granting

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[3] *See Brennand, T.,* Concessions for Windfarms: A New Approach to Wind Energy Development, *Report prepared for the Working Group on Energy Strategies and Technologies of the China Council for International Cooperation on Environment and Development, Beijing China, August, (1997) and Reddy, A.K.N., R.H. Williams, and T.B. Johansson*, Energy After Rio: Prospects and Challenges, *United Nations Development Programme, (1997).*

concessions to companies for the exploration and development of wind resources in a selected area, over a certain period of time. The concessions are to be issued through a competitive process (e.g., bidding), and the government is to be responsible for enforcing the regulations, ensuring the issuance of long-term power purchase agreements, managing the payment of royalties, and establishing the specifications for technology transfer. Because the project developer assumes all of the risk in evaluating and developing the concession, the government mitigates its risk and also receives the benefits associated with attracting new industries to remote areas and eventually lowering costs because of the economies of scale for large wind turbines. In order for this to succeed, the government has to ensure transparency in the negotiation process, so that competition is enhanced and the financial risks to the project developer are minimised.

Concessions are an emerging opportunity to develop rural areas with renewable energy systems, using primarily private sector capital. The commitment of the government to clearly define and enforce the rules and regulations of the concession is an assurance to the project developer or investor that the business environment remains stable and equitable. The private sector is likely to be able to attract financing because of these assurances and the large-scale size of the project stands to help offset transaction costs. By promoting a true private sector approach, rural areas can be developed in a cost-effective and profitable manner.

7.5.5. Fee-for-Service Using Micro-Enterprise Zones

One novel approach that can offer fee-for-service energy services from a centralised facility is a Micro-Enterprise Zone (MEZ). An MEZ might be a single building or a cluster of buildings that are provided energy services from a centralised power source. The zone may even have a small mini-grid serving outlying customers. An MEZ may be operated by an MFI, an NGO, or a cooperative. The operator invites micro-enterprises to establish themselves in the facility, where they can access the electricity on a fee-for-service basis.

The centralised approach lends itself to a variety of business support activities, such as micro-enterprise assistance, banking, and a quality, stable working environment. Which services the MEZ provides may depend on the nature and capability of the operating organisation. For example, an MFI that develops an MEZ may offer credit to the entrepreneurs in the facility for working capital for their businesses or for electrical tools and machines.

A centralised facility may have cost advantages with technologies that have efficiencies of scale such as micro-hydro power or wind technology. While these technologies require a large investment that few rural customers can take on, they provide cost-effective service when the cost is spread over a large number of end users. In addition, maintenance and fee collection are centralised in one place, enabling more efficient provision of these services.

In the MEZ approach, the operating organisation maintains ownership of the system. The operator may be able to access favourable credit terms because the MEZ is a large investment, and the operator is likely to have a better credit rating than a single villager. These financing benefits are then passed on, in the form of lower fees, to the MEZ beneficiaries.

It is important to note that this concept is not proven in the field, since few micro-enterprise zones have been implemented to date. The large investment required, the more complex community institutional structure, and the sophisticated technology requirements are all barriers. However, the fact that MEZs can take advantage of economies of scale, and offer very low regular payments suggests that MEZs may be an option.

7.5.6. Internal Barriers to Renewable Energy Financing

In many ways, energy system financing demands a departure from the tried-and-true methods of microfinance. MFIs may be understandably reluctant or unable to make the modifications to their loan programmes that are needed for energy system financing. On the other hand, if this barrier can be overcome, energy system financing may be an opportunity to make MFIs more viable and more sustainable.

Loan Size: When the energy system price is larger than a typical loan size, difficulties may ensue. Larger loans mean higher interest rates and lower transaction costs. However, bank staff may feel constrained in finding members with a long enough history to recommend such a large loan. MFIs with limited access to up-stream financing may refrain from making large loans in favour of reaching more people through smaller loans. Many MFIs lend for short loan terms, often less than a year. When loan amounts are large, longer term financing may be the only way to bring payments within the reach of end users.

Target Market: The size of the loan also defines a certain target market. If the loan is much larger than a typical loan, then, perhaps, a different strata of the population may be interested in that item. The MFI has to decide if it is going to lend only to its members, or if it can expand its programme to serve the entire community.

Fixed Asset Lending: MFIs typically lend specifically for working capital. In some cases, a RET is a fixed asset for an income-generating business. In other cases, it is a quality of life improvement that offsets other energy expenditure. In either case, it is rare that the RE system leads to a direct and steady generation of income typical with an MFI loan. For this reason, the loans may appear to have higher risk than typical loans.

7.6. WHAT MAKES FINANCING WORK

The success of any financing approach for renewable energy depends on the degree to which it meets and completes several key tasks, including finding sustainable financing mechanisms, making strategic alliances, reducing transaction costs, and minimising risks.

Microfinance institutions can make themselves better candidates for financing by developing a strong business plan, offering suitable collateral or guarantees, and collecting data on pilot programme experience. Early data on repayment and default rates, willingness and ability to pay, and transaction costs can enable the financier to most accurately judge the risk involved in the project. When such data is not available, the financier has no choice but to assume maximum risk for the project, resulting in unacceptable credit terms and/or basic unwillingness to lend at all.

7.6.1. Institutional Conditions for Microcredit

In order for microcredit to be a viable option, it is necessary that policies be credible, that there be an appropriate legal infrastructure and enforcement mechanisms. The latter need to ensure practical lending and repayment measures, remove policy biases and hidden subsidies that cause market distortions, and establish integrated and efficient financial markets that put credit with the reach of the rural population. Governments can work to strengthen the rural markets and implement reforms that improve the overall business environment.

Rural energy programmes, whether they offer sales or services, depend on the viability of the contracts that support them. This can only be possible if there is transparency, accountability, and risk-bearing capacity in the government. In addition, strategic alliances are bolstered by the legal bonds between the partners. In environments where corruption or bureaucracy reduces the effectiveness of legal contracts, such programmes cannot flourish. Likewise, overly restrictive credit laws and regulations can make such programs inefficient, or impossible to implement.

