Renewable Energy Potential in Selected Countries

Volume I: North Africa, Central Europe, and the Former Soviet Union

and

Volume II: Latin America

Final Report

Energy Sector Management Assistance Program
(ESMAP)

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Foreword

This report summarizes the work performed under an Energy Sector Management Assistance Programme (ESMAP) project under the title Regional Strategy for Renewable Energy Identification. The work, performed during 1995 and 1996, was planned to cover all regions of the World Bank where renewable energy resource development seemed promising, including North and Sub-Saharan Africa, Eastern Europe and the former Soviet Union, Asia, and Latin America.

The countries covered in this section of the report are Morocco, Tunisia, and Egypt from the North Africa Region, and Armenia, Bulgaria, Georgia, Kazakhstan, the Kyrgyz Republic, and Russia from Eastern Europe and the former Soviet Union. The work and missions for this work were undertaken with the clearance and support of the respective Sector Operating Division of the Bank and, in those countries where they exist, with the active support and participation of the resident mission. The support of the resident missions, particularly those of Kazakhstan, the Kyrgyz Republic, and Russia, was and continues to be particularly helpful. Local participation and involvement also were primary objectives of the missions, to ensure local ownership and continuation of the effort.

The work undertaken proved helpful in identifying some potential projects and moving them to the preparatory stage. In other cases, projects are under consideration but have not yet been included in the Bank's lending program. It must be kept in mind that ideas that depart from the well-trodden path often take time to germinate and bear fruit. Follow-up work, in the form of detailed feasibility or preinvestment studies, has been initiated. Whatever the immediate outcome may be, the work performed raised the consciousness both of the Bank's clients and of Bank staff of the need to explore renewable energy as a viable alternative to conventional fuels and of the importance of new technologies to a future of environmental compatibility and sustainable development. Thus, the objective of the Bank's Solar Initiative, supported by ESMAP funding, was fulfilled. Follow-up work will be essential for bringing the initiatives to fruition.

The report was prepared by Achilles Adamantiades, Power Engineer Consultant, and Birgit Eitel, candidate for a Ph.D. in energy economics at the university of Nuremberg in Germany and summer intern in 1997. The authors are indebted to numerous individuals for their input and comments, most notably Dennis Anderson, Charles Feinstein, Ernesto Terrado, Anil Cabraal, Richard Spencer, and Willem Floor. The strong support of Karl Jechoutek, Chief, IENPD, and Richard Stern, Director of the Industry and Energy Department when this work was performed, is acknowledged. The work was completed under the direction of Dominique Lallement, ESMAP's Manager.

Abbreviations

AME	Agence pour la Maîtrise de l'Energie (Tunisia)
ASTAE	Asia Technical Alternative Energy (Dept.)
CDER	Centre pour le Développement des Energies Renouvables (Morocco)
DH	District heating
EBRD	European Bank for Reconstruction and Development
EdF	Electricité de France
EE&RE	Energy efficiency and renewable energy
EEF	Energy Efficiency Fund
ESMAP	Energy Sector Management Assistance Programme
ENVGC	Environment Department's Global Climate (Division)
EU-PHARE	European Union PHARE Program
FCCC	Framework Convention for Climate Change
FSU	Former Soviet Union
GEF	Global Environment Facility
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producers
MEDA	Mediterranean Assistance (Program of the European Union)
NEDO	New Energy and Industrial Technology Development Organization (Japan)
NRC	National Research Center
NREA	New and Renewable Energy Authority (Egypt)
NREL	National Renewable Energy Laboratory (US)
OECD	Organization for Economic Cooperation and Development
ONE	Office National de l'Electricité (Morocco)
OPIC	Overseas Private Investment Corporation (US)

PPA	Power purchase arrangements
PV	Photovoltaic (cells or modules)
PV-SHS	Photovoltaic solar home systems
RE	Renewable energy
RD&D	Research, development, and demonstration
SOD	Sector Operating Division
SWH	Solar water heaters
TA	Technical assistance
TACIS	Technical Assistance for the Commonwealth of Independent States
UNDP	United Nations Development Program
USAID	United States Agency for International Development

Units of Measure

^{o}C	degree Celsius
^{o}F	degree Fahrenheit
GW	gigawatt
GWh	gigawatt hour
kcal	kilocalorie
kg	kilogram
km	kilometer
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt hour
kWp	kilowatt peak
m	meter
M^3	cubic meter
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWp	megawatt peak
psi	pounds per square inch
toe	tonnes of oil equivalent
TWh	terawatt hour (billion kWh)
s	second
Wp	watt peak
Y	year

Executive Summary

Introduction

1. Renewable energy (RE) resources have been attracting growing interest in both the industrialized and the developing world in the last five to eight years. The main drivers for this interest and accelerated activity have been the expected strong demand for energy in the developing world and environmental concerns, particularly of the risk of drastic climate change as a result of the increasing accumulation of greenhouse gases in the atmosphere. Although long-term forecasts of climate change cannot be made with any certainty, the consensus in the international community is that it would be prudent as an insurance policy to take measures to reduce the emissions of greenhouse gases to the atmosphere.

2. A first approach would be to embark on intensive measures to achieve higher energy efficiency—for which there is ample scope. However, owing to the large suppressed demand for energy in the developing world, notably in countries with large populations and low per capita energy consumption, this approach should proceed in tandem with an effort to introduce technologies that produce low carbon emissions. Another concern is the existence of large rural populations that have no access to energy supplies. This is a problem that cannot be resolved by simple connection to an electric grid, because this would entail large capital expenditures and would be uneconomic; the solution instead may lie in emerging noncarbon technologies for the supply of electricity and small, distributed power sources based on renewable energy.

3. Several RE technologies have made significant penetration in the energy market. Direct solar technologies include either solar thermodynamic or photovoltaic applications, and indirect solar include wind and biomass technologies. In addition, geothermal and small hydro resources also are conventionally included in the RE category. The increased interest and rapid growth in these applications has been stimulated by a significant drop in cost over the last decade and technical improvements that have increased their efficiency, reliability, and longevity; other advantages of RE applications are their modularity, short lead times, the large solar potential in developing countries, favorable land-use features, and ease of decommissioning. The leading technical improvements include manufacturing innovations; improvements in solar cell and system design, with attendant conversion efficiency improvements; aerodynamic advances in wind turbine design; and other mechanical, electrical, and electronic innovations. The cost of wind energy, for example, was reduced by these technical improvements and economies of scale from a level of US$ 0.15–0.20 per kWh in 1987 to about US$ 0.04–0.08 per kWh in 1997.

4. The Solar Initiative of the World Bank was established with two major objectives: (a) to provide active support to the Bank's regional units for the identification and preparation of renewable energy (RE) projects that are commercial or near-commercial; and (b) to play a coordinating, strategic, and catalytic role in removing barriers to the introduction of renewable and other environmentally sustainable technologies in developing countries. The initiative also foresees a role in the facilitation and

coordination of international activities in research, development, and demonstration (RD&D). Within the Bank Group, the first objective requires proactive efforts to identify and include renewable energy projects in the lending portfolio, and has realized the identification, appraisal, and approval of a number of standalone renewable energy projects.

5. An important impetus for this development was provided by the establishment of the Global Environment Facility (GEF), which after a first pilot stage has been restructured and replenished and is now in its first official phase, GEF-I. This facility, reflecting worldwide concern with global environmental degradation, as highlighted during the Earth Summit Conference in Rio de Janeiro in 1992, has raised commitments of about US$ 1.5 billion to provide incremental funding on a grant basis for projects that have substantial long-term environmental benefits. One of the four areas of GEF support is the reduction of greenhouse gas emissions.

6. This study was undertaken by the Energy Sector Management Assistance Program (ESMAP), managed by the World Bank. One of the main purpose of ESMAP activities is to provide support for national or regional energy strategies, which lead to project identification and preparatory studies. This is an important role, because while funds may be readily available once a viable project has been identified they tend to be scarce at the initial stages of strategic planning and project identification. A number of regional strategy studies was undertaken to: (a) explore more closely the potential of RE resource development in regions that look promising; (b) perform a first screening of resource categories and projects for further consideration; and (c) stimulate the support of local authorities, the World Bank, and multilateral organizations for more detailed feasibility studies and, if possible, initiate the inclusion of an RE project or project component in the lending program. The study was heavily supported, with funding and in kind, by other donor agencies.

7. This report covers two regions: the North Africa region and countries of Central Europe and the former Soviet Union (FSU). The decision to conduct regional rather than specific country studies was made to take into account the commonalities of the shared characteristics of a group of countries. Such commonalities may be a high level of insolation, a similar industrial infrastructure, or similar cultural or economic traditions. They introduce the possibility that the consolidation of regional markets could enable the realization of economies of scale in regional development, and enable cost savings to be made by combining missions to several countries of a region.

Results and Conclusions of the Study

8. **Egypt**. Egypt is endowed with good fossil fuel resources—discoveries of which have increased in recent years—and thus is a strong exporter. Nevertheless, RE resource development has attracted strong interest in Egypt because of (a) the country's high level of insolation, (b) the economic viability of such development, (c) the potential for freeing fossil fuels for export, and (d) the country's desire to play a leadership role in the region. The main areas of activity are windfarms (in which large strides have been made on the banks of the Red Sea); solar water heaters (which have been developed, but not to a sufficiently large degree); and photovoltaic cells for special applications. The authorities

have also decided to launch an integrated solar combined-cycle project with expected assistance from the GEF and the European Union's Mediterranean Assistance (MEDA) program, to be implemented as a private sector power project. These efforts are supported by the National Renewable Energy Authority (NREA). Overall, Egypt is well placed to take a regional lead in the development of RE resources.

9. **Morocco**. Morocco has a low endowment of fossil fuels and imports most of its energy needs. The country has abundant solar insolation and other RE resources, however. Morocco's motivations for RE development are to: (a) reduce the requirements for fossil fuel imports; (b) expand rural electrification at least cost; (c) reduce the use of fuelwood (reliance on which is the cause of widespread deforestation); and (d) use energy to increase the supply of water. A windfarm, to be implemented as a private sector project, has been awarded to a foreign consortium, and the viability of a grid-connected integrated solar combined-cycle plant is being examined with support from the European Union and the World Bank. Strong bilateral and multilateral TA support has assisted Morocco in implementing several projects that use PV systems to serve isolated rural populations. Morocco also has strong institutions that could be important in promoting the dissemination of RE applications in the country.

10. **Tunisia.** Although Tunisia possesses indigenous fossil fuel resources, these are expected to be inadequate to meet future demand, which is showing a strong growth rate. Deforestation caused by extensive fuelwood use for household energy also is a factor behind the increased interest in the development of RE resources, which are abundant. The high level of insolation has already led to the development of solar water heaters, with support from the GEF. In addition, the contract for a first windfarm, a 10 MW project at Cap Bon, has been awarded to a foreign consortium. More windfarms are to follow. Given the support of the government agency that is in charge of energy efficiency and RE, a strong increase of the RE component in the energy mix is expected in the next 10–15 years. A separate RE development strategy study, performed under ESMAP and published in a separate ESMAP report, made specific and quantitative recommendations for the further development of solar water heaters, PV solar home systems for rural populations, windfarms, and solar thermodynamic power plants. It also offered suggestions for the institutional incentives that it perceived as necessary to make possible the accelerated development of RE resources.

11. **Regional Aspects (North Africa).** Although the lack of study resources and certain political factors meant that several countries of the region were not covered by this study, substantial benefits for a regional approach to RE development in North Africa are foreseen. Strong similarities exist across the region; for example, in solar resources, level of economic development, the conditions of rural populations, and problems of deforestation. Common cultural characteristics and political links could support the development of regional markets, enabling economies of scale in manufacturing and introducing the benefits of competition. More specifically, the interest of several regional countries in the development of solar thermodynamic technology (in the form of integrated solar combined-cycle), could provide the necessary stimulus to elevate the technology to commercial viability. The three solar thermodynamic projects mentioned above, in conjunction with similar projects planned or under consideration in India, Mexico, Namibia, southern Spain, and Crete, are individual elements of a regional

development strategy that could provide sufficient incentive to manufacturers and to private developers to seek commercial competitiveness in the technology.

12. **Russia**. Russia possesses enormous reserves of conventional fuels, nonconventional fuels, and hydro resources, making the development of RE resources problematic. There are nonetheless some places in which RE development would have economic merit. For example, the northern territories, which have large ethnic populations and sensitive environments, do not have access to energy networks and their present mode of energy supply is uneconomic. These territories are endowed with good-to-excellent wind and abundant biomass resources, and the development here of RE resources therefore would make good economic and environmental sense. Local manufacturing capabilities and the ongoing conversion of defense industries to civilian applications furthermore could contribute low-cost equipment to the development of RE resources, which in turn could help ensure continued local employment. In Kamchatka and the Kuril islands in eastern Russia, the existence of geothermal resources also seems viable, provided the demand exists and prices are right. The existing institutional setup is impressive in terms of the number of institutions and their technical capabilities, but knowledge of economic and financial analysis methodologies is inadequate. Several bilateral organizations, mainly of the European Union and the United States, are helping Russia to address this weakness.

13. **Bulgaria**. The Bulgarian energy system is characterized by high fuel imports and an unreliable and low-efficiency electricity system. The local fuel is a highly polluting, low-grade coal, and the nuclear plant at Kozloduy is known for its less-than-adequate safety features (although this inadequacy has been improved with foreign technical assistance (TA)). Installed capacity is large, and demand has drastically dropped. Assuming that demand will pick up in the future and raise prices to higher levels, as the World Bank believes is imperative, the most promising RE development is in biomass (mostly in the form of agricultural waste), small hydro, and wind at favorable sites of the Black Sea, such as the Kaliakra peninsula. Given that Bulgaria imports most of its fuel and that it has relatively high insolation, solar water heaters also could be an economically viable industry. The country is host to active technical assistance programs in the RE and energy efficiency subsectors; the introduction of RE applications will reduce its heavy dependence on fuel imports and provide alternatives to substitute for the capacity of the four units of Kozloduy that, by agreement with the G7 leading industrial nations and other donors must be shut down and retired in the near future.

14. **Kazakhstan and the Kyrgyz Republic**. Kazakhstan and the Kyrgyz Republic were the focus of an intensive regional study supported by a separate ESMAP project. A separate report was issued at the conclusion of this study. Since the study was initiated under the regional studies project, it is included in the present report.