Rural users base their energy choices on the information they have about their electrification status. The main questions they have are: "Where is the grid going? And when will it get to me?" When politicians promise near-term electrification, naturally, residents are hesitant to invest in an energy system that they view as a short-term solution. Governments need to set out clear guidance about their electrification plans in order to support markets for renewable energy options. Secondly, markets can be distorted by well-meaning aid programmes that provide renewable energy technologies at a subsidised price. The intent may be to promote renewable energy systems, but the effect of these programmes stands to undermine the existing local energy market players who provide services at market rates.

7.6.2. Forming Strategic Alliances

The challenge of meeting remote rural needs with non-traditional energy technologies, in an economically sustainable way requires diverse skills and organisations. Forming strategic alliances is a means by which organisations with complementary capabilities can combine their strengths to meet the challenge. In the case of MFI intermediaries in the energy services delivery chain, a technology supplier, designer, or manufacturer is the most likely choice in forming a strategic alliance. Some issues to consider in the creation of strategic alliances follow.

- Do the partners have similar priorities and goals? For example, if an MFI, working primarily with extremely poor populations, is looking for energy services that target its clientele, can it be happy with a supplier that focuses on a more affluent target market? Will the supplier feel limited by an MFI that is only able to serve a portion of its target market?
- What checks and balances regulate the partners responsibilities? If the supplier fails to provide sufficient follow up service, will the customer respond by not repaying the MFI? Likewise, if the supplier is expected to be the main promoter of the RET, what happens if she/he ceases to promote the product? Is the MFI able to do the promotion, or is the fund going to stagnate?
- One of the strengths of a strategic alliance is that the reputations of both the MFI and the partner guarantee the quality of the final product to the end user. Is there sufficient trust between the two organisations to risk the brand equity of either organisation? The biogas support program in Nepal described in the case studies provides end user financing for biogas digesters, but only for systems supplied by licensed providers who adhere to a stringent set of regulations for the digester construction.
- Are both organisations equally apt at reducing costs? Many MFIs have earned their success through their ability to cut the cost of providing rural services. If the partner has less ability to cut these costs, then the contribution of overhead to product cost may seem inordinate to the MFI. The MFI may decide to take over the role of rural service provision or to cut out the partner alltogether. Conversely, rural-based suppliers have found the interest charged by rural consumer credit organisations to be excessive, leading to non-viable institutional partnerships.

7.6.3. Reducing Transaction Costs

One of the key barriers to affordability is the impact transaction costs have on energy system prices. Transaction costs are the costs incurred when buying or selling assets. These include costs that are not specified between buyers and sellers, because of incomplete contracting or deliberate opportunism by either or both parties. They also include costs of transportation, installation, financing, etc., which may be anticipated by both parties, but nevertheless raise the price and act as barriers to market growth. Transaction costs increase the price of renewable energy technologies at all stages of the delivery chain. As long as programmes providing renewable energy to rural customers remain small, disbursed transaction costs stand to keep the price high. Transaction costs are caused by the following.

- Remote maintenance and repair infrastructures are essential to ensure that quality of service is maintained, but are unsustainable before a critical mass of customers is reached.
- Rural sales, marketing and installation processes are time-consuming and resource-intensive.
- Bulk purchasing reduces unit costs and economises shipping expenses. Likewise, transportation, importation costs, sales, and financing activities are time-consuming and resource-intensive. The inefficiency of these steps contributes to the existing high price of renewable energy technologies in rural areas.
- End user financing done on a piece-meal basis can be difficult and bureaucratic for the financial intermediary. Staff that is experienced and accustomed to energy system loans can provide more streamlined financial services.
- Upstream financing is often only available for large-scale projects. Donors and multilateral development banks may be interested in financing credit for rural energy, but are unable to finance a large number of tiny programmes independently.

Reducing transaction costs lowers the price of the energy system to the end user, thus expanding the market and increasing the impact of the program. Ways that MFIs can lower transaction costs include achieving economies of scale, simplifying transactions, and externalising costs.

7.6.4. Achieving Efficiencies of Scale

Achieving the scale required to significantly reduce transaction costs is not easy. Indeed, the success of rural energy programmes depends on the transaction between villager and rural supplier, which happens on a necessarily very small scale. Often times, the organisations that excel at this relationship are themselves small, local, and have limited budgets. Large organisations, such as the Grameen Bank in Bangladesh, have had success "ramping up" by starting with a small pilot programme and then expanding it. Such an approach may be successful with MFIs that have scaled up their lending programme in a similar manner. In other cases, "bundling" loans may be an effective way of providing capital to several programmes in one step. By creating a loan fund that can be accessed by a variety of providers, large donors or multilateral lenders can channel funds for renewable energy, without undergoing the time-consuming and costly process of closing loans with each individual institution.

7.6.5. Simplification

Simplification can occur in both the technical and financial programme areas. By creating quality robust energy systems that are not prone to frequent repair and maintenance and do not rely on difficult to find replacement parts, system designers can reduce the requirements and cost of repair and maintenance infrastructure. Certainly, a repair infrastructure is a prerequisite for success in any technology dissemination process. Yet, if the number of household visits a technician makes is reduced from 10 to 2 per year, the cost savings are significant, particularly if that household requires a full day of travel to reach. Just as importantly, streamlining financial transactions can reduce financial overheads. Long and complex forms and agreements can often be simplified to make the loan process shorter, without sacrificing essential information.

7.6.6. Externalising Costs

Programme managers worldwide have found clever ways to assign externally the costs that inflate overhead expenditure. Cost externalisation can take place in all arenas of programme operation including financing, sales, and repair. For example, an MFI that provides financing for an RET, which is provided by a local supplier, can have the supplier pre-screen the applicant for the loan and even fill out the application. Renewable energy dissemination programmes in West Bengal, India, pay independent promoters a small commission for recommending their renewable energy systems to prospective buyers. In addition, these promoters are trained in basic repair and maintenance of the energy systems. The end users pay these technicians on a per-service basis, thus alleviating the burden of follow-up repair on the supplier and providing quicker, more convenient service to the customer.

7.6.7. Removing Market Distortions

While the ability to pay for energy service relates the energy cost of service to the income of the customer, willingness to pay depends on the perceived affordability of the item compared to other available options. Market distortions can make least-cost energy options appear to be less affordable than other options. For example, in Indonesia, the perceived low cost of diesel generators, due to government subsidies on diesel fuel, leads villagers to strongly prefer that rural electrification option. Few villagers are aware of the real costs of electrification. A recent World Bank study of six rural electrification programmes has found that each charges consumers less than the full economic cost. In Maharashtra, India, for example, end users pay only 9 percent of the real cost of electric service.[2] While such policies may stem from a humanitarian motive, they have the unfortunate impact of devaluing the economic virtues of renewable energy alternatives.

Some renewable energy technologies rely on imported components. Protective import tariffs designed to encourage local manufacture or protect local industries may drive prices up. As markets grow, increased in-country manufacturing certainly becomes an option, through joint ventures and other partnerships. However, such ventures are likely to remain limited until rural energy markets mature. In the meantime, these tariffs and duties on renewable energy equipment have the effect of driving up the cost of basic energy services to the poorest members of society. More prescient trade and energy policies can potentially direct national resources towards rural electrification, without bias towards a single rural electrification technology.

7.6.8. Minimising Risk

To date, MFIs have proceeded with enthusiasm, but also caution, as they have entered the role of financing energy services. MFIs face several risks from energy programs including:

- technical failure;
- end user dissatisfaction;
- end user non-repayment;
- end user non-interest due to high cost; and
- unexpectedly high overhead costs.

While all of these risks need to be weighed, perhaps the one that is most daunting is the possibility of end user non-repayment. Customer credit history, loan guarantees, and the use of collateral (both asset-based and social) are all measures with which MFIs are familiar to ensure repayment. For energy system financing, several factors compound the challenge of repayment.

7.6.9. Guaranteeing End User Satisfaction

A primary cause of end user non-repayment is dissatisfaction with the energy service. The quality of service provided by the energy technology needs to be clearly explained to the end user, before the sale or service contract is closed. In addition, the supplier/strategic ally should have a good record of end user training and service.

2 *Cabraal, A et al.* Best Practices for Photovoltaic House-hold Electrification Programs, *The World Bank, Washington DC, 1996.*

7.6.10. Customising Repayment Terms

Many villagers that depend on agriculture or other seasonal activities for their livelihood generate income in yearly or seasonal cycles. In addition, the energy may be needed more urgently in certain times of the year (for irrigation, for example). Where this is the case, customising repayment schedules to coincide with seasonal income and usage cycles can make it easier for customers to afford the energy service.

7.7. CASE STUDIES

Case Study #1: Bangladesh: Grameen Shakti End User Financing for Small PV Systems

Recognising the need for electricity from its client micro-entrepreneurs, the Grameen Bank embarked on a renewable energy initiative in 1996, by starting an affiliate not-for-profit company called Grameen Shakti (GS). The new non-profit was able to attract seed financing from E&CO and Stichting Gilles Foundation to capitalise a revolving credit fund and cover a portion of its operating expenses. The total seed funding amounted to US$150,000, of which US$102,000 went into a revolving credit fund for end user credit.

Designing an End User Credit Scheme

By selling small solar photovoltaic electric systems, GS provides its customers with electric alternative to displace the existing expenditures on kerosene, candles, and grid-based battery charging. GS offers its customers a choice of system sizes. The smallest, based on a 17 W panel, costs US$300, and the largest, based on a 60 W panel, costs US$800. To mitigate the high up-front cost, GS has implemented a two-year credit program at 8 percent interest (equivalent to the interest rate on their housing programme). End users pay 25 percent of the cost in a downpayment. Grameen Shakti includes a mark-up in its prices, to cover its operating expenses. The mark-up percentage is lower for the lowest cost systems, bringing the cost down for the poorest customers, and establishing an "entry level" service which can be upgraded as the end users save more money.

Minimizing Transaction Costs

Maintenance service during the first two years is included with the purchase price. After that, maintenance is provided on a fee-for-service basis from the local retail office. As an independent company, Grameen Shakti capitalised on the Bank's rural network and reputation as it built its own network around the existing infrastructure. Grameen Shakti utilised the Grameen Bank's approach of hiring low-cost, minimally-educated labour, and training them on the job. This labour is much less expensive than the university-educated and city-based engineers employed by the private sector suppliers. Moreover, this approach side-stepped the expense of travel from Dhaka to the village for every maintenance call.

Building Capacity

While Grameen decided to handle both the technical and financial operations of the programme rather than relying on a strategic partner, it realised from the beginning the necessity to separate the renewable energy programme from the banking program. The renewable energy programme needed to be as independently viable as was the banking programme. Moreover, bank staff did not have the time to add sales, marketing, and system maintenance to their current tasks. There needed to be sufficient institutional capacity from within both programmes at each local office.

Current Status and Sustainability

To date, Grameen Shakti has sold over 800 Solar Home Systems from 10 unit offices. The organisation's initial successes has helped it attract, in

1997, a US$750,000 loan from the International Finance Corporation's Small and Medium Enterprises Program, one of the loan mechanisms of the Global Environmental Facility (GEF). The loan is repayable in 10 years, at 2.5 percent interest. As an incentive to overcome the obstacles to end user financing of rural electrification technology, Shakti is to be given half the total loan amount to capitalise a cumulative risk fund, if the loan is repaid on schedule. The existence of such a fund puts Shakti in a stronger position to receive commercial financing to continue its operations after the IFC funding ends. Grameen Shakti expects to be profitable within three or four years.

Other Activities

In addition to its commercial solar sales operations, Grameen Shakti has also developed pilot projects for activities that fall within its mission of developing energy resources for rural micro-entrepreneurs. A major action-research effort has been the development of four wind-powered micro-enterprise zones. These micro-enterprise zones provide 24-hour AC power on a fee-for-service basis to entrepreneurs who carry out electricity-utilising enterprises on the premises. The systems have been installed since November of 1998.

Case Study #2: Dominican Republic: ADESOL/Red Solar/Soluz

The Association for the Development of Solar Energy, Inc. (ADESOL), is an organisation promoting innovative energy solutions for non-electrified zones of the Dominican Republic. ADESOL works closely with the network of small local PV enterprises—the Solar Network—which provide a crucial product-supply link between importers/distributors and the rural customer base. ADESOL supports these enterprises by providing end-user credit to their customers. Consumer financing has played an important role in catalysing the market and extending the micro-enterprise's reach.