15. **Kazakhstan** has large reserves of conventional resources, but these are largely undeveloped and would require extensive network development or upgrading to be able to service what is a very large territory. The problem of Kazakhstan's size is further compounded by the fact that the country comprises two fairly well developed regions (the north and the south) separated by a largely unpopulated steppe, and that the two regions are connected only with weak networks. In addition, the system suffers from high losses

and low reliability. The exploitation of its good RE resources could improve the energy supply picture in the country. Wind resources, particularly at the Djungar Gate near the eastern border with China, are excellent and could be developed to provide end-of-line support to the network and perhaps to make power exports. A feasibility study financed by the United Nations Development Program (UNDP) was undertaken to analyze the economic potential of wind development at Djungar Gate, and plans for investments are being discussed. A number of small hydro sites also are promising and could be developed to reduce the high dependence of the power system on polluting coal. Photovoltaic cell development could be viable for the country's nomadic shepherds, who do not have access to electricity.

16. **The Kyrgyz Republic** has a low endowment of conventional fuels but possesses good hydro resources that are only partly developed. The country's motivation for RE development is provided by the need to reduce fuel imports, the desire to provide rural nomadic populations with electricity, and the existence of an important manufacturing capability in solid state semiconductor materials at Orlovka and Tashkumyr. In addition to hydro power, solar water heaters could play an important role, as the number of sunshine days is high. Since the market in the Kyrgyz Republic is small, consideration of the potential demand in neighboring countries of the region underlines the merits of a regional approach to market development. This is particularly applicable to the market for solar home systems based on photovoltaic cells. Low electricity prices are, however, a serious impediment to RE development.

17. **Armenia**. The main characteristic of Armenia's energy system is its total dependence on imported fuels, brought in with difficulty because of an inadequate transportation network. This factor has curtailed economic development in this land-locked country, particularly in the last 10 years. In addition, the electricity system depends to a large extent on the Soviet-built Medzamor nuclear reactor. Armenia thus clearly has a strong motivation to develop its indigenous RE resources. The short visit by the World Bank mission identified the potential for development of solar water heater technology, most likely with a foreign partner; the potential of small hydro power generation; and the potential of biomass, in the form of agricultural or forest waste, for local district heating boilers. Geothermal resources also exist and merit examination. Strong interest by bilateral assistance agencies has provided Armenia with support for a number of studies and small pilot projects; these could form the basis for the larger development of RE resources in the most promising applications.

18. **Georgia**. Georgia was assigned by the FSU to develop hydro resources in the Caucasus region. Its electricity system consists of a large hydro component and one large thermal plant. The country is heavily dependent on imports of fossil fuels. Although the principal priority is the rehabilitation of existing plant, RE resources could be developed in the future with economic advantage. The most promising technologies are wind, in regions with good resources, and solar water heaters; there is also some limited potential for the exploitation of geothermal resources for district heating applications.

19. **Regional Aspects (Central and Eastern Europe)**. Regarding the above countries as a group, certain regional aspects emerge. First, they all share the legacies of the Soviet Union, notably in their economic structure, mentality, and methodologies.

Second, they depend on each other for a number of goods and services and are trying to transition to a *modus operandi* appropriate to a market economy framework. The development of regional markets would be a natural outcome of this effort: on the supply side, complementary industrial capabilities could be identified and joint development and production activities could be organized; on the demand side, enlarged markets for goods and services could be created and marketing efforts performed more effectively.

Renewable Energy Potential in Selected Countries

Volume I: North Africa, Central Europe and the Former Soviet Union

Energy Sector Management Assistance Program
(ESMAP)

1

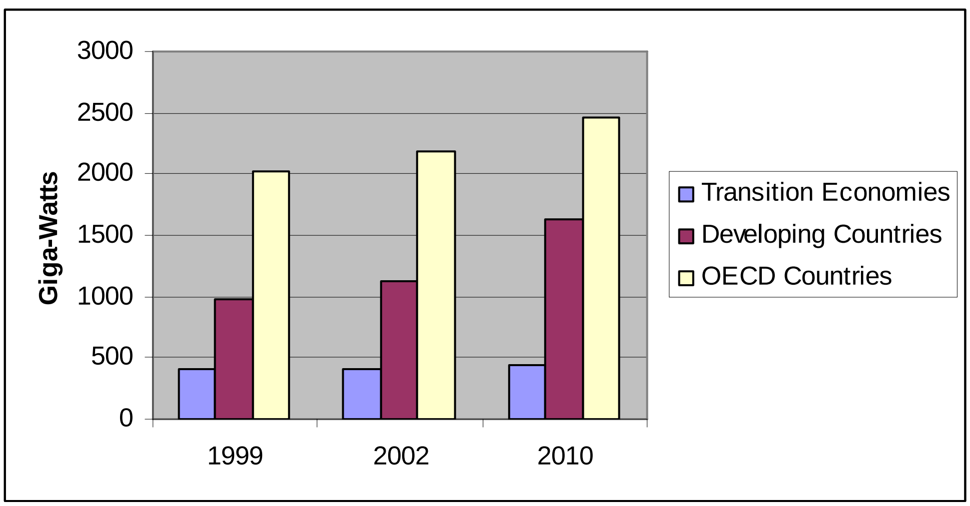
Introduction

The Driving Forces

1.1 Renewable energy (RE) resources have been attracting growing interest both in the industrialized and in the developing world. The main drivers for this interest and activity are the expected strong demand for energy in the developing world; environmental concerns, particularly of the risk of climate change as a result of the accumulation of greenhouse gases in the atmosphere; the need for least-cost energy for rural poor populations; and the recent technical and cost improvements in RE technologies.

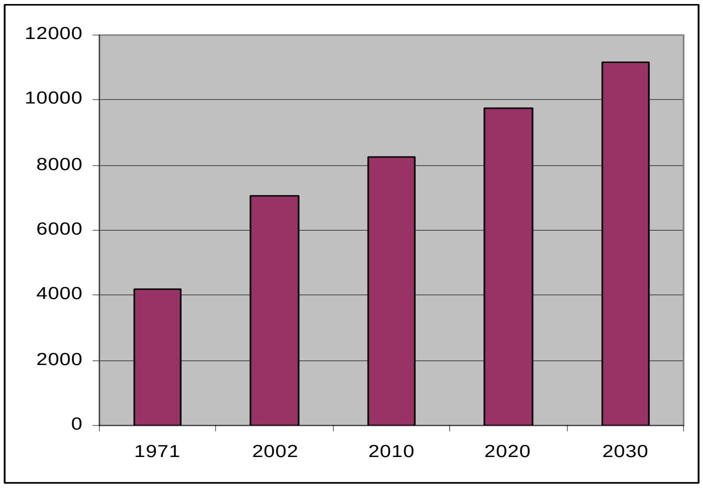
1.2 **Strong Demand Growth**. Although the demand for energy in industrialized countries is slowing down and is expected to level off or even decline, in developing countries it is expected to show continued growth. This trend is shown in Figure 1.1, which exhibits past and forecast future generating capacity.

Figure 1.1: Net Installed Generating Capacity



Sour**ce:** World Energy Outlook 2004

Figure 1.2: World Energy Consumption Scenarios (historic and forecast)



Source: World Energy Outlook 2004

1.3 **Concerns about Climate Change**. With the exception of nuclear and hydro[1] energy, the fuels used in electricity generation release, at varying rates, so-called greenhouse gases to the atmosphere. These greenhouse gases have the capacity to bring about climatic changes that could be highly disruptive of social and economic life. The broad global scientific consensus[2] on this subject is remarkable. The global dynamics of energy demand and availability of resources suggest that the use of fossil fuels will continue rising, thus further destabilizing the atmospheric dynamics. For economic as well as environmental reasons, energy efficiency measures therefore are both important and desirable; however, these measures alone cannot bring about a reduction in carbon emissions given the pressures to satisfy unmet energy demand, particularly in developing countries. The "natural" net absorption rate of carbon by the earth's oceans and land is considered to be about 2–3 billion tonnes, but the carbon emission rate is about 6 billion tonnes per year and is growing almost in direct proportion to energy demand. Even within an energy-efficient scenario, it is conceivable that emissions could exceed 10 billion tonnes per year in 20 years and 20 billion tonnes in 50 years (Figure 1.3).

1.4 **Energy for Rural Poor Populations**. Another strong motivating factor for energy professionals is the fact that about 2 billion people of the earth's population do not have access to modern energy services. Such services are pivotal for the improvement of the quality of their lives. The World Bank's World Development Report of 1992 noted that a number of health hazards threaten the lives of those children and adults who depend on traditional fuelwood for their energy supply. In 1996, the Bank issued a major paper on improving energy supplies to this underprivileged segment of the population (IBRD 1996). Central to the mission defined in the paper is the potential role of

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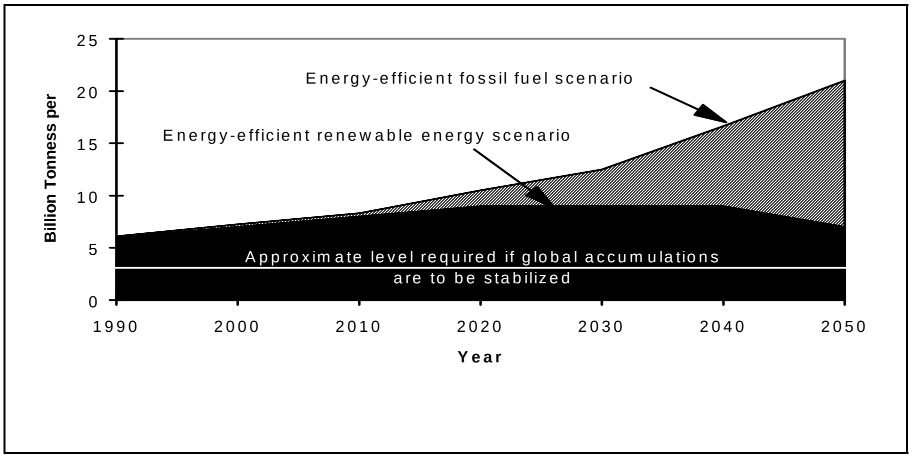
[1] Lakes, particularly in the tropical zones, emit often large amounts of methane, one of the primary greenhouse gases. This methane commonly originates as a result of biodegradation or, in some cases, of subterranean processes.

[2] See the periodic reports of the Intergovernmental Panel on Climate Change (IPCC).

renewable sources of energy, such as direct solar, wind, and biomass, in providing environmentally sustainable and least-cost electricity supply to rural areas.

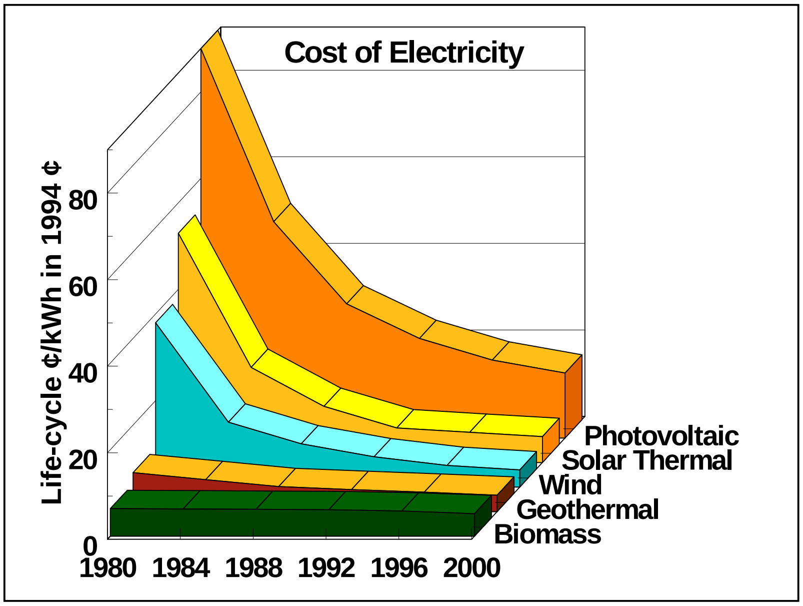
Figure 1.3: Global Carbon Emissions under Two Scenarios



Source: Anderson (1991; 1994).

1.5 **Developments in RE Technologies.** A shift away from fossil fuels in energy production seems the only realistic scenario if the total accumulation of greenhouse gases in the atmosphere is to be stabilized. Several renewable energy technologies are emerging, notably solar technologies (mainly direct conversion through photovoltaic cells, or solar thermal schemes for hot water or power generation), biomass, geothermal resources, and wind. The cost of most of these technologies has come down significantly in the past 10 years, such that they now are close to being or are actually commercially viable. They are interesting to investors for other reasons, also: (a) their modularity renders them suitable for large as well as for small-scale applications, and means they are more flexible in meeting forecast demand; (b) their short lead times reduce risk and financing charges; (c) they have potential for market expansion and rapid dissemination, particularly in developing countries that possess good renewable energy resources, such as high insolation; and (d) they have favorable land-use features (for example, solar plants enable the use of desert areas and windfarms enable multiple use of land). The comparative ease and speed of decommissioning once a plant has completed its useful operational life—for practical purposes, we are dealing with "reversible" technology—is likely to be a further attraction. Finally, the modularity of a solar installation may allow for "live" maintenance (i.e., maintenance while the plant is operating); this too should help to improve operational performance and reduce maintenance costs. These advantages have attracted considerable private sector interest.