Forming an Energy Service Company

An outgrowth of one of the original micro-enterprises involved with ADESOL, now one of the country's importers/distributors, Soluz Dominicana, S.A., is implementing an important innovation in linking financing and product supply. Based in the North coast province of Puerto Plata, Soluz Dominicana offers a PV fee-for-service option to rural micro-enterprises and households in Puerto Plata, and two neighbouring provinces. In 1995, Soluz established a subsidiary aimed at serving 5,000 customers in the Dominican Republic and, more recently, expanded to Honduras.

Current Status and Sustainability

The company markets four different size PV units, ranging from 15 to 50 Watts, for set monthly fees of up to US$20. In this scenario, end users are buying only the energy services provided by solar home systems. There is no downpayment nor ownership, so removing the system because of non-payment is less of a struggle. The monthly payments are collected on an individual basis. Following installation, users deposit their payments in cash at designated collection points in the community. The fees can be adjusted to offset any currency devaluation that may occur. This approach has proven to generate demand far beyond what is possible with cash and credit sales. The Soluz model for a renewable energy service company has attracted attention from many groups looking to encourage private sector involvement in the rural markets. By late 1998, Soluz Dominicana was serving almost 1800 PV fee-for-service customers.

Supporting the Development of Micro-Enterprises

Many of the enterprises in the country have formed as a result of Enersol/ADESOL training activities. The equipment/component/spare parts infrastructure was set up originally through Enersol's training programme in each country. This has resulted in the formation of several dozen independent micro-enterprises, serving rural areas. These micro-enterprises are run by entrepreneurs and are supplied by various importers/distributors, as well as Soluz. There are about four to six importers/distributors in each country, and the micro-enterprises can shop around for the best prices. The local entrepreneurs' own target retail markets (usually having limited geographic scope) are self-contained, with their own technical and financial infrastructures. Maintenance and repair of the systems are done by Soluz Dominicana and Soluz Honduras. The technical training has led directly to the creation of some 15 independent micro-enterprises, serving 18 of the country's 30 provinces.

On behalf of its affiliates, Soluz buys almost all components, including modules, ballasts, and controllers, directly from manufacturers. Soluz Dominicana and Soluz Honduras buy the batteries locally and assemble lighting fixtures and some controllers. At this time, there is no local manu-facture or assembly of panels in the Dominican Republic or Honduras for the Soluz operation. Customs and duties on the equipment are accounted for as a cost of doing business.

Case Study #3:
Nepal: Biogas Support Program

The Nepali government had a national initiative to promote biogas plants since 1972, although it enjoyed limited success, installing about 400 plants per year. By 1992, the total number was 6,615 plants. That year, the government of Nepal (HMG/N) and the Dutch development agency SNV/Nepal joined forces to increase the penetration of biogas plants through the Biogas Support program. The Dutch government agency, DGIS, granted US$2.91 million to administer the programme and provide a fund for subsidies. Beneficiaries were expected to pay US$4.17 million, through bank loans or payments in kind. The programme developed a subsidy schedule, with different degrees of subsidy for three regions (in increasing order of under-development)—the Terrai (plains), the middle hills, and the remote hills. End users in these regions received a subsidy of US$100, US$144, and US$173, respectively. The total cost of the system ranged from US$252 for a 4 m^3 system to US$605 for a 20 m^3 system. The subsidy was the same, regardless of system size. Most of the plants were financed by loans with an interest rate of about 17 percent and a repayment period of 7 years.

Developing a Strategic Alliance

During the first phase, July 1992-July 1994, one biogas company, the Gabor Gas Company (GGC), completed most of the biogas installations in the project. The Agricultural Development Bank (ADB/N) provided loans to finance the beneficiaries component of the cost. The ADB/N also administered the subsidy. The programme operators saw that there would be a benefit to having the participation of a wider group of financial and technical intermediaries.

Creating an Enabling Environment for Sector-Wide Growth

In the second phase, July 1994-July 1997, other banks and private companies were enabled to take part in the programme. The goal was to strengthen the biogas sector as a whole. In order to participate, private companies were required to undergo training and licensing through the Biogas Support Programme. In addition, the biogas plants had to adhere to a strict guideline of design, construction, operation and after sales service. Biogas companies paid a fee of US$7.30 per plant installed to help offset the costs of these activities. By 1997, the number of biogas companies that participated in the program had grown to 36. The number of rural finance institutions had increased to three. In addition, HMG/N increased the viability of biogas sector growth, by granting exemption of duty on biogas accessories.

Current Status and Sustainability

By 1997, a total of US$2.52 million had been disbursed in subsidies, including US$20,176 financed by GCN. A total of 20,200 plants were sold during the period of 1992-97, more than tripling the entire sales during 1972-1992. Although the currency devalued significantly since 1992, the subsidy amount remained the same, resulting in a gradual decrease in the real value of the subsidies, although subsidy-free operation had not yet become feasible.

Case Study #4: ITDG: Financing Microhydro Entrepreneurs in Peru

The cooperative El Tinte in the Departamento of Cajamarca, Peru, produces fresh milk for a distribution company called INCALAC. They have four cows and produce about 500 litres of milk per day. Before installing their micro-hydropower plant (35 kW), they had milked the cows by hand and carried the product to cool in the river. The inconsistent quality of milk this method produced resulted in a low purchase price of US$0.06/litre, rather than the full price of US$0.11/litre. The addition of power has improved the productivity of their enterprise in several ways. They use a refrigerator to control the temperature of the milk, resulting in higher quality, better hygiene, and a consistent sales price of US$0.11/liter. This provides an additional income of US$671/month. With the total system cost having been US$35,000, the additional income allows the cooperative to pay for the system within 5 years.

Socio-Economic Benefits

In addition to being able to pay off their loan, the cooperative has reduced its labour expenditure by using electric milking machines. The houses near the dairy have all been electrified, and distant houses are able to charge 12 V batteries for domestic lighting. As a further benefit, the cooperative has installed a grain mill. The members save the cost of transportation to the city, in addition to having created a viable business in their own community.

Creating a Revolving Credit Fund

El Tinte has been able to implement its micro-hydropower station through a loan from a fund set up by the Interamerican Development Bank (IDB) and managed by Intermidiate Technology Development Group (ITDG). To date, the rotating fund for mycro-hydropower plants has funded 15 systems in rural Peru. The loans are repaid within five years at eight percent interest. The credit amount varies from US$10,000 to US$50,000. The fund is capitalised by a US$400,000 grant from the IDB. ITDG is currently seeking financing to expand the fund, as demand exceeds the availability of funds.

7.8. PROMOTING INSTITUTIONAL CHANGE

7.8.1. Government

Governments play an important role in creating the enabling environment for microfinance institutions, NGOs, and the private sector to participate in rural energy provision. To achieve this goal, governments can:

- **promote efficient markets** by developing a transparent legal and regulatory framework, not cluttered with overly restrictive regulations. Efficient markets demand the rationalisation of import duties and tariffs to reflect their impact on the price of basic energy services. Moreover, they require that governments give equal treatment to the range of rural electrification technologies;

- **promote universal access to electricity** through "smart" subsidies, which channel national resources to rural electrification without creating a bias to a particular technology; and

- **incorporate social and environmental costs of energy technologies in policy making.** While market forces encourage the least-cost options, these do not take into consideration the environmental and health implications of many conventional technologies. It is the responsibility of governments to ensure that sustainable choices are made by incorporating the social and environmental advantages of renewables in energy, rural electrification, and trade policy.

7.8.2. Financial Institutions

Channeling funds from large sources to small rural applications requires innovation and dedication from financial institutions. To meet this challenge, financing institutions should:

- **use bundling to make small-scale financing available.** By incorporating several loans into one fund, transaction costs are minimised, and small operations receive the financing they need;

- **understand renewable energy technologies and be willing to fund them.** Financing institutions accustomed to funding conventional energy projects may be surprised at the specific needs of energy system financing. Understanding the issues implicit to renewable energy development stands to help financial institutions make informed decisions;

- **open a special "window" for renewable energy financing.** By creating a special section devoted to renewables in the organisation, bank staff within this section can build up its experience with renewable energy projects, developing the competencies necessary to evaluate renewable energy projects. In addition, the borrower will be able to work with an organisation that caters to his/her particular needs; and

- **develop new mechanisms for risk mitigation.** The International Finance Corporation's Small and Medium Enterprises program has already developed a "cumulative risk fund" which can be used to offset the risk to lenders. Such innovations may pave the way for commercial financing of renewables.

Several financing institutions have already decided to play a role in rural renewable energy services delivery.

7.8.3. Non-Governmental Institutions (NGOs)

NGOs can play a useful role in stimulating linkages between disparate programmes. For example, they can:

- **form a bridge between micro-entrepreneurs and renewable energy technologies.** Rural development NGOs can help rural entrepreneurs take advantage of more efficient energy technologies. This micro-enterprise support activity is often too resource intensive for private companies or banking programmes to undertake; and

- **build institutional capacity.** Many small-scale renewable energy suppliers and MFIs do not have the institutional capability to seek out and obtain the financing they need to develop their programmes. NGOs can play an important role in supporting and building the institutional capacity of such organisations, so that they can ramp up their operations and perform in the way necessary to be sustainable. A variation on this theme is the start-up renewable energy supplier that begins as an NGO and grows into a commercial entity. Many of the successful renewable energy operations mentioned in this chapter have created an NGO in the initial phase as a crucial step in the institutional formation and learning process (e.g., Soluz).

7.8.4. Donor Community

The donor community can facilitate the development of microcredit energy programmes, provide technical assistance, and catalyse industry partnerships in order to expand the reach of sustainable energy services. Its role can include:

- **protecting local market players.** By being aware of the importance of local energy entrepreneurs and businesses, donors can create programmes, which reinforce, rather than destroy, these important intermediaries;

- **financing projects.** Donors can play a crucial role in financing projects in the early stages of project development, until renewable energy projects are able to build a stronger record of financial viability; and

- **encouraging direct foreign investment.** Through education, networking, and policy building, donors can encourage investment in renewable energy businesses and loan programmes to increase the available pool of capital for these activities.

7.9. CONCLUSIONS

The role of energy in sustainable development cannot be underestimated. Energy selectively impacts all of the foci of development, exacerbating problems of population growth, undernutrition, gender inequalities, poor health, and lack of access to education. However, unless sustainable delivery approaches are developed to recover costs and engender economic development, the rural people that need these energy services are going to remain underserved. There are a variety of financial mechanisms targeted at the end user. These offer significant opportunities to help many people acquire necessary energy services at an affordable price and stimulate markets for sustainable energy. These flexible lending schemes include micro-credit, fee-for-services, leasing, and others. Lessons from past experiences indicate that, while financing is a key component of energy service delivery, it is necessary to carefully design initiatives so as to support the creation of new markets and avoid market distortions. Financial modalities have to be tailored to local conditions, and further efforts are required to pilot innovative and replicable approaches that better serve the needs of the people.

REFERENCES

Chapter 1

References

Arthur, B., March 1989, "Competing technologies, increasing returns and lock-in by historical events", *The Economic Journal*, pp.99.

Baldwin, S.F., 1986, *Biomass Stoves: Engineering Design, Development, and Dissemination.* Volunteers in Technical Assistance, Rosslyn, VA, and Center for Energy and Environmental Studies, Princeton University, Princeton, New Jersey, USA.

Barnes, D.F., K. Openshaw, K.R. Smith, and R. van der Plas, 1994, *What Makes People Cook With Improved Biomass Stoves?,* World Bank Technical Paper #242, Energy Series, World Bank, Washington, DC.

Brennand, T., 1996, *Concessions for Windfarms: a New Approach to Wind Energy Development. Report prepared for the Working Group on Energy Strategies and Technologies of the China Council for International Cooperation on Environment and Development,* Beijing, China.

Dasgupta, P.S., February 1993, *Scientific American*, pp. 26-31.

Dutt, G., 1995, "Energy-efficient and environment-friendly refrigerators", *Energy for Sustainable Development*, **1**(5), pp. 57-67.

EC/UNDP (European Commission and the United Nations Development Programme), 1999, *Energy as a Tool for Sustainable Development for ACP Countries*, New York.