Figure 1.4: Photovoltaic Module Cost



Source: Lallement, PPT presentation, "Lallement's PPP to WEC.BuenosAires.102401-F"

1.6 Technical developments and an accumulation of operational experience have helped drive down the cost of renewable energy. Consider photovoltaic (PV) cells, the historical and projected costs (Figure 1.4). In the early 1970s, PV modules (a collection of PV cells) cost several hundred thousand dollars per peak kilowatt (kWp) produced, and applications were largely confined to aerospace and other specialized uses. By the early 1980s, costs had fallen to around US$ 25,000 to US$ 50,000 per kWp; by 1990, they had fallen to US$ 6,000 per kWp, making PV modules commercially viable for a wide range of small-scale uses. In industrial countries, PV cells are used to generate power for telecommunications, to provide cathodic protection of oil and gas pipelines, as a source of electricity in homes and buildings, and in various "luxury" applications. Demonstration projects using PV modules as a source of supplementary grid power are also being conducted in several OECD countries, with positive results.[3] In developing countries, common applications are for village and domestic lighting, water pumping, battery charging, and to supply electricity to rural health clinics and schools. An interesting point about this development is that PV modules typically are supplied by

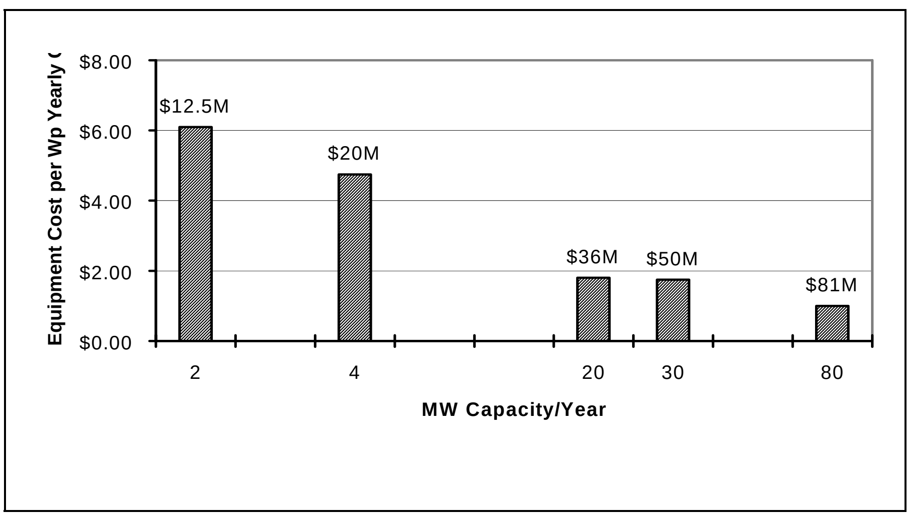
[3] In June 1997, an award was announced by the Greek Government for a 5 MW-peak grid-connected plant on the island of Crete. The project, which enjoys financial support from the European Union, is to grow to an eventual size of 50 MWp in 9 MWp additional trenches, bringing the project to its full 50 MWp output in 2003. The cost of the first trench is estimated at US$ 17.75 million, or US$ 3.55 per Wp, with the total 50 MW project cost estimated at US$ 120 million, or US$ 2.4 per Wp. It is also interesting to note that the project has been structured as a BOO project, with the plant owner selling electricity to the local island grid at US$ 0.082 per kWh. This price is set in accordance with a Greek law of 1994 that obligates the public power company to purchase power from private plants generating energy from renewable energy sources. A similar PV scheme, to use World Bank financing and Global Environment Facility (GEF) grant support, is being considered for the state of Rajasthan in India. Similar power schemes are also under negotiation for Nevada and Hawaii in the United States.

market vendors at prices that fully cover cost (the systems also are taxed) in contrast to grid-supplied electricity, which is subsidized. Engineering and economic data suggest that further progress can be expected on at least two fronts:

- *Scale economies and technical progress in production.* This point is illustrated in Figure 1.5, which shows the required manufacturing equipment cost, and Figure 1.6, which illustrates the investment per MWp for various scales of PV manufacturing, with corresponding module prices. Although the information depicted in the figure comes from one PV manufacturer, several other firms confirm that it is basically correct (some say it is too optimistic, while others state that even greater cost reductions are possible at these scales). The curve shown in Figure 1.6 is similar to the S-learning or experience curve that has been observed in many industrial applications as they penetrate the market. Figure 1.6 exhibits a steep decline in the range between a 2–4 MW plant and a 10–20 MW plant. This transition in the cost curve is where the PV industry finds itself at present, with the largest plants operating at a capacity of 8–12 MW.

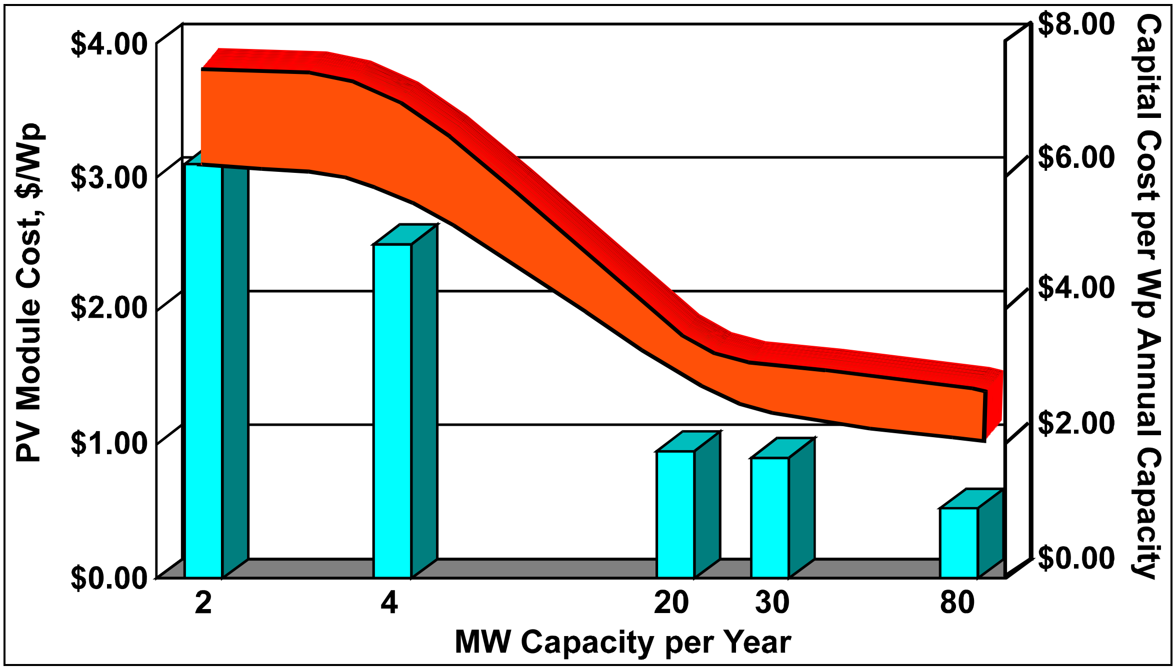
- *Further developments in cell, module, and systems design, and improvements in conversion efficiencies.* Work is proceeding on the development of improved materials, the use of multijunction devices and novel cell designs to capture a higher proportion of the solar spectrum, and the use of concentrator (Fresnel) lenses to focus sunlight onto high-efficiency cells.

Figure 1.5: PV Manufacturing Equipment Cost



Source: Global Environment Facility

Figure 1.6: Manufacturing Scale and Module Cost



Source: Global Environment Facility

1.7 The U.S. Department of Energy has projected that, with market expansion, the cost of PV electricity generation should eventually decline to about US$ 2 or less per Wp (including balance-of-systems costs) (Annan 1992).

1.8 Progress in solar-thermal schemes also has been noteworthy. Experience with solar-thermal power stations dates only to the mid-1980s, and with only 350 MW of capacity having been built and set into operation (in the state of California), the cost dynamics have not been demonstrated clearly. However, solar-thermal schemes have been technically proven for large-scale generation, at costs of US$ 3,000 per kW and US$ 0.12 to US$ 0.20 per kWh. Steam conditions compare well with those of fossil and nuclear stations, typically 6,900 kPa (1,000 psi) and 370° C (700° F), and at Kramer Junction in California, operational performance has improved over the approximately 10 years that the solar fields there have been in operation.[4] Further, as with PV modules, economies of scale in manufacturing are far from being achieved and the technical possibilities have scarcely been explored. For example, central receiver technologies offer the prospects of major efficiency gains and reductions in costs through significantly increasing steam pressures and temperatures, and thermal storage schemes that would make this technology suitable as a dispatchable unit are also being investigated.

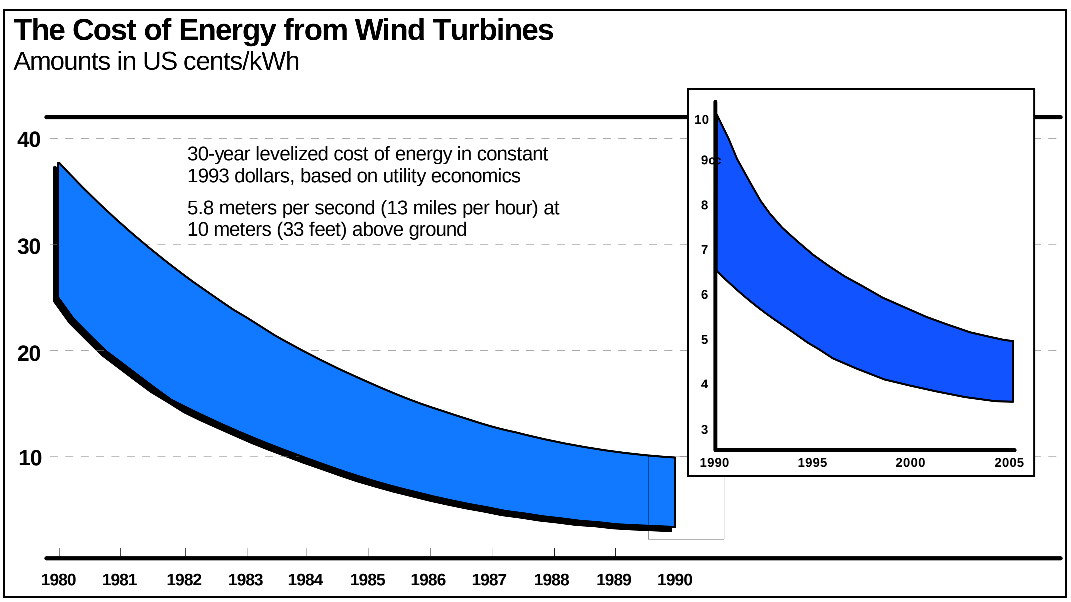
1.9 Research on a range of materials and design concepts is proving fertile, and ample scope remains for further gains in conversion efficiencies, from the present 7–15 percent range to the 15–30 percent range for both PV modules and solar-thermal

4 Availability is reported to be 99 percent and total output is 108 percent of peak rated capacity.

stations. The potential is especially large in many developing countries where solar insulation is high and energy markets are growing rapidly.

1.10 Significant progress has also been made in derived forms of solar energy, such as the use of wind and biomass resources for power generation (Johansson et al. 1993; Ahmed 1993). In the case of wind, costs have declined from around US$ 0.15–0.25 per kWh to US$ 0.04–0.08 per kWh in favorable locations (Figure 1.7). Technical developments have been rapid and impressive, most notably in the areas of more efficient blade designs, the use of lightweight but stronger materials and variable-speed drives, and the elimination of reduction-gear mechanisms through the introduction of electronic controls for frequency and voltage regulation. As a result of these cost reductions and of favorable policies and financial incentives in many industrialized and developing countries, wind development has seen dramatic growth worldwide (Figure 1.8). The United States had a strong lead in the 1980s and early 1990s, but the growth in wind power in the mid-1990s has been most noteworthy in Europe and the rest of the world,[5] reflecting the different historical development of renewable energy policies and incentives in these countries. Less often noticed have been the declines in the costs of biomass energy—for ethanol and for power generation—reviewed by Ahmed (1993). Booth and Elliott (1990) provide a succinct review of the prospects for further reductions in the costs of power generation from biomass.

Figure 1.7: The Cost of Energy from Wind Turbines



Source: U.S. Department of Energy

1.11 As a result of these developments, interest increased among the World Bank's shareholders as well as in borrowing countries for an accelerated program of renewable energy development. World Bank activities in alternative energy resources, focused primarily in the Asia region, have been proceeding for some time, but were

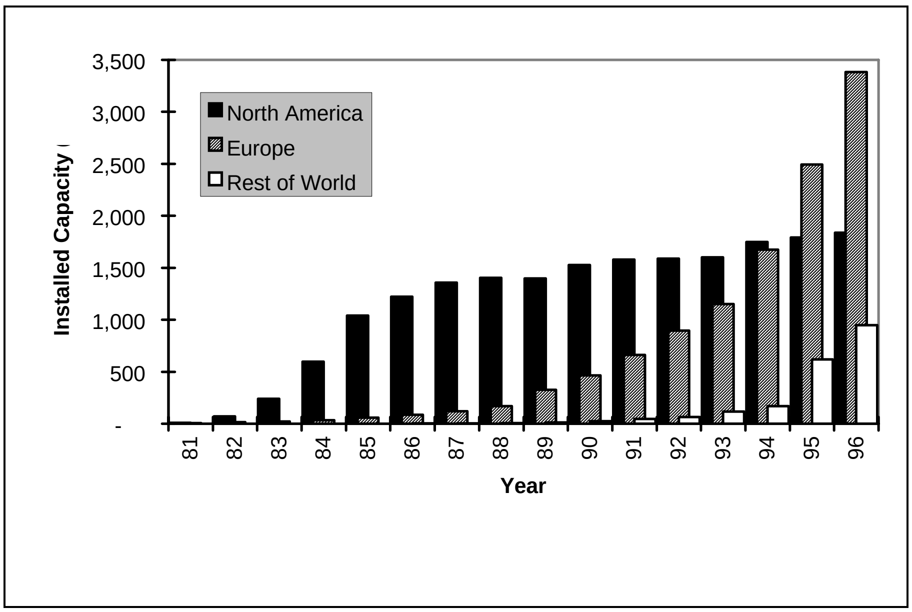
5 The largest portion of the category "rest of the world" is represented by India, where more than 750 MW of wind power has been installed in the last few years.

expanded as a result of the heightened concerns on global climate change raised in the Rio de Janeiro Conference of 1992 and of the cost reductions being realized in renewable energy, a broader initiative was needed.

The 1994 Solar Initiative

1.12 Several units in the World Bank Group have been working in developing standalone projects or project components featuring renewable energy applications. These include technical departments and operational divisions in the Asia, Africa, Latin America, South Asia, and Middle East regions; the Asia Technical Alternative Energy (Department) (ASTAE); the Energy Department; the Environment Department's Global Climate unit (ENVGC) at the central part of the Bank; and the Technical and Environment Departments of the International Finance Corporation (IFC). The term "Solar Initiative," originally referred to a program launched by the Energy Department Power Division (IENPD) in the spring of 1994 to refer to the collective efforts of all units Bank-wide in renewable energy development.

Figure 1.8: Wind Energy Capacity Worldwide



1.13 The Solar Initiative was established with two major objectives: (a) to provide active support to the Bank's regional units for the identification and preparation of renewable energy (RE) projects that are commercial or near-commercial; and (b) to play a coordinating, strategic, and catalytic role in removing barriers that impede the introduction of renewable and other environmentally sustainable technologies in developing countries, including facilitation and coordination of international activities in research, development, and demonstration (RD&D). Within the Bank Group, the first objective called for more proactive efforts to identify and include renewable energy projects in the lending portfolio. The reference to near-commercial applications is significant, as it deviates somewhat from the Bank's fundamental principle of financing least-cost projects of proven technology that are fully commercial.

1.14 The economic logic being applied in this case was based on the following two premises: The first is that the incrementally higher cost of near-commercial applications could be offset by global environmental benefits, thus "equalizing the field" vis à vis conventional energy forms and technologies that incur negative global externalities which are not included in their cost calculation. The second was to recognize the positive externalities of technical progress and innovation that will be encouraged by expanding the market for renewable energy. As with the case of negative externalities, there is a simple but powerful insight from elementary economic theory to weigh alongside more subtle factors concerning risks and public and private responsibilities. The simple insight is that a subsidy or tax incentive on investment expenditures can be justified so long as there is evidence that further investment itself will help to further reduce costs, for example, through learning-by-doing or by leading to further innovation. This new approach has enabled the identification, appraisal, and approval of a number of standalone renewable energy projects in the past few years.