Hoff, T.E., H.J. Wenger, and B.F. Farmer, 1995, "Distributed generation. An alternative to electric utility investments in system capacity", *Energy Policy,* **24** (2), pp.137-148.

Kammen, D.K., 1995, "From Energy Efficiency to Social Utility: Lessons for Cookstove Design, Dissemination and Use", in *Energy as an Instrument for Socio-Economic Development,* UNDP, New York.

Karekezi, S., 1992, "The development of stoves and their effectiveness", *Renewable Energy Technology and Environment,* **1**, Pergamon Press, pp.46.

Kartha, S., T.G. Kreutz, and R.H. Williams, March 1997, *Rural Electrification via Small-Scale Biomass Gasifier/ Solid Oxide Fuel Cell/Gas Turbine Power Plants*, Center for Energy and Environmental Studies, Princeton University.

Krugmann, H., 1987, *Review of Issues and Research Relating to Improved Cookstoves (IDRC-MR152e)*, International Development Research Centre, Ottawa.

Kumar, S.K. and D. Hotchkiss, 1988, *Consequences of Deforestation for Women's Time Allocation, Agricultural Production and Nutrition in Hill Areas of Nepal,* International Food Policy Research Institute, Washington DC.

Leach, G., 1992, "The energy transition", *Energy Policy*, **20** (2), , pp. 116-123.

Nörgård, 1991, "Low Electricity Appliances: Options for the Future", in T.B. Johansson *et al.* (eds.), *Electricity—Efficient End-Use and New Generation Technologies and Their Planning Implications,* Lund University Press Lund, Sweden.

North, D., Spring 1992, "Institutions and Economic Theory", *American Economist*, pp 3-6.

North, D., 1991, *Institutions, Institutional Change and Economic Performance*, Cambridge University Press.

The World Bank, December 1992, *Pakistan Living Standards Management Study (LSMS), 1991.*

Philips, M., 1991, *The Least Cost Energy Path for Developing Countries: Energy Efficient Investments for the Multilateral Development Banks*, IIEC, Washington, DC.

Reddy, A.K.N., 1991, *Barriers to Improvements in Energy Efficiency (LBL-31439)*, Lawrence Berkeley Laboratory, Berkeley, USA.

Smith, K.R., 1987, *Biofuels, Air Pollution and Health—A Global Review*, Plenum Press, New York.

Smith, K.R., G. Shuhua, H. Kun, and Q. Daxiong, 1993, "100 Million Biomass Stoves in China: How Was It Done?", *World Development,* **18**, pp. 941-961.

Suarez, C. E., 1995, "Energy Needs for Sustainable Human Development", in *Energy as an Instrument for Socio-Economic Development*, UNDP, New York.

UNDP, 1995, *Human Development Report 1995*, New York, Oxford University Press.

UNDP, 1996, *UNDP Initiative for Sustainable Energy*, New York.

UNDP, 1997, *Energy After Rio: Prospects and Challenges,* United Nations Publication, New York.

UNEP/WHO (United Nations Environment Programme and the World Health Organisation), 1992, *Urban Air Pollution in Megacities of the World*, Blackwell Publishers.

WEC, 1995, *Financing Energy Development: The Challenges and Requirements of Developing Countries*, London.

WEC/IIASA (World Energy Council/International Institute for Advanced Systems Analysis), 1995, *Global Energy Perspectives to 2050 and Beyond,* London and Laxenburg, Austria.

The World Bank, 1990, *Capital Expenditures for Electric Power in the Developing Countries in the 1990s*, Energy Series Paper No. 21 (1990), Washington DC.

The World Bank, 1992a, *World Development Report: Development and the Environment*, Oxford University Press, New York.

The World Bank, 1992b, *The Bank's Role in the Electric Power Sector*, Washington, DC.

Worrell, E., 1995, "Advanced technologies and energy efficiency in the iron and steel industry in China", *Energy for Sustainable Development,* **II** (4), pp. 27-40.

Chapter 2

References

Annecke, W., 1999*, Concept Paper for Energy and Women: Lessons Learned*, EDRC, University of Cape Town, South Africa.

Anon., 1998, "Resources: Training on Energy Saving for Female Entrepreneurs", *ENERGIA News*, **2**(3), p.15

Best, 1988, *Biomass Energy Services and Technologies; The use of wood fuel in rural industries in Asia and Pacific Region,* Regional wood development programme in Asia, FAO, Bangkok.

Clancy, J. S., 1999, *Cottage Industries, Discussion Document*, Household Energy Development Organisation Network (Hedon*)*, http://www.energy.demon.nl/hedon/docs/cottage.htm

Everts, S. and Schulte, B., 1997, "Vietnam Women's Union Promotes Solar Energy", ENERGIA News, **1**(3), pp. 12-13.

Goldon, J., 1986, *Biomass Energy Devices for Income Generation at the Household and Community Level.* ITDG, London.

International Labour Organisation, 1987, *Linking Energy with Survival: Energy, Environment and Rural Women's Work*.

Lele, D., 1998*,* "Gender Equity in International Petroleum Projects: Women in The Oil and Gas Sector", *ENERGIA News*, **2**(3), pp. 10-11.

Nathan, D., 1997, "Economic Factors in the Adoption of Improved Stoves"*, ENERGIA News,* **4**(4), pp. 8-10.

Oliveros, A. D. 1997, "Energising Rural Areas of Peru", *ENERGIA News*, **1**(3), pp.14-15

Stone, L., 1998, "Solar Baking under the Sonoran Sun", *ENERGIA News*, **2**(1), pp.12-13

Wamukonya, L. and Davis, M., 1999, *Socio-economic Impacts of Rural Electrification in Namibia, Report 1: Comparison between Grid, Solar and Unelectrified Households*, EDRC, University of Cape Town, South Africa.

UNDP, 1995, *Human Development Report 1995*, New York, Oxford University Press.

UNDP, 1997, *Energy After Rio: Prospects and Challenges*, United Nations Publications, New York.

Background Materials

UNDESA, 1997, *Integrating Gender Issues into Energy Planning*, Training Workshop prepared for UN/DDSMS, Technology and Development Group, University of Twente, The Netherlands.

ENERGIA News secretariat, *ENERGIA News*, ETC Energy, Leusden, The Netherlands.

Carol M. and Shahra R., 1998, *Gender Analysis: Alternative Paradigms*, UNDP Gender in Development Monograph Series #6.

UNDP and European Commission, 1999, *Energy as a Tool for Sustainable Development for African, Caribbean and Pacific Countries*, United Nations Publications, New York.

Cecelski, E., 1995, "From Rio to Beijing: Engendering the Energy Debate", *Energy Policy*, **23**(6), pp.561-575.

Skutsch, M., 1998, "The Gender Issue in Energy Project Planning: Welfare, Empowerment or Efficiency?", *Energy Policy*, **26**(12), pp.945-955.

Chapter 3

Background Materials

Intergovernmental Panel on Climate Change (IPCC), 1996, *Climate Change 1995*, Cambridge University Press, Cambridge.

UNDP, 1998, *Issues and Options: The Clean Development Mechanism,* United Nations Publications, New York.

UNDP, 1999, *Promoting Development While Limiting Greenhouse Gas Emissions: Trends and Baselines,* United Nations Publications, New York.

Chapter 4

Background Materials

Ahmed, K., 1994, *Renewable Energy Technologies: A Review of the Status and Costs of Selected Technologies*, The World Bank, Washington DC.

Cabraal, A., M. Cosgrove-Davies, and L. Schaeffer, 1996, *Best Practices for Photovoltaic Household Electrification Programs*, The World Bank, Washington DC.

Johansson, T.B., H. Kelly, A.K.N. Reddy, and R.H. Williams, 1993, *Renewable Energy Sources for Fuels and Electricity*, Earthscan Publications Ltd. and Island Press.

Office of Technology Assessment, 1995, *Renewing Our Energy Future*, Publication OTA-ETI-614, U.S. Government Printing Office, Washington DC.

UNDP, 1997, *Energy After Rio: Prospects and Challenges*, United Nations Publications, New York.

The World Bank, 1996, *Rural Energy and Development: Improving Energy Supplies for Two Billion*, Development in Practice Series, The World Bank, Washington DC.

Chapter 5

Background Materials

Anderson, D., 1995, "Energy Efficiency and the Economists: The Case for a Policy Based on Economic Principles", *Ann. Rev. Energy Environm* **20,** pp.495-511.

Bates, R.W., 1993, "The Impact of Economic Policy on Energy and the Environment in Developing Countries", *Ann. Rev. Energy Environm.* **18,** pp.479-506.

Bergh, J.C.J.M. van den., 1999 (Ed.), *Handbook of Environmental and Resource Economics,* Edward Elgar Publishing, Cheltenham, UK

Gadgil, A., and Sastry, A., 1994, "Stalled on the Road to Market: Lessons from a Project Promoting Lighting Efficiency in India", *Energy Policy,* **22,** pp.151-162.

Geller, H. and Nadel, S., 1994, "Market Transformation Strategies to Promote End-Use Efficiency", *Ann. Rev. Energy Environm.* **19,** pp.301-346.

Goldemberg, J., Johansson, T.B., Reddy, A.K.N., and Williams, R.H., 1988, *Energy for a Sustainable World*, Wiley Eastern Limited, New Delhi, India.

International Energy Agency, 1992, "Use of Efficiency Standards in Energy Policy", IEA/OECD, Paris, France.

International Energy Agency, 1996, "Voluntary Actions for Energy-Related CO_2 Abatement in IEA Member Countries", IEA/OECD, Paris, France.

International Energy Agency, 1997, "Energy Efficiency Initiative (Volume 1 and 2)", IEA/ OECD, Paris, France.

Intergovernmental Panel on Climate Change, 1995, *The IPCC Second Assessment Report. Vol.2 Scientific and Technical Analyses of Impacts, Adaptations and Mitigation of Climate Change*, Cambridge University Press, Cambridge, UK.

Levine, M.D., Hirst, E., Koomey, J.G., McMahon, J.E. and Sanstad, A.H., 1994, *Energy Efficiency, Market Failures, and Government Policy,*Lawrence Berkeley National Laboratory/ Oak Ridge National Laboratory, Berkeley/Oak Ridge, USA.

Lovins, A.B. and Lovins, L.H., 1991, "Least-Cost Climatic Stabilization", *Ann. Review of Energy* **16,** pp.433-531.

Martin, N., Worrell, E., Sandoval, A., Bode J-W., Phylipsen D., (Eds.), 1998, *Industrial Energy Efficiency Policies: Understanding Success and Failure (LBNL-42368),*Lawrence Berkeley National Laboratory, Berkeley, USA

Price, L.K., Michaelis, L., Worrell, E., and Khrushch, M., 1998, "Sectoral Trends and Driving Forces of Global Energy Use and Greenhouse Gas Emissions", *Mitigation and Adaptation Strategies for Global Change,* **3,** pp.263-319.

Reddy, A.K.N., Williams, R.H., and Johansson, T.B. 1997, *Energy After Rio, Prospects and Challenges*, United Nations Development Programme, United Nations, New York, NY.

Sathaye, J. and Meyers, S. (Eds.), 1995, *Green-house Gas Mitigation Assessment: A Guidebook*, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Schipper, L. and Meyers, S. with Howarth, R. and Steiner, R., 1992, *Energy Efficiency and Human Activity: Past Trends, Future Prospects*, Cambridge University Press, Cambridge, UK.

Stout, B.A., 1989, *Handbook of Energy for World Agriculture,* Elsevier Applied Science, London, UK.

The World Bank, 1999*, The Energy Service Industry, The Experience of the United States and Canada,* Energy Sector Unit, Energy, Mining and Telecommunications Department, The World Bank, Washington, DC.

World Energy Council, 1995, *Efficient Use of Energy Utilizing High Technology: An Assessment of Energy Use in Industry and Buildings,* London, UK.

Worrell, E., Levine, M., Price, L., Martin, N., Broek, R. van den., and Blok, K., 1997, *Potentials and Policy Implications of Energy and Material Efficiency Improvement,* Department for Policy Co-ordination and Sustainable Development, United Nations, New York, NY.