The Global Environment Facility

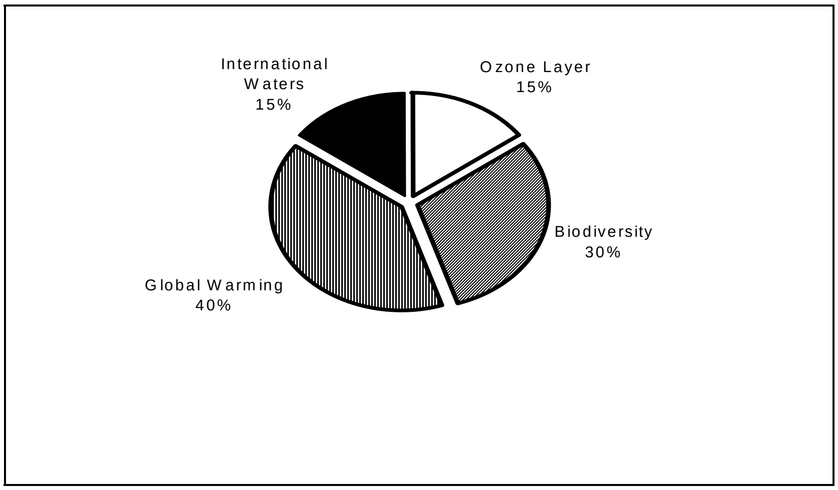
1.15 An important impetus for this development was provided by the establishment of the Global Environment Facility (GEF), which after a first pilot stage has been restructured and replenished and is now in its first official phase, known as GEF-I. This facility, reflecting the worldwide concern about global environmental degradation highlighted during the Earth Summit Conference in Rio de Janeiro in 1992, raised commitments of about US$ 1.5 billion to provide incremental funding on a grant basis for projects that have substantial long-term environmental benefits (Figure 1.9).

1.16 Four areas of environmental concern were covered by the GEF: (a) ozone layer depletion, (b) ocean water pollution, (c) loss of biodiversity, and (d) global climate change. About 40 percent of GEF funds are allocated to projects that seek to reduce greenhouse gas emissions into the atmosphere and hence to alleviate concerns about global climate change.

1.17 The GEF provides incremental grant financing of projects that fall into one of the above categories under the following conditions: (a) the project is not economically viable if compared with conventional options due to differential technology cost, institutional barriers for initial introduction, or high transaction cost, but has the advantage of mitigating greenhouse gas emissions; (b) the recipient (developing) country must be eligible by having signed and ratified the Framework Convention for Climate Change (FCCC); and (c) the government of the country must submit an official request stating that the project is part of its overall strategy to fulfill its obligations under the FCCC. GEF grants usually go to the government but can, with the government's consent, go directly to the private sector developer and owner of the project.

1.18 The projects that are submitted to GEF for support are defined under two categories: Type I and Type II. Type I projects are those for which the national benefits (NB) are greater than the national costs (NC), and which offer global benefits (GB) in the form of reductions in carbon emissions (NB>NC and GB>0). These are projects that developing countries should be undertaking in their own best economic interest, using official aid as and when conditions require and merit it, even if global warming were not an issue and the GEF did not exist (these are often referred to as “win-win” projects). Good examples are the economically efficient use of flared gas or coal-bed methane for power generation; reducing waste in the production and use of energy through price and institutional reforms; afforestation programs on farmlands and watersheds (in which carbon-fixing is a by-product); the substitution of commercial energy for traditional cooking fuels; and the use of PV modules and small hydro schemes for electricity supply in remote areas when the costs of alternatives, for example diesel gen-sets, would be higher.

Figure 1.9: Global Environment Facility Funds



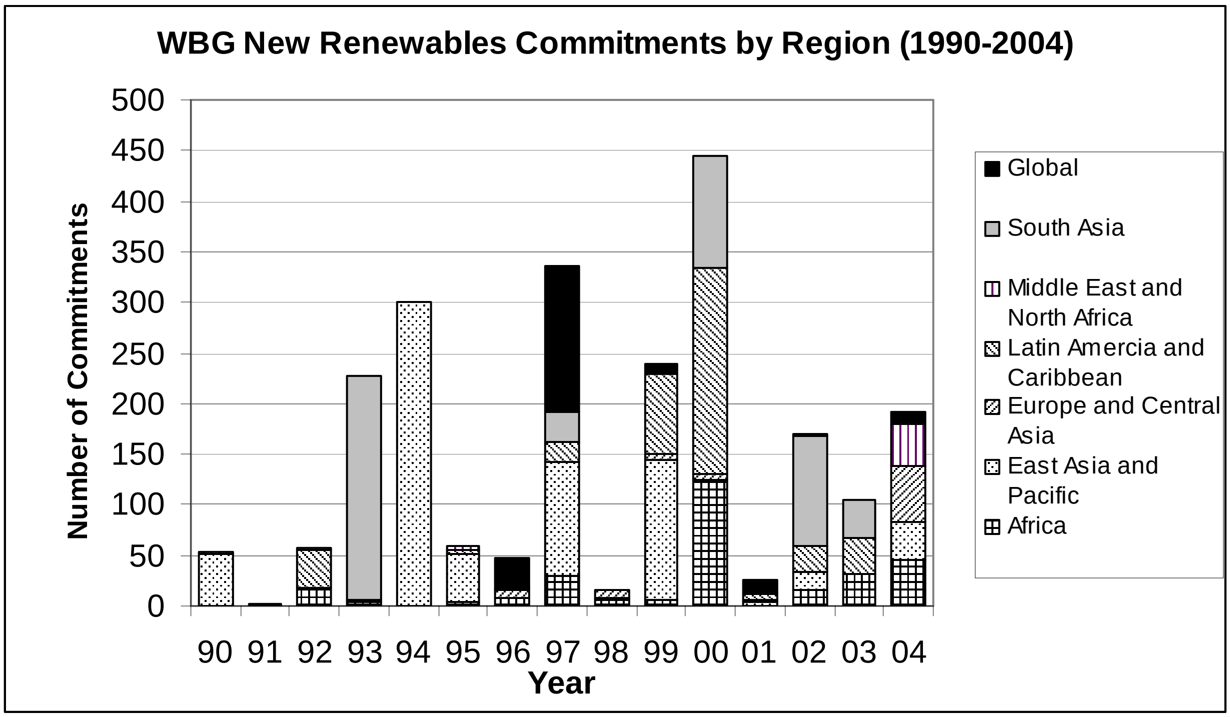
Source: Global Environment Facility

1.19 Type II projects are those for which the national economic benefits are less than the national economic costs (NB<NC), but whose global benefits are such that the project is justified under GEF criteria (NB+GB>NC). Several types of project fall into this category, including PV modules, solar-thermal power systems, wind power, biomass power based on gasifiers and gas turbines, sustainable biomass production to substitute for fossil fuels, fuel cells, and various projects that move the energy efficiency frontier outward. Examples of the latter category are efficient lighting and water heating; advanced, high-efficiency gas-turbine cycles; irrigation pump sets powered by renewable energy; and reducing the energy intensity of industrial processes.

1.20 Whereas Type I projects are provided for by official development assistance programs Type II projects are not, and therefore the GEF is concentrating its efforts on the latter. It nonetheless can consider Type I projects on an exceptional basis. A number of technologies and applications already meet the economic criteria, as noted above, including PV modules for rural electrification and special applications; windparks, where favorable resource conditions exist; and certain biomass applications for power generation. As experience is gained and the technologies slide down the learning curve, such projects will help reduce the cost of Type II applications elsewhere. GEF funds can be blended (leveraged) with commercial and other development assistance funds (as in the case of the India Renewable Energy Project), thus reducing the development and transaction costs faced by GEF recipients in developing projects elsewhere and greatly enhancing the scope and effectiveness of GEF funds.

1.21 As a result of GEF support and of the Solar Initiative, the number of renewable energy projects financed by the Bank grew remarkably during the last few years, as shown in Figure 1.10.

Figure 1.10: New Renewables Commitments by Region (1990-2004)



Source: World Bank

ESMAP Activities

1.22 In the renewable energy field, the main purpose of ESMAP activities was to provide support for RE national or regional strategies, followed by project identification and preparatory studies. ESMAP has played an important role as funds are scarce at the initial stages of strategic planning and project identification (they become more readily available at later stages, once a viable project has been identified). The reason for this is obvious: the risks are higher at the initial phase as uncertainties may be large about resource assessment, economic and financial viability, the existence and strength of local partners, and the local institutional framework and conditions. Careful planning and selection of countries or regions is needed to minimize the risk of a failed endeavor—although it must be recognized from the outset that only a limited number of cases explored will bear fruit.

1.23 The screening process to limit the range of investigation includes the perusal of extant studies and other relevant material; consultations with agencies and persons that have performed related work in the country or region; taking the advice of resident missions; and making exploratory, low-cost missions as a preamble to determining in which countries or regions it is worth investing the resources necessary for more extensive studies. In addition, ESMAP leveraged its funds with resources from other agencies and organizations that have a shared interest in the work. As will be explained in the individual studies described in this report, such leveraging of funds was successfully done in almost all cases.

1.24 **Phase I** of the review of the potential for renewable energy in selected countries covered two regions:

- North Africa, focusing on Morocco, Tunisia, and Egypt, which are considered likely to move forward to the development of RE projects

- Central Europe and the countries of the former Soviet Union, particularly Armenia, Bulgaria, Georgia, Kazakhstan, the Kyrgyz Republic, and Russia

1.25 **Phase II** focused on work performed in Latin America and the Caribbean.

1.26 The report is structured as follows: for each country, the work performed is summarized, giving the preliminary resource assessment, price, and institutional framework; local capabilities and institutions; preparatory work performed; bilateral and multilateral assistance programs; and plans for project preparation and/or implementation. Overall conclusions for each country or region are also offered.

2

North Africa Region

2.1 **Regional Strategies.** A regional strategy often is crucial to the development of a renewable energy market. For example, in Tunisia a solar water heating program is underway. Solar thermal power technology, based on parabolic trough collectors, examined for Morocco and for Egypt and Tunisia. Israel, perhaps in collaboration with Jordan, also is planning to install such a plant. Proposals for solar thermal plants on the Greek island of Crete and at Huelva in southern Spain have been submitted to the European Union Commission for support. A Mediterranean strategy involving both industrialized and developing countries thus is emerging, creating a strong market for solar technology. This could lead to a decrease in production costs that in turn could enhance the economic viability and hence the market penetration of this technology. Depending on the outcome of prefeasibility studies and, should the countries concerned request them, the GEF and the World Bank could support further feasibility studies and investment projects in this technology. It is important to note that the Mediterranean strategy for this technology is being complemented by the project now under preparation in India to which the GEF recently committed US$ 49 million in grant support; projects under consideration in other developing countries possibly also could complement the strategy.

Egypt

RE Work to Date

2.2 The government of Egypt realized in the early 1980s that conventional energy resources would fall short of satisfying the country's needs in the long run. Accordingly, a national strategy was designed to include exploitation of the country's several renewable energy resources, particularly wind, solar, and biomass (World Bank/ESMAP 1996). The strategy included, among other objectives, a target for RE utilization and development. Specifically, RE was targeted to meet at least 5 percent of primary energy needs by the year 2005.

2.3 Egypt has taken many strides in the RE field since the early 1980s. In line with developments in conventional energy resources, RE has evolved in its role as a contributor to the overall energy supply situation. RE utilization and development has predominantly concentrated on the following applications: small windfarms, solar water heaters, solar thermal industrial process heat, and PV for village and remote applications.

2.4 **Wind**. To date, the Hurgahada windfarm is the largest operational windfarm in the North Africa and Middle East region. More than 40 wind turbines have a total installed capacity of 5 MW.

2.5 **Solar thermal** technologies have been widely demonstrated for application in domestic solar water heaters. About 200,000 m^2 of collectors are in operation;[6] solar industrial process-heat applications in food and textile plants also have been designed, built, and tested.

2.6 **Solar photovoltaic** systems range from those with capacities of less than 35 kWp (adequate for an ice making machine, for example) to about 2 MWp.

2.7 **Biogas** applications. Work done by the National Research Center and the Agriculture Research Center has produced more than 80 demonstration biogas plants. The majority of these are of household size; three or four are of farm size.

2.8 Additional activities in RE development include:

- a solar atlas for Egypt
- a total of 2 MWp of PV applications
- a wind energy measuring network composed of 35 sites
- a wind atlas for the Gulf of Suez coast
- one local manufacturer of PV modules with a yearly production of 500 kW
- nine local manufacturers producing solar water heater components and systems

Renewable Energy Potential

2.9 Egypt has abundant RE resources, including wind, solar, hydro, and biomass. To determine the potential for RE utilization and development for the year 2005, resource cost curve (RCC) analysis was carried out for the most promising technologies: solar thermal power, solar thermal for industrial process heat, photovoltaic conversion, wind, and biomass. (Hydro is not considered in this study, as the potential has been almost fully exploited.)

2.10 Particularly good conditions exist for **wind energy**, with excellent sites existing along the Red Sea and Mediterranean coasts. Sites with annual average windspeeds of about 8.0–9.0 m/s have been identified along the Red Sea coast and with speeds of about 6.0–6.5 m/s along the Mediterranean coast. The RCC shows that by 2005, 1.7 GW of wind energy systems could be installed at levelized costs of US$ 0.05/kWh or less. However, based on the plans of the Ministry of Electricity and Energy, the upper practicable limit of exploitation is 1 GW.

2.11 Solar radiation intensity is high, at about 2,000–2,200 $kWh/m^2/y$. Toward the southern desert regions, it reaches about 2,500–3,200 $kWh/m^2/y$. The RCC analysis

6 This is a small quantity considering the size of the population (60 million in 1996) and the insolation in Egypt. Greece, for example, with a population of 10 million has about 2 million m^2 of collectors.

shows that by 2005, 140 GW of solar energy could be installed at levelized costs of US$ 0.05/kWh. The Ministry of Electricity and Energy derived upper practicable limits of 0.7 GW of solar thermal electricity generation and 0.3 GW of photovoltaic systems.

2.12 Projected at a modest 3 percent of total consumption, the use of **solar thermal** for industrial process heat would produce savings of about 500,000 toe/y. However, the potential for penetration is hampered by the obsolete design of the process plants and the fact that conventional methods for energy conservation could be two to three times as effective in delivering energy savings.

2.13 **Photovoltaic** conversion, the costs of which are US$0.20–0.40/kWh, was found to be most suitable for standalone applications. Although Egypt has experience in targeted applications such as advertising, telecommunications, signaling, refrigeration, and cooling, the further exploitation of this application will be dependent on the willingness of users to pay. PV conversion is likely to be limited to small, remote systems.

2.14 The most promising **biomass resources** are identified as animal farming waste, used as feedstock for biogas digestors, and municipal solid waste, used as boiler fuel. The biomass potential in Egypt is about 90,200 Gcal/y. By 2005, 0.25 GW of biomass generating capacity could be developed.

Institutional Aspects

2.15 Many organizations have been involved in the RE field, including the National Research Center (NRC), universities, and other public organizations. The activities of these organizations range from exploratory research to the implementation of pilot and demonstration projects. The main impetus behind the development of RE has been the New and Renewable Energy Authority (NREA). Established in 1986, the NREA laid the foundation for the development of RE initiatives and paved the way for a strengthening of the future role of RE technologies. However, further institutional development is needed, as described below.

Recommendations for Further Work

2.16 The goal for RE utilization and development, as set by the Egyptian authorities, is for RE to supply 5 percent of the country's primary energy needs by 2005. In general, the objectives for RE development should be in line with the government's energy sector objectives, which are to move systematically to a market-oriented economy, specifically by giving the public sector greater autonomy and by increasing private sector participation in energy ownership and operations. In line with the energy sector objectives, specific RE objectives should be to:

- maximize the contribution of RE to the Egyptian energy balance and to ensure RE has a significant impact on the economy;
- build RE systems and projects where economically viable and environmentally beneficial;
- take appropriate measures to develop renewable technologies and to implement applications that are approaching technical maturity, and encourage local participation;

- strengthen and transform the NREA into a commercially oriented entity;
- identify and mobilize innovative financing mechanisms to support RE projects and programs;
- pursue private sector involvement in RE project development and operations;
- benefit from periodic training and development on RE project management and operations; and
- strengthen local manufacturing capabilities in the field of RE utilization and development.

2.17 Based on the current level of progress in the RE field, the original target of 5 percent of the country's primary energy to be supplied by 2005 from nonconventional sources such as wind, solar, and biomass is unlikely to be achieved. The revised target suggests instead a figure of about 2.5 percent.

2.18 One particular problem for the dissemination of RE projects is the weakness of the existing institutional structure. The NREA is a policy setter as well as a project implementor. If the present pilot and demonstration projects are to be carried forward as large-scale commercial projects, the NREA needs institutional capacity for project-oriented task assessment, evaluation, analysis, financial modeling, risk-analysis, and so on. In the short to medium term, international experience suggests that the NREA should take over the responsibility of owning and operating RE power plants. In the long run, the NREA can divest itself of its operational responsibilities and concentrate on promoting the RE industry in Egypt.

2.19 Based on the expected changes in the power sector, the establishment of a separate and transparent regulatory mechanism for overseeing the power sector operations is recommended. The tasks of such a mechanism would include the sanction of licenses for new plants, adjustment of prices based on predefined criteria, and setting the rules of entry and exit for private sector participation.

Morocco

General Energy Sector Considerations

2.20 Morocco has a variety of energy resources, including oil, natural gas, oil shale, coal, hydro, uranium, biomass, wind, and solar energy. However, the proven reserves of conventional energy sources are either small or have a high unit cost of production. Morocco imports around 90 percent of its energy needs, principally as oil but also as gas, coal, and electricity. Recent developments in the energy sector have been characterized by wide reforms that have included market liberalization, commercialization of the state energy monopolies, and the involvement of private sector investment in new infrastructure. The objectives of this restructuring are to reduce the burden on government finances and to improve the efficiency of the energy enterprises.

2.21 The Moroccan authorities face pressing energy-related problems, especially in rural areas. Those listed below are particularly significant:

- The need to increase rural electrification above the current level of 25 percent.
- Reduction in the use of wood as a fuel. The burning of fuelwood supplies close to 25 percent of primary energy; such a level of use is not sustainable and is causing progressive deforestation, with all its consequent effects.
- The need to increase the supply of water to counter the effects of the severe droughts that have plagued the country for the past 12 years or so.

2.22 A preliminary assessment of the RE potential in Morocco was undertaken, with ESMAP support, in the context of a prefeasibility study for a solar thermodynamic project to provide power for the grid.

RE Potential

2.23 Renewable energy is assuming a more prominent role in helping Morocco to meet its energy needs. The expansion of RE—in forms in addition to the long-standing supply of elecricity from hydropower and of traditional biomass fuels—represents the application of technologies developed and commercialized in developed countries over the last 20 years.

2.24 The RE technologies with the most promising near-term applications in Morocco are: (a) wind-generated electricity to supply the Office National de l'Electricité (ONE) grid; (b) solar thermodynamic power for grid-connected installation; and (c) small-scale electricity supply from PV panels for rural lighting, television and radio, and battery charging.

2.25 Regarding **wind energy**, the proposed Morocco sites at Khoudia Blanco, near Tetouan, and Sendouk, near Tanger, have average windspeeds of 11.8 m/s and 8.8 m/s, which make them exceptionally attractive sites for wind power plants. Successful exploitation of these sites could lead to a market for several hundred megawatts in the future. The growth of wind-generated electricity will depend on decisions by ONE to add windfarms to its program of diversification of supply sources. Important steps have already been taken; following the issuance of an a Request for Proposals in November 1994 for a 30–40 MW windfarm at Khoudia Blanco, the award of contract to the winning bidder with a mutually agreed power purchase agreement (PPA) has been finalized and implementation of the project is underway. Negotiations are also well advanced for a 3–5 MW German-financed windfarm at Sendouk.

2.26 **Photovoltaic applications** are attractive for rural electrification, as Morocco has about 39,000 villages in rural areas. Some 5,000 of these villages already have some form of electricity from decentralized sources, but the remaining 34,000 are not connected to the grid. During the 1980s, the Centre pour le Développement des Energies Renouvables (CDER) installed demonstration PV projects in rural areas, and some individuals, especially Moroccans living overseas, financed the installation of PV systems to power television, radio, and lighting in the rural homes of their families. Such early demonstrations have led to a continuous and significant growth of PV installations since 1988. The market has grown at an average rate of 14.2 percent per year, reaching a level of 1.3 MW of PV imports in 1993. This rapid growth in PV use reflects three factors:

- a demand for lighting and television where grid-provided electricity is not available;
- a confidence in PV technology to operate effectively; and
- the affordability and availability of PV panels.

2.27 The government's policy decisions also support future market evolution. In 1994, the 42.5 percent duty on RE equipment was removed and an exemption from value-added tax guaranteed. These decisions, which together create a price reduction of 60 percent for PV panels, should further support the burgeoning market.

2.28 The market for **solar water heaters** continues to remain stagnant at a relatively low level, although installed systems are evident throughout the country. The lack of market expansion is disappointing, because solar water heaters can usefully substitute for the use of imported hydrocarbons, as demonstrated in Mediterranean countries with similar conditions. Small wind and micro hydro power systems in the Atlas mountains also have important potential that has yet to be developed.

Institutional Aspects

2.29 The Moroccan **Centre pour le Développement des Energies Renouvables (CDER)** is active in the field of solar thermal systems, photovoltaics, solar thermodynamics, wind energy, and biomass. CDER today is increasingly assuming a mantle of expertise in RE applications through its work in the following areas:

- actively engaging with ONE to generate grid-connected electricity based on wind and possibly direct solar;
- implementing a national decentralized electrification program using PV panels as well as conventional technologies;
- working with other government ministries to plan the use of RE systems;
- developing important databases for wind and solar insolation.

Renewable Energy Strategy

2.30 To evaluate the potential of renewable energies further, the government has expressed a strong interest in carrying out a global study in the exploitation of RE in Morocco. Such a study would focus on the potential of RE resources to solve the problems of the sector outlined above and to explore other possibilities that may emerge in the course of the study.

2.31 The aim of the study would be to recommend a strategy that would ensure the optimum exploitation of the RE resources in Morocco over the period 1995–2015. The study would cover wind, solar (PV, solar-water heating, and solar thermodynamic), small hydro (<20 MW), biomass, and geothermal resources. For these resources, the study would:

- bring together and analyze existing data and studies on the renewable resources and identify those areas which require further study and analysis;
- develop and implement an assessment methodology that would permit the mapping of the resource and its potential contribution, taking into account economic, technical, environmental, social, and demographic factors for the resources themselves and their substitutes;
- analyze the institutional and market opportunities and constraints for the development of the renewable resources;
- formulate a plan of action for the development of the various RE resources.

Conclusions and Recommendations

2.32 Morocco has one of the greatest endowments of solar energy resources in the world and its full and rational exploitation warrants a serious look. A systematic RE strategy could examine in a rigorous manner the priorities of the sector and identify the most viable projects. The development of wind energy through the work of the private sector has already made a good and substantial start. Solar thermodynamics also should be given serious consideration, as a grid-connected application in combination with gas in an integrated solar gas combined cycle (ISCGC) plant. The ESMAP effort assisted in designing the terms of reference of a prefeasibility study that was then undertaken by a consortium of European consultants with financing from the EU MEDA program. With the conclusion of the prefeasibility study, the selection of plant configuration and site, and the willingness of the local electricity authority to participate or buy power from such a plant, the next step could be initiated. With support from the GEF, which has offered to fund a feasibility and detailed engineering study, and with a further capital grant contribution from the GEF, the project could be made attractive to the private sector. Such a step could help develop a Mediterranean strategy that could bring the cost of this technology down. Photovoltaics could assist in bringing electricity to remote rural areas without incurring the high costs of grid extension. RE development would be an important tool in Morocco as the country seeks to arrest forest deforestation and to fulfill its obligation under the Framework Convention for Climate Change (FCCC). The mission, supported by ESMAP, raised the profile of RE resources with local authorities and highlighted the possibilities of financing RE projects.

Tunisia

Objective of the Report

2.33 The World Bank, at the request of the Tunisian authorities and with the support of ESMAP, launched an RE strategy study for Tunisia. The objectives of the study were to establish a clear diagnosis of problems in the sector; compare renewable and energy efficiency measures and set their competitiveness; and identify the areas in which development efforts would have the biggest impact on the energy market. The RE strategy study was undertaken with ESMAP support and was performed by a consortium of French consultants, headed by the firm INESTENE, under the management of the

World Bank's Solar Initiative (World Bank/UNDP 1996). This section summarizes the results of the study.

The Energy Sector in General

2.34 Tunisia is experiencing major change in its energy sector. Local production of hydrocarbons is decreasing, with an energy supply deficit expected by 2000 and the shortfall projected to reach as much as 7–8 Mtoe per year by 2010. At the same time, power consumption is increasing about 7 percent per year. In response to these factors, Tunisia gave its energy sector one of the highest priorities in its national plan of 1997–2001, focusing on developing the use of natural gas and accelerating the use of RE, in the belief that RE can make a considerable contribution to the problems of the sector.

RE Work to Date

2.35 The burning of fuelwood accounts for 14 percent of Tunisia's primary energy consumption. Other RE sources make low contributions to the country's energy supply, but experiments have been undertaken in almost all RE technologies and these are now well known. The costs are still high, as public financing has had little success in encouraging private sector participation, but the last few years nonetheless have seen a strong surge in RE development.

2.36 Funding through the 1994 GEF program has seen the implementation of efficient **solar water heaters** in the tertiary sector, notably by hotels, public baths, and hospitals. **Photovoltaic** generators have been established by rural electrification programs, **geothermal** energy is used to heat greenhouses in desert areas, and **biogas** is mainly used by individual farms.

Renewable Energy Potential and Contributions to CO_2-Emissions Reduction

2.37 The following describes the economic potential of some possible RE technologies and applications in Tunisia to the year 2010.

2.38 The potential savings from the use of **solar water heaters,** which could be developed by 2010, is approximately 160,000 toe per year. This technology is cost-efficient wherever natural gas is not being destributed. For this potential to be realized, the local production of solar collectors must be developed. Joint ventures have been formed to this end.

2.39 **Wind energy** has been proven competitive. A favorable site has been identified at Cap Bon, northeast of Tunis, and the decision made to establish there a 10 MW windfarm. Prospective private sector developers have been invited to tender for the project, and a power purchase agreement has been proposed. The construction of 10 similar plants by 2010 would deliver a potential savings of 55,000 toe per year, at a cost of approximately US$ 0.07/kWh.

2.40 **Photovoltaic** modules allow the supply of electricity at least cost to the most remote rural populations. Even with current electrification plans, it is estimated that 3 percent of Tunisia's population (an estimated 350,000 people), will not be connected to the grid by 2010. Photovoltaic solar home systems (PV-SHS) could provide electric service to these people.

2.41 The potential of **biogas energy**, produced from domestic waste, is about 100,000 toe at a cost of about US$ 0.04/kWh. The implementation of a pilot plant will verify if this application has good potential.

2.42 The savings that could be realized from **geothermal** applications is about 7.5 ktoe by 2010.

2.43 The need to fight desertification requires an improvement in the traditional use of wood for cooking. The *tabouna* oven and other traditional wood burners have an energy efficiency of 4–10 percent. The simple installation of a lid on the tabouna can, through better management of inflowing air and heat recovery, reduce the amount of wood needed; it also can reduce greenhouse gas (GHG) emissions. Assuming the distribution of more efficient ovens, the total consumption of firewood should decline from 799 ktoe in 1994 to 526 ktoe in 2010.

2.44 By 2010, RE potentially could provide for one-fourth of national primary energy consumption by 2010, rising from today's 580 ktoe to 1 Mtoe of non-wood-based energy. This would enable Tunisia to eliminate 505 ktoe of oil imports, with obvious environmental benefits: for example, the energy scenario without the development of RE would see emissions of 10 million tonnes of CO_2 in 2010, compared to 4.3 million tonnes in 1994. The development of RE also could eliminate the emission of 2 million tonnes carbon equivalent in the form of methane from domestic waste.[7]

2.45 The potential of RE beyond 2010 will depend on the competitiveness of the different RE forms and technologies, the evolution of oil prices in the world market, and technological progress.

Institutional Aspects

2.46 The institution responsible for promoting the development of renewable energies in Tunisia is the Agence pour la Maîtrise de l'Energie (AME). AME was established in 1985 and has undertaken RE development in numerous areas, including windmills for pumping water, solar energy for hot water production, and PV panels for rural electrification. AME has the tools necessary to undertake a coherent approach to RE, define the possible contribution of RE, and enable the introduction of RE applications in the different markets.

Recommendations for Further Work

2.47 Most RE technologies have now progressed beyond the experimental stage, and a true transformation is underway that should see the massive commercialization and dissemination of RE. There is a need to focus on the following challenges:

- streamlining public organizations and activities to support the wider dissemination of RE
- promoting private sector participation

[7] Methane has about 24 times more effect as a GHG than CO_2.

- attracting public and private financing through raising the cost-effectiveness of RE technologies
- decentralizing AME
- implementing a follow-up/evaluation process
- establishing a national financing fund to enable a sustained policy
- coordinating international involvement

2.48 These challenges are interrelated. To bring cohesiveness and effectiveness to RE development, a strategic program should be adopted in which the roles of each party and actor of the economy would be defined.

2.49 It is especially important to coordinate the public participants in RE development. The study recommends the decentralization of AME, with the creation of two agencies in the Sahel and in the south. A strengthening of the administrative framework furthermore will be necessary to enable the large-scale distribution of PV systems, as the target group—the rural population—has limited education and low incomes. The role of field administrators needs to be reinforced to efficiently implement these policies. The national utility (Societé Tunisienne de l'Electricité et du Gas (STEG)) also could support the training and coordinate the activities of the private enterprises that will set up the PV modules and provide follow-up.

2.50 The private sector could play a much bigger role than it does today, particularly in profitable applications. Participation is possible at three levels: the provision of financial packages, technical implementation, and the undertaking of specific functions within the development of the different technologies. The private sector also could fill the gaps in the organization of the different sectors, by, for example, maintaining PV systems and selling water heaters to private users.

2.51 Legal, regulatory, and tariff changes also are necessary for RE to be developed to its potential. The following legal and regulatory changes are recommended:

- introduction of a fixed premium for PV system subscribers, to ensure equipment renewal and maintenance;
- introduction of a regulation promoting solar hot water production in, for example, new housing, hotels, and public baths;
- the offer by STEG to independent power producers of power purchase agreements (PPAs) that are favorable to RE, in consideration of the positive contribution of RE to the greenhouse effect.

Financing of RE Projects

2.52 Realization of the potential of RE described here would imply an investment of 1.34 billion Tunisian dinars (TD)[8] by 2010, of which public funds would cover TD 420 million. For the Ninth Plan period (1997–2001), investments have been

[8] One Tunisian dinar is roughly equivalent to US$ 1.

estimated at TD 200 million, including TD 88 million in public assistance (national resources and international cooperation).

2.53 In numerous cases, RE that is competitive on the basis of lifecycle costs is disadvantaged by the upfront investment required. The 5 percent assistance rate planned by the new Investment Code is insufficient to encourage widespread adoption of RE technologies, and thus does not reflect the genuine public benefits of these solutions. A law complementary to the Investment code is needed. AME has proposed the creation of a fund, to be fed by an additional tax on gasoline, that is being considered by the government. The amount that would be collected through this tax is estimated to be about TD 5 million per year.

2.54 International cooperation can play an important role in the development of RE in Tunisia, in areas such as research and development, support to the organization of RE institutions, and in accelerating the dissemination of successful technologies. International assistance is especially recommended in the following areas:

- Development of local production of solar water heaters, through partnership with experienced manufacturers and introduction in the market of a simple collector for household use. Assistance to local manufacturers, possibly through favorable loans, should be a good investment.
- Dissemination of PV systems for the rural electrification of the 70,000 households that cannot be connected by STEG to the grid by 2010. Due to the high cost of such a program, it is likely that partial grant financing would be needed. Any such program should be based on the ability to pay and should include strong measures for sustainability.
- Assistance in the construction of the first windfarm.
- A demonstration plant of the solar thermodynamic type under a Mediterranean strategy. Partial financing by grant would be necessary to bring costs to the level of competing technologies. GEF or EU grant funds would be helpful in this effort.[9]

[9] The EU has a Mediterranean Assistance program through which it is assisting Morocco, Egypt, Greece and Spain in this area.

3

Central Europe and the Former Soviet Union

Russian Federation

Objective of the Report

3.1 Russia was selected for exploratory work in RE development because of its large size, its large variety of circumstances, and keen interest on the part of bilateral and multilateral agencies, notably the U.S. Agency for International Development (USAID) and the EU Commission's Technical Assistance for the Commonwealth of Independent States (TACIS) program. The World Bank, with assistance from staff of the U.S. National Renewable Energy Laboratory (NREL), has performed a preliminary study to obtain a tentative assessment of RE potential and the possibilities for its development in Russia (see also Martinot and Touryan 1996).

The Energy Sector in General

3.2 Russia possesses large conventional energy resources. However, approximately 20–25 million people in Russia live in regions unreached by the central electric and gas networks. Most of these people are connected to smaller, autonomous power grids, but approximately 8 million of them are served by standalone generation systems using either diesel fuel or gasoline. About 90 percent of these 8 million people live in collective farms or villages, with the remaining 10 percent living on small single-family farms. The standalone generators typically are diesel systems with a capacity of up to 1 MW (an estimated 10,000 such systems serve collective farms or settlements) or gasoline systems with capacities of 500 W to 5 kW (an estimated 60,000 such systems are installed). An estimated half of these systems are no longer operating because of fuel delivery problems or high fuel costs. The primary sources of energy along the northern Arctic shore are diesel and gasoline power stations, of which there are more than 500,000, consuming 6.5 million tonnes of fuel per year. Fuel is brought in in metal containers that are not reused: an estimated 250,000 tonnes of these containers are abandoned along the shore in many districts of Siberia, Yakutia, the Okhot Sea, and the Kuril Islands. In addition to the economic waste, this system also is the cause of ecological damage to forest and tundra vegetation and fauna; for example, disrupting the nesting and reproduction of mammals and marine birds.

3.3 Historically, farmers were connected to the electric power grid at no charge. However, 250,000 privatized farms must now pay if they wish to be connected to the grid, at a cost estimated at US$ 8,000–10,000/km. Typical distances from a farm to the grid in the central regions are just a few kilometers, but these increase to more than 10 km in northern regions such as Vologda and can be up to 50 km or more in Siberia. Such distances make connection to the grid prohibitively expensive.

3.4 Furthermore, there exist in the northern territories about 10 million people of 30 indigenous nationalities whose economic conditions are poor and whose lifestyle would be threatened by the intrusion of conventional energy networks. The increasing cost of fossil fuels and transportation and the collapse of the centralized Soviet system created a major problem in energy supply to the Northern Territories, where 95 percent of fuel is either solid (coal) or liquid (gasoline and diesel). The Russian authorities today are interested in helping these nationalities develop local and renewable energy sources. The northern zone includes the European North, with a population of 4,866,000; the Siberian North, with 2,013,000; and the Far East North, with 3,127,000.

RE Potential

3.5 Soviet planners did not seriously consider non-hydropower RE in their development plans, with the result that Russia today has practically no non-hydropower RE. The Soviets undertook research and development of several forms of RE, including solar thermal, solar photovoltaic, wind, geothermal, biomass, and tidal power, and these efforts resulted in a few test installations and some fairly well-developed technologies, especially in solar photovoltaic cells. Practically no commercial use of RE has occurred to date, however, with the exception of a few small geothermal installations. Wood accounts for less than 1 percent of primary energy consumption (for wood stoves and heating in remote areas), and other forms of RE make nearly zero contribution. Yet the opportunities are enormous. A variety of RE exploitation is possible across Russia, but it should be noted that the varied latitude, climate, terrain, and enormous size of the country that makes this possible also makes it is impractical to consider Russia as a single entity with respect to RE. A region-based characterization is important.

3.6 **Wind resources** in Russia theoretically could produce all of the electric power that is used in Russia today. Large areas of the country have annual average windspeed greater than 5–7 m/s at or near ground level, with suitable winds most prevalent in the far northern and eastern regions. Population densities are extremely low in these regions, but small, dispersed wind-diesel systems for individual farms and settlements have the potential to be economically viable because the costs of importing the diesel and gasoline fuels that currently are used for existing power generation are high. Large, grid-connected windfarms make the most sense in the North Caucasus region, where wind resources also are good but where large population centers exist. The Republic of Kalmykia in the North Caucasus is the first region in Russia to have installed a grid-connected windfarm. This 22 MW windfarm is being installed with the support of RAO EES Rossii, a private, joint-stock company with ownership or controlling interests in most of Russia’s electric power infrastructure. The U.S.-Ukrainian joint venture Windenergo also was founded in 1992, and by early 1996 had manufactured and sold to the Crimean regional electric utility an estimated 100 units of 100 kW wind turbines. These units are producing power in the Crimea at reported costs of less than US$ 0.04/kWh. Wind resources also are known to be good on the Baltic Sea coast, notably on the offshore Estonian islands.

3.7 **Biomass** waste from agriculture, industry, and other sources in Russia is estimated at more than 300 million tonnes per year. This waste potentially can be converted into biogas equivalent of 60 million tonnes per year of equivalent fuel (Perminov 1994).[10] Biomass resources from forest harvesting and thinning are plentiful in the northern forest regions, including St. Petersburg. The annual production of wood waste in the St Petersburg is about 250,000 m^3 (12 percent of annual wood processing), of which perhaps one-third to one-half goes completely unused. It is estimated that for the rest of the northwest region (including Karelia, Vologda, Komi, and Arkhangelsk), annual production of wood waste is about 2.5–7.5 million m^3 (depending on how much production capacity is actually being used). As a preliminary calculation, taking a production estimate of 5 million m^3/y and an assumed one-half of wood waste available for biomass, and making basic assumptions about conversion efficiency, woodchip-to-solid volume conversion, and wood energy content per cubic meter chipped, total heat production from this waste could be of the order of 7 million MWh, representing a total boiler capacity of 1,000–2,000 MW.

3.8 The main **geothermal resources** exist in Kamchatka and the Kuril islands in eastern Russia and in the North Caucasus regions. One estimate of the technical potential of geothermal energy in the eastern regions is 2 million kWh per year. In the North Caucasus, there exist thermal zones at a depth of 4 km that could be exploited by fluid circulation systems and that could produce an estimated 80 million kWh per year. One 80 MW geothermal station exists in Kamchatka and a 60 MW station is being proposed, with foreign participation. The Ministry of Science also is proposing a US$ 350 million geothermal station in Kamchatka. Progress on this project however has stalled due to lack of financing; while the European Bank for Reconstruction and Development (EBRD) has shown interest in the proposal, much work needs to be done to assure the market for the power, on prevailing and future tariffs, on owner arrangements, and other details.[11]

3.9 Solar energy potential is generally limited because of Russia's high latitude. Some off-grid applications for **photovoltaics** appear economical in comparison with the costs of making electric grid connections, but the "avoided costs" of grid connection must be considered in the context that lack of resources means that many such connections simply cannot be made now or in the near future. Russia nonetheless has considerable capability in PV-panel manufacturing, as the scientific and technical know-how originating in the Soviet space program gradually moves into the commercial domain—for example, a joint venture has been set up between Energy Conversion Devices of the United States and the Russian concern KVANT (part of a government scientific laboratory) to produce amorphous silicon wafers through the continuous deposition process. PV production in Russia however remains targeted mostly to the export market, including the markets of Central and South Asia.

[10] In the FSU and other countries of Central and Eastern Europe, all fuels are reduced to quantities of a standard or equivalent fuel that is defined as coal with a heating value of 7,000 kcal/kg.

[11] Since the missions that led to this report were completed, a geothermal power project has been initiated in eastern Russia with support from the EBRD.

3.10 A **solar thermodynamic** experimental installation in the Crimea has provided some useful measurements of solar insolation; the plant is now idle, however, and cooperation with Ukrainian scientists and engineers is not active. Insolation measurements also have been recently carried out in the northern Caucasus region by the St. Petersburg Voeikov Main Geophysical Observatory, on order from the St. Petersburg firm LenHydroProject. The measurements indicate that, in certain areas of the Caucasus, perpendicular annual insolation levels can reach 2,000 kWh per square meter per year. Given the availability of natural gas in the area and plans to increase production capacity, however, prospects for this technology and its application do not seem good.[12]

3.11 The use of solar radiation for **solar water heating (SWH)**, particularly during the summer months, offers the potential to reduce conventional fuel consumption in district heating systems and in independent home, hospital, tourist, and industrial installations. (District heating systems operate during the summer to supply hot water only, and hence lose their advantage as combined-heat-and-power plants.) This potential is high in the Caucasus and south-central and southeastern regions of the Russian Federation. The technology is commercially available in many countries of the Mediterranean region, and any development in Russia therefore would have to be based on strictly commercial principles. Joint ventures with foreign firms are the most likely avenue for the launch of a commercial SWH business.

Institutional Aspects

3.12 Institutions involved in RE at the federal level include:

- The **Russian Scientific Committee for New and Renewable Sources of Energy.** Formed jointly between the Ministry of Science and the Academy of Sciences, this committee's objectives are to: develop strategies and policies for RE development; direct scientific research and technology development efforts; fund pilot and demonstration projects and provide technical expertise; and coordinate the exchange of information between Russian organizations and with enterprises and international organizations and firms.
- The **Intersolarcenter,** founded in 1995, is a noncommercial, nongovernmental organization devoted to research, education, demonstration projects, and equipment development and testing in the field of RE. So far, it receives funding only from the Ministry of Science, but additional funding has been pledged by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the Ministry of Fuels and Energy.
- The **Ministry of Nationality Affairs and Regional Policy** has prepared a study to evaluate RE in the far northern and eastern regions of Russia. This study includes demand analysis, technical options for utilization, credit and finance mechanisms, and program development. The Ministry

[12] Plans are under consideration for solar thermodynamic plants in countries of Northern Africa and the southern Mediterranean, where insolation is higher and the need for power greater (see sections on Morocco, Egypt, and Tunisia).

of Fuel and Energy is unable (or unwilling) to provide credit for this program, so the Ministry of Nationalities is seeking other sources, including private banks. According to Deputy Minister Volgin, the regions themselves will have to guarantee such loans,[13] as the ministry does not have the financial resources or authority to provide such guarantees.

- The **Ministry of Science** has been funding research and development (R&D) for RE for many years, and in the 1990s funded such projects in partnership with industry. These projects have been overseen by a Renewable Energy Committee within the ministry. In recent years, financing has been curtailed drastically and activities have become minimal. In 1994, the ministry financed 700 million rubles worth of projects (of the order of US$ 300,000). These projects included a 1.5 MW PV plant and a 1.5 MW geothermal plant in the Stavropol region; biogas production technologies; and a few other bio-energy projects, including utilization of biomass wastes and greenhouses.
- The **Ministry of Agriculture** has developed a program for the development of RE in agriculture and has been sponsoring R&D of RE in agriculture through the Research Institute of Electrification of Agriculture.
- The **Ministry of Fuel and Energy** has a Department of Energy Efficiency and Renewable Energy. Its work so far has mostly been to collaborate and pledge support for RE activities by other ministries (for example, the Ministries of Science and Nationalities), and to include RE in federal energy planning and program concepts.
- **RAO EES Rossii** is a private, joint-stock company with ownership or controlling interests in most of Russia's electric power infrastructure. RAO EES Rossii has been investing modest amounts of money in renewable energy R&D, deployment projects, and production of RE equipment. Projects have primarily involved grid-connected windfarms using turbines of 100 to 1,000 kW, geothermal electric power stations, and some solar and biomass installations.
- Additionally, many **research institutes** are conducting activities in technology development and resource assessment. These include the Krzhizhanovsky Power Engineering Institute, the Moscow Aviation Institute, the Central Aviation Institute, the Research Institute of Electrification of Agriculture, and others.

Existing Assistance Programs and Recommendations for Further Work

3.13 In the past few years, several international assistance programs and activities related to RE in Russia have taken place or are ongoing. These include:

- The Swedish government agency NUTEK has provided technical assistance (TA) and has lent capital to Russian organizations for district

[13] Regional Administrations with elected officials have acquired considerable authority for policymaking at the local level and for decisionmaking on financing projects and providing guarantees.

heating boiler conversions from oil and coal to biomass fuels. The project in Sestroretsk is one of the few existing examples of boiler conversion to biomass yet to take place in Russia. Total lending for this program in all countries of the FSU exceeded US$ 30 million by 1995.

- U.S. Department of Energy. Since 1993, the National Renewable Energy Laboratory (NREL) has undertaken several activities under an agreement with the U.S. Department of Energy, including information exchange and technical assistance, collection of resource assessment data, technology demonstration projects, evaluation of village-power opportunities for hybrid wind and biomass projects in remote regions in northern Russia, and facilitation of joint ventures.
- USAID (U.S. Agency for International Development) awarded US$ 1.25 million to the Ministry of Fuel and Energy for small-scale (1–30 kW) hybrid windpower systems in the Russian far north.
- The German government has provided TA and equipment for a small number of 30 kW wind turbines in the Saratov region.
- The United Nations Economic Commission for Europe (UNECE) has promoted information exchange, conferences, and the coordination of multilateral assistance efforts for energy efficiency and renewable energy in Russia.

Conclusions and Recommendations

3.14 The enormous wealth of conventional fuels and extensive networks in the Russian Federation, together with low tariffs, present a serious obstacle to the development of RE. RE resources nonetheless are large, and in certain regions, particularly those in which the population has unusual needs and circumstances, there is strong interest in RE development. The conversion of former defense industries to peaceful uses furthermore is making available know-how and industrial capabilities that can be directed to the advancement of RE. Additionally and importantly, RE development would mark a departure from a culture of central planning and control, with an emphasis on large capital-intensive projects, to distributed decentralized projects under local jurisdiction and control.

3.15 In this light, the development of RE resources in certain cases appears both feasible and commercially viable. Comprehensive analysis of markets and technical-economic opportunities continues to be hindered by a lack of adequate data and project experience, but there appear to be four key markets in which there are investment opportunities that are cost-competitive with conventional forms of energy. These are:

- Electricity for villages and small settlements from hybrid diesel and biomass.
- Electricity for electric power grids via wind and geothermal generation in locations where resources are good and the need for power exists.
- Biomass use as fuel in boilers feeding existing district heating systems.

- Solar water heaters for use in institutional or residential buildings, particularly in the southern regions (Black Sea and Caucasus) where insolation is adequate.

3.16 In a significant development, a 1996 Russian law “On Energy Efficiency” for the first time allowed independent power production in Russia. The federal law makes possible electric power production from RE sources by private developers. With its financial and fiscal incentives, this law should stimulate RE development in many parts of the Russian Federation.

3.17 A paper prepared by the Ministry of Fuel and Energy on a proposed program for energy in the Northeastern Territories, in which 10 million people are not connected to the electric grid, foresees the supply of electricity via hybrid systems that will use about 70 percent RE and about 30 percent traditional fuels (Russian Federation, Ministry of Fuel and Energy 1996). A first project, with a time horizon to the year 2000, aims at reaching 900 villages—about 150,000 people—in 31 regions. The proposal has been presented to a number of international finance institutions for possible funding.

3.18 The interest in the development of RE resources in Russia has the potential to break old patterns of thought and action and, under certain conditions, to provide economic solutions. It is therefore appropriate that the efforts of bilateral and multilateral aid agencies, as well as those of international finance institutions such as the World Bank, be redoubled. The main effort should be directed toward: (a) selecting technologies, sites, and applications that make economic sense; (b) installing pilot projects that will demonstrate their viability; and (c) strengthening local capabilities in the selection, preparation appraisal, and implementation of RE projects. Although the Bank’s lending program does not include any RE projects, various possibilities and proposals are under consideration. As a logical next step, a full-scope study should be launched to investigate RE potential in the most promising technologies and regions.

Bulgaria

The Energy Sector in General

3.19 The energy sector in Bulgaria is characterized by a high energy intensity (about 2.5 times the energy intensity of OECD countries). Energy prices are subsidized at below cost-recovery levels, reducing incentives for industrial restructuring and thus helping to perpetuate high energy intensity. But even in a context of improved energy efficiency, Bulgaria would still have significant difficulties with energy supply. The country imports about 75 percent of its primary energy needs, much of which comes from increasingly unreliable sources in Ukraine and Russia. More than 85 percent of Bulgaria’s electricity is supplied from highly polluting, lignite-burning thermal plants (60 percent of which have been in operation for more than 20 years) or from the Kozloduy nuclear power plant, two units of which are expected to be retired in 1998 (largely due to safety concerns), followed by an additional two units by 2010.[14] Bulgaria is, therefore,

[14] The Kozloduy nuclear power plant comprises four 440 MW units of the VVER type that are considered to be not in compliance with international safety standards, and two 1,000 MW units of later Soviet technology that include the necessary safety provisions. The international community, particularly the G7 countries, has been pressing Bulgaria to retire the four VVER 440 units.

squeezed between uneconomical high energy consumption and a projected capacity shortage even should consumption levels be significantly reduced. Regarding RE development, careful consideration must be given to the high installed capacity of about 12,000 MW and the available capacity of about 9,000 MW, compared to peak load of about 7,000 MW. Any new RE capacity must be justified on the basis of special needs and benefits, such as local (captive) generation, loss reduction, transmission line stability support, or avoidance of substation upgrading and expansion.

3.20 In response to these problems, the Government of Bulgaria has developed an energy policy that includes as priorities energy conservation and efficiency measures and the development of local energy resources, particularly renewables.

3.21 The World Bank, with collaboration from consultants of the United States Agency for International Development, USAID and the European Union Commission's Technical Assistance Program to Eastern Europe (EU-PHARE) program, has conducted a preliminary examination of the RE potential in Bulgaria. The results of this examination are reported in this section.

Renewable Energy Potential

3.22 According to present estimations, **biomass resources** could provide 5 percent or more of Bulgaria's primary energy needs. Areas of particular promise include agricultural waste, woodchips, energy crops, and animal waste. The EU-PHARE program is developing three demonstration projects, two exploiting woodwaste for boilers and the third using an anaerobic digester to provide gas from cattle dung.

3.23 Bulgaria has more than 160 **geothermal** production sites and more than 1,000 boreholes, about one-half of which may be exploitable. The country's experience with some types of geothermal technology is therefore reasonably well advanced. Geothermal heat could be utilized as input to district heating (DH) systems or for electricity production. It is estimated that the total heat potential from geothermal resources in Bulgaria is approximately 480 MW, of which only a fraction has been exploited. The EU-PHARE program also is developing a demonstration project using geothermal resources for spa purposes.

3.24 **Hydroelectric** experience in Bulgaria is extensive. **Large hydro** installed capacity is 1,970 MW, and there is increasing interest in **small hydro** projects. There are approximately 14 private small hydro producers in Bulgaria and an estimated untapped potential for small hydro of 212 MW. The EU-PHARE program is considering development of one or more small hydro projects, all of which would be integrated into existing water supply pipeline cascades and which would supply electricity to the grid.

3.25 Bulgaria has experience with **solar water heating**, **photovoltaic technologies**, and **passive solar projects**. The number of projects that have been implemented is small. Certain solar energy applications, such as solar water heaters, could be immediately economic, given international prices for imported petroleum products and natural gas. If the market for such systems can be stimulated, possibly with appropriate incentives by the government, the solar water heater industry could take off rapidly, making a sizable contribution to the country's energy balance and helping generate a local manufacturing industry (possibly to be organized as a joint venture with a foreign firm).[15] Approximately 50,000 m^2 of solar water heating panels have been installed throughout the country. The EU is developing a project to demonstrate an active solar system for hot water at a private hotel. Photovoltaic technologies also are being considered for applications in niche markets, remote power for households not connected to the grid, and integrated building systems.

3.26 While there is considerable interest in **wind technology**, agricultural pumping is the only area in which wind resources have been regularly exploited. There are only a few examples of small wind generators (5 kW). An independent assessment of wind data has concluded that there is good potential for expanding the exploitation of wind resources. The EU-PHARE program is examining several possible wind demonstration projects, both standalone and grid-connected. According to a preliminary wind resource assessment at the Kaliakra peninsula on the Black Sea coast, the site is capable of generating 20 MW at a cost of approximately US$ 0.05 /kWh.

Institutional Aspects and Local Capabilities

3.27 Although the institutional structure and the energy institutions in Bulgaria are characterized by weakness, there are several encouraging developments. First, a number of groups have emerged that work as private consulting firms in the areas of energy efficiency and renewable energy. USAID consultants are active in creating and/or strengthening a number of energy service companies (ESCOs) such that they can play a significant role in preparing, presenting, implementing, and supervising projects in energy efficiency and renewable energy (EE&RE), and training courses are being conducted to accomplish this goal.

3.28 Local capabilities include several energy service companies focused on EE&RE, legal and institutional firms, state technical institutes that gradually are being converted into joint-stock companies seeking outside contracts, and a local manufacturing base for hydro electromechanical equipment and solar thermal collectors.

Existing Activities and Recommendations for Further Work

3.29 As described above, considerable work has been and continues to be conducted with bilateral and multilateral grant aid, particularly that provided by the EU-PHARE program and USAID. The development of RE resources has been the object of a study financed by the EU program. The demonstration projects are predominantly of small scale, with a heavy component of the cost met by EU grant. Although the commercial viability of some of these projects is subject to question, their completion and successful operation will establish whether or not RE projects can be replicated on a larger scale and make a sizable contribution to Bulgaria's energy problems.

3.30 For the wider dissemination of RE, it is essential that electricity prices rise to higher levels, as agreed with the Bank under the power project now under implementation. Further market stimulation could be achieved by the provision of additional financing.

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[15] A fairly extensive discussion of the various possibilities for RE development can be found in the consultants' report titled "Technical and Economic Assessment of Bulgarian Renewable Energy Resources - March 1996."

3.31 In the legal domain,[16] an energy law is being discussed in parliament that would set the major directions and principles for the sector. The law includes provisions for the production of electricity by independent power producers (IPPs) and the sale of power to NEK's grid. (NEK is the Bulgarian state utility, which is being restructured on commercial principles.) An energy efficiency fund (EEF) through which projects in energy efficiency but also in RE can be funded has been created by government decree, but as of the time of writing had collected no funds and had not become operational.

3.32 Concerning energy policy, the government has proceeded to separate the roles of policy and regulation from those of ownership and management of energy assets. A Ministry of Energy has been established to be in charge of formulating general policy in the sector, and a regulatory commission also is being set up. The ownership and management of generating assets has been given to NEK.

3.33 Based on the work performed to date, projects of a total cost of about US$ 30–40 million would not be difficult to identify. Criteria for eligibility, procedures for project evaluation and approval, methods for supervision, and payback procedures must be established.

Financial Intermediation

3.34 One possible mechanism for funding projects in EE&RE areas where there are a large number of potential applicants could be the establishment of a line of credit through an existing fund (for example, the EEF or the ECO Trust Fund). The fund could be strengthened and properly equipped to perform project appraisal, loan approval, project supervision, and other related functions.

3.35 With appropriate and adequate funding, the EEF could become an effective vehicle for channeling funds to projects on EE&RE.

3.36 Another possibility is the ECO Trust Fund, which is established in Bulgaria and which was established through a US$ 200,000 institution-building grant (IBG). The main purpose for which the ECO fund was created to finance environmentally beneficial projects; however, other projects that have similar effects, such as EE&RE projects, are also included in the fund's charter. Although most monies are being dispensed as grants, it is also possible that they be furnished as loans to provide a sustained source of project financing. The first contribution to the ECO fund was 20 million Swiss francs, the result of a debt-for-nature swap between the Bulgarian and Swiss governments, to be transferred to the fund in 10 semiannual installments. The fund expects additional swap agreements with other governments.

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[16] Reviews of existing laws and decrees in the energy sector have been prepared by a local firm and by international consultants under EU-PHARE financing. One report, dated May 2, 1996, was made available to the mission by the Regional Energy Center, an office established by DG-XVII of the EU Commission to assist the development of studies and projects that have regional rather than narrowly national significance.

Conclusions

3.37 Bulgaria's high capacity and prevailing low energy prices do not favor the development of RE. However, with energy prices rising to international levels and national policies in place to reduce dependence on imported fuels and to replace the capacity that will be lost with the retirement of the four units of the Kozloduy nuclear power plant, RE development, coupled with efficiency measures, makes good sense. Solar water heaters are commercially viable and could be developed quickly. Wind and small hydropower also could be viable propositions. Based on these considerations, the Bank has included in its lending program a project focused on energy efficiency that will also include a component of RE.

Kazakhstan and the Kyrgyz Republic

3.38 As in the case of northern Africa, a regional approach was taken in the study on Kazakhstan and the Kyrgyz Republic. A preliminary mission included three countries of the Central Asia Republics: Uzbekistan, Kazakhstan, and the Kyrgyz Republic. The study resulted in a report covering Kazakhstan and the Kyrgyz Republic (IENPD 1997). The study was supported by ESMAP with contributions from and the participation of bilateral and multilateral grant agencies: The United Nations Development Programme (UNDP) contributed to institutional arrangements and technical assistance; the U.S. National Renewable Energy Laboratory (NREL) aided in wind resource assessment and wind case study analysis; Japan's New Energy and Industrial Technology Development Organization (NEDO) aided in PV assessment; and the U.S. Department of Energy (USDOE) assisted through the involvement of seconded staff.

Objective of the Report

3.39 The study was undertaken at the request and with the encouragement of the sector operating division responsible for the countries of Central Asia (EC3IV). Its main motivation was to assess each countries' dependence on energy imports, owing to either lack of indigenous energy resources, as in the case of the Kyrgyz Republic, or to inadequate development of existing resources and regional imbalances, as in the case of Kazakhstan, and to investigate anecdotal information that RE resources are available in abundance in these countries. The work started in March 1996 with a reconnaissance mission, with the main mission following in May and June 1996.

3.40 The main objective of the study was to perform a preliminary assessment of the RE resources in the two countries, to identify the most promising resources for development, and to perform preliminary analysis of a small number of opportunities that appear to hold the most promise for investment in each country. It also is worth noting that the study took a regional approach to market development, examining the possibility of the joint development and marketing of RE systems across the region.

3.41 From its inception, the study was meant to be a first step in a process that could be followed by other actions and steps, leading to an RE project and development program. After the preliminary results of the mission were issued, the UNDP proposed and approved a preinvestment study for wind development in Kazakhstan. At the request of the local authorities, a regional workshop was held in Almaty in September 1997 at which were presented the main results and conclusions of the study as well as the studies, findings, plans, and proposals of other international donors and private investors.

3.42 The following paragraphs summarize the findings in Kazakhstan and the Kyrgyz Republic. General conclusions and recommendations viable for both countries also are given.

Kazakhstan

Energy Balance and Impetus for RE Development

3.43 Kazakhstan has large reserves of exploitable coal, oil, and gas, and it therefore is expected that the energy sector will play a significant role in the economic development of the country. However, Kazakhstan has electricity deficits that have to be covered by imports from Russia in the north and from other Central Asian countries in the south. The size of Kazakhstan and its geography (the country is divided into north and south by a central desert region), together with the concentration of coal deposits in the north, means that the country must make large investments in its transmission systems, which are the source of high losses and low reliability. The power sector needs considerable rehabilitation and serious upgrading if the country is to decrease its heavy reliance on electricity imports.

3.44 The main motivation for RE development in Kazakhstan are the needs to:

- replace imports of electricity, especially in the southern region;
- extend access to electricity to the country's remote and nomadic populations;
- protect the country's delicate ecosystem by reducing the dependence of the electricity generation system on coal (presently at 85 percent);
- reduce line losses and improve stability and reliability by installing dispersed and end-of-line generation stations that use RE resources.

Renewable Energy Resource Potential

3.45 The RE resource potential in Kazakhstan is significant but was largely neglected under the Soviet regime, which favored large centrally owned and managed projects. The country has about 5,000 villages that have no electricity service, and grid extension to supply these villages would most likely be uneconomic. Development of RE resources could serve electricity production needs at the national and local levels; RE power generation also can be appropriate to situations in which small distributed loads are required.

3.46 Kazakhstan's **hydro potential** is large, amounting to an estimated 170 TWh/yr. Only about 7.1 TWh/yr has been exploited, with another 23.5 TWh/yr possible in the near future. Within this total, small hydro potential (defined as units of less than 10 MW) is very significant. Based on existing studies that include hydro projects up to 30 MW, there are about 570 potential small hydroelectric power projects (HEPs), offering about 2,354 MW of installed capacity and 8,510 GWh of mean annual production. If one restricts unit size to less than 10 MW, the total potential installed capacity is 1,380 MW and annual energy production 6,315 GWh. Some of the potential projects under consideration are based on existing irrigation channels, a fact that makes them readily available for implementation at low cost and in a short time period. The mission visited a few projects that appeared very promising, especially the Chillik cascade and sites identified along the Bartogay and main Almaty canal. A case study on the Bartogay and Almaty canal small hydro project (which would involve the combined exploitation of the Bartogay irrigation dam and the two waterfalls at the Almaty irrigation canal), demonstrated the potential of this technology. The proposed installed capacity is 20 MW at the foot of Bartogay, 11.5 MW at the first fall of the Almaty canal, and 10.5 MW at the second fall, giving a total capacity for the project of 42 MW and an expected average annual electricity production of 150 GWh. Using conservative assumptions, the capital investment cost is estimated at about US$ 40 million and the levelized electricity cost at US$ 0.0285/kWh. Assuming a sell-on price of US$ 0.05/kWh (the current price paid for electricity imports), the rate of return of the project would be 18.3 percent and the payback period 7.6 years. This furthermore does not take into account the environmental benefits of the proposed scheme. A more detailed study of this and other proposals nonetheless remains necessary.

3.47 Kazakhstan also offers excellent opportunities for large development of **wind power**, especially at the Djungar Gate, close to the border with the Xinjiang Province of China, and the Chillik corridors, where annual average windspeed ranges from 7 to 9 m/s and 5 to 9 m/s, respectively. Additional factors such as proximity to an existing high-voltage transmission line, good correlation of the wind's seasonality with the power demand of the system, and a local market make development of these resources attractive. As a case study, two sites were explored at Djungar Gate, corresponding to two wind measuring stations: Zhalanaschkol, with an estimated capacity factor of 26 percent, and the Druzhba, with a capacity factor of 33 percent. The analysis assumed for the first plant an installed capacity of 40 MW and was performed with conservative cost assumptions from similar recent cases (capital cost of US$ 1,100 per installed kW, for example, in India), giving a total plant cost of US$ 44 million. The following variations (sensitivity analyses) were used: four electricity prices were assumed, US$ 0.025, US$ 0.05, US$ 0.0625, and US$ 0.075 /kWh; and three cases: a base case, at constant 1996 U.S. dollars, a case with a 2 percent electricity price escalation to reflect the effect of economic and price reforms, and a case with a US$ 10 million grant, possibly from the Global Environment Facility (GEF), to account for the first introduction of the technology and higher transaction costs. No environmental benefits were accounted for. In the base case, at US$ 0.05/kWh the rate of return is 8.4 percent and 11.3 percent for the two sites. With the assumption of a US$ 10 million grant (about 23 percent of capital cost) and the US$ 0.05/kWh price figure, the IRR rises to 11.6 and 15.0 percent for the same two sites.

3.48 **Solar energy** resources in the country are, despite Kazakhstan's high latitude, stable and adequate, owing to its favorable climatic conditions. Sunshine hours are 2,200–3,000 per year and insolation energy 1,300–1,800 kWh/m^2/y, making it possible to consider **photovoltaic solar home systems** (PV-SHS) for rural areas—and especially portable PV systems for nomadic populations. Based on the data provided by the mission's local counterparts, it is estimated that a market potential exists in

Kazakhstan to absorb, in the time span of five years, an upper limit of 40,000 small, portable PV units of 20 W capacity each. The net cost for the small portable PV units is estimated at US$ 12.2 million. Avoided cost calculations indicate that these systems are 30 percent less costly than the kerosene lantern base case on a cost per lumen hour basis. PV panels and systems could be produced locally on a commercial basis and marketed in a region comprising several countries of Central Asia. While it should be possible to use local technical capabilities, foreign capital and expertise would be needed to aid the design of modern solar home systems; modernize PV production technology (including the production of silicon wafers, solar cells, and modules); organize maintenance and service organizations; establish spare parts programs and stores; and putt in place small-scale financing mechanisms.

3.49 Based on the above-mentioned insolation level, **solar water heaters**, particularly in remote areas without access to gas pipelines, also should be viable in Kazakhstan. The technology is commercial and the capabilities to undertake local production are good.

3.50 **Geothermal** and **biomass resources** were also examined but were considered to be of low potential for electric power production. Small-scale, specialized cases such as the use of biogas for cooking and fertilizer production and of geothermal resources for heating purposes are more suitable for investigation by local government or bilateral aid programs.

Institutional Aspects

3.51 No formal institution exists for the development of RE sources. There are various R&D institutes, design institutes, and state companies involved in work related to renewable resources. These organizations include:

- Kazakhstan Scientific Research Institute of Power Engineering, focusing on small hydropower development and research into new techniques for harnessing wind power.
- Kazakhstan Energy Center, which is mainly concerned with energy conservation and efficiency but which also works on renewables.
- Institute Kazelenergoproekt.
- Design and Investigation Institute.
- Scientific and Industrial Association.
- Almatyenergo.

3.52 The sector is characterized by a lack of coordination, lack of clear policies, and lack of a strategy for development. The Ministry of Energy has a small unit for RE planning and overview, but it is not adequate to cover the needs of the sector, especially where important issues such as policy development and the commercialization and financing of projects are concerned.

Recommendations for Further Work

3.53 The development of **small hydropower** should be given the highest priority within RE resource development, as Kazakhstan is replete with small hydro resources. More specifically, the Chillik cascade and sites identified along the Bartogay and main Almaty canal show significant investment potential.

3.54 **Windpower** also should have a high priority. As an initial investment project, the mission analyzed and recommended that in-depth studies be carried out for the development of the 40 MW Djungar Gate windfarm. A total potential of 1,000 MW or more of generating capacity has been estimated, and a follow-up study of the case study windfarm is now under way through a UNDP/GEF project.

3.55 Recommendations for **solar water heating**, **solar photovoltaic** units for nomadic populations, **biogas energy**, and **geothermal power** are described jointly for both Kazakhstan and the Kyrgyz Republic after the section on the Kyrgyz Republic, including the general commercial, economic, and policy aspects that should be developed for the further promotion of RE.

The Kyrgyz Republic

Energy Balance and Impetus for RE Development

3.56 The Kyrgyz Republic depends on imports of coal, oil, and gas for about 60 percent of its primary energy supply. It possesses abundant hydroelectric resources and exports hydroelectricity (mainly to Kazakhstan) generated from the dams of the Naryn river. The country’s hydropower resources nonetheless are only partly developed.

3.57 The main motivation for the Kyrgyz Republic to develop its renewable energy resources are the needs to:

- capitalize on its financially attractive RE resources;
- reduce its dependence on imported fossil fuels, by using RE for heating applications;
- provide electricity to rural areas and nomadic populations not connected to the grid at lower cost than grid extension;
- use its industrial capabilities—specifically, its facilities for silicon crystal manufacturing—to produce photovoltaic cells and panels;
- expand the exploitation of its hydro resources through small hydro development, to leverage the advantages of such development (including its low environmental impact, low capital cost, and ability to engage local and regional interest and enable local and regional control);
- improve system reliability, stability, and efficiency by developing power generation near the centers of consumption.

Renewable Energy Resource Potential

3.58 The Kyrgyz Republic has large **hydro potential**, estimated at 163 TWh/y, but only 73 TWh/y is technically feasible and only 48 TWh/y economically exploitable.

In the Soviet era the region was assigned the role of providing hydropower to the broader regional interconnected system. Small hydro projects continue to contribute to the total hydro potential and are most promising, as shown in the following case study. The Karakol Small-Hydro Project is located on the Karakol river in the important commercial and tourist region of Karakol, at the eastern end of Issik-Kul lake. The project envisages the installation of a small hydroelectric plant with 4.5 MW capacity and 31.5 GWh mean annual electricity production. With conservative cost assumptions from recent and similar projects, the estimated investment cost of the plant is US$ 6.7 million, and the levelized production cost US$ 0.0268/kWh. Using an electricity price of US$ 0.035/kWh, the rate of return is 13 percent and the payback period 13 years. Environmental benefits could add 1–2 percent to the rate of return. The main justification for the project is that electricity supply in the Karakol region is frequently interrupted and that special tax-relief measures in this industrial zone would make the project attractive to local industry.

3.59 The Kyrgyz Republic has stable and adequate **solar energy** resources, despite its high latitude. It has about 2,600 h/y of sunshine, and insolation energy of 1,500–1,900 kWh/m^2/y. The market potential for **photovoltaic solar home systems** among the country's nomadic population is estimated to be around 14,000 portable 20W PV units over a period of five years. The total hardware cost for such a project is estimated at US$ 4.27 million. Simple calculation of electricity output is not an adequate measure of the benefits that would be provided by such a program. Comparison with the standard lighting energy source, kerosene, is much more appropriate: Avoided-cost calculations indicate that solar home systems are 30 percent less costly than the kerosene lantern base case on a cost per lumen hour basis. In-depth market surveys and pilot projects nonetheless would be required to accurately characterize the market and verify the feasibility and economic potential for a full-scale project. The Kyrgyz Republic also has two important industrial installations that served about 30 percent of the needs of the Soviet Union's space and defense industries for crystalline silicon for solid-state devices. The Orlovka plant makes single-crystal silicon, and the unfinished Tash-Kumyr plant was designed for polycrystalline silicon. The Orlovka plant today produces silicon blocks for a foreign customer on a toll basis.

3.60 **Solar water heaters** appear to have significant market potential, as the Kyrgyz Republic has no extensive district heating networks; this is due, historically, to the dominant role of inexpensive hydroelectric power. A case study carried out under this survey assumes a market penetration within five years of 12,000 m^2 of solar collectors for domestic use and 3,000 m^2 for commercial use. The investment cost for these solar collectors is estimated at about US$ 8.8 million, including circulation tanks. Based on this investment and assuming a discount rate of 10 percent, an equipment lifetime of 15 years, and a maintenance cost of US$ 40 per year per unit, the levelized cost of the heat produced would be around US$ 0.054 per million calories, a figure that is marginally competitive with conventional systems using high-cost fossil fuels. These costs include the use of imported equipment: it is estimated that with indigenization and installation experience, costs could fall 20 percent. Lifetime energy savings would be 41 gigacalories per system.

3.61 **Wind** data indicate modest resources of commercial promise; however, the country's terrain is such that localized areas of more commercially attractive resources may well exist. It is recommended that a wind resource assessment and monitoring program be undertaken with bilateral or multilateral technical assistance.

3.62 **Geothermal** sources also are modest, but could be viable for applications such as dairies, health spas, wool-washing, fish farms, and other applications.

3.63 **Biomass resources** do not seem to be promising. Limited fuel supplies and the small market potential indicate that biomass power development currently would not be an efficient use of scarce development resources.

Institutional Aspects

3.64 The State Business Project KUN (the Kyrgyz word for "sun") is the principal organization for promotion of RE activities in the Kyrgyz Republic, and functions as the focal point for this subsector. KUN was set up in 1993 in accordance with a presidential decree. Its governance rules and operational programs have the approval and support of the Kyrgyz government. According to these rules, KUN is to carry out scientific and technical activities concerning solar, wind, biogas, and other alternative energy sources. The project includes not only scientific programs but also design activities and a number of manufacturing enterprises. Although KUN is a government establishment, it does not form part of any ministry or holding company; technically under the Vice Prime Minister, who is also in charge of energy policy, it is positioned to function in a quasi-independent fashion. This arrangement is intentioned to render KUN free from bureaucratic controls and enable it to generate quick responses to project development needs and also seek outside funding. However, KUN's facilities need considerable upgrade and modernization and the staff must address important issues related to the development of RE sources, especially in areas of policy, commercialization, and project financing.

3.65 The most important factor inhibiting RE development in the Kyrgyz Republic is the prevailing low price of electricity. (It has been reported that the tariff is US$ 0.8/ kWh for the "lifeline" consumption level of 1,200 kWh per household per month. This contrasts with a World Bank recommended lifeline level of about 150 kWh per household per month). This tariff level, which may be adequate to cover the operating costs of long-depreciated hydropower stations, makes it impossible for any new source of power to compete.

Recommendations for Further Work

3.66 Assuming that RE projects can sell power to the grid at a reasonable price, high priority should be given—as is the case in Kazakhstan—to the development of **small hydropower**. In the Kyrgyz Republic, the Issyk-Ata cascade and the Karakol site in particular show significant investment potential.

3.67 In the area of **photovoltaics**, the solar cell manufacturing, module assembly, and export company at Orlovka, the Kyrgyz Republic's single-crystal