Chapter 6

Background Materials

International Energy Agency, 1998, *Renewable Energy Policy in IEA Countries Volume II : Country Reports*, Publication 92-64-16186-4, Paris, France.
International Energy Agency, 1999*, World Energy Outlook 1999 Insights Looking at Energy Subsidies: Getting the Prices Right*, Publication 92-64-17140-1, Paris, France.

UNDP, 1997, *Energy After Rio: Prospects and Challenges*, United Nations Publications, New York.

UNDP, UNDESA and the World Energy Council (WEC) (expected 2000), *the World Energy Assessment,* New York.

The World Bank, 1996, *Rural Energy and Development: Improving Energy Supplies for Two Billion*, Development in Practice Series, The World Bank, Washington DC.

The World Bank Group, 1999, *Fuel For Thought: Environmental Strategy For The Energy Sector*, Washington, DC. (Available on website at http://www.worldbank.org/html/fpd/energy/)

Chapter 7

Background Materials

Cabraal, A., M. Cosgrove-Davies, and L. Schaeffer, u, 1996, *Best Practices for Photovoltaic Household Electrification Programs*, The World Bank, Washington DC.

Gregory, J., S. Silveira, A. Derrick, P. Cowley, C. Allinson, and O. Perish, , 1997, *Financing Renewable Energy Projects: A Guide for Development Workers,* IT Publications, UK.

Gunaratne, L., October 1998, "Funding and Repayment Management of PV System Dissemination in Sri Lanka II", in *the Proceedings of the Workshop on Financial Services for Decentralized Solar Energy Applications II*, Harare,Zimbabwe.

National Rural Electric Co-operation Association (NRECA), November 1982, *Proceedings: Productive Uses of Electricity in Rural Areas*", Dhaka, Bangladesh.

Interamerican Development Bank, 1998, *Promotion of Rural Renewable Energy Micro-enterprises in the Northeast Region of Brazil (Internal Document).*
IT Peru, 1998, *Energia para el Area Rural del Peru,* Lima, Peru.

Kittleson, D., October 1998, "Productive Uses of Electricity: Country Experiences", *Proceedings of the Village Power Conference*, Washington DC,.

National Renewable Energy Laboratory (NREL), (expected 2000), *Renewable Energy for Micro-enterprise*, Golden, USA.

Ramani, KV, May 1998, "Financing Energy Services and Income-Generating Opportunities for the Poor—A Case Study of Project ENSIGN", *Proceedings of the Workshop on Institutional Co-operation for Solar Energy in the Mekong Riparian Countries*, Hanoi.

UNDP, 1997, *Energy After Rio: Prospects and Challenges*, United Nations Publications, New York.

Sustainable Energy Solutions, 1998, *Asia-Pacific Economic Co-operation, Guidebook for Financing New and Renewable Energy Projects*, NEDO, Tokyo.

The World Bank, 1994, *Rural Electrification in Asia: A Review of Bank Experience*, Washington, DC.

WEBSITES

We give an overview of selected websites. An overview like this can not, by definition, be complete. Over 1000 websites give information on energy and environmental related issues. A regularly updated website with links to most energy websites is that of the Netherlands Energy Research Foundation (ECN) : *http://www.ecn.nl/eii/main.html*

Policies and Programmes

Intergovernmental

United Nations Framework Conference on Climate Change (UNFCCC): *http://www.unfccc.de*
UNDP - Energy and Atmosphere Programme (EAP): *http://www.undp.org/seed/eap*
UNEP Collaborating Center on Energy and Environment *http://www.uccee.org*
UNIDO Energy and Environment: *http://www.unido.org/doc/online.htmls*
UNITAR Climate Change Training: *http://www.unitar.org/cctrain*
United Nations - Economic Commission for Europe: *http://www.unece.org*
World Bank: *http://worldbank.org*
World Bank Global Environment/Climate change: *http://www-esd.worldbank.org/cc*
European Union: *http://europa.eu.int*
European Commission - DG 17 (Energy): *http://europa.eu.int/en/comm/dg17/dg17home.htm*
European Community Research and Development Information Service (CORDIS): *http://www.cordis.lu*
Global Environment Facility (GEF): *http://www.gefweb.org*
Intergovernmental Panel on Climate Change (IPCC): *http://www.usgcrp.gov*
International Energy Agency (IEA): *http://www.iea.org*
IEA Energy and Environmental Technology Information Centres (EETIC): *http://www.eetic.org*
IEA Heat Pump Centre: *http://www.heatpumpcentre.org*
IEA Energy Technology Data Exchange (ETDE): *http://www.etde.org*

Other Useful Links

African Energy Policy Research Network (AFREPREN): *http://www.afrepren.org*
American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE): *http://www.ashrae.org*
Asia-Pacific Energy Research Centre: *http://www.ieej.or.jp/aperc/index.htm*
CADDET Energy Efficiency: *http://www.caddet.org* (database on energy efficient technologies)
Greenhouse Gas Technology Information Exchange (GREENTIE): *http://www.greentie.org*
Greenhouse Gas R&D Programme (IEA): *http://www.ieagreen.org.uk*
Energy Efficiency and Renewable Energy Network (U.S. DOE): *http://www.eren.doe.gov*
Energy Technology Support Unit (ETSU, UK): *http://www.etsu.com*
Home Energy Magazine (journal): *http://www.homeenergy.org*
International Institute for Sustainable Development (IISD): *http://www.iisd.ca*
Lawrence Berkeley National Laboratory (LBNL): *http://www.lbl.gov*
National Renewable Energy Laboratory (NREL): *http://www.nrel.gov*
North American Organisation of ESCOs (NAESCO): *http://www.naesco.org*
Oak Ridge National Laboratory (ORNL): *http:/www.ornl.gov*
Overview Energy Links on the Internet: *http://www.ecn.nl/eii/main.html*
SOLSTICE, Centre for Renewable Energy and Sustainable Technology: *http://solstice.crest.org/index.html*
Stockholm Environment Institute (SEI): *http://www.sei.se*
Sustainable Building Sourcebook: *http://www.greenbuilder.com*
U.S. Department of Energy (USDOE): *http://www.doe.gov*
U.S. Environmental Protection Agency (USEPA): *http://www.epa.gov*
World Energy Council (WEC): *http://www.worldenergy.org*
World Resources Institute (WRI): *http://www.wri.org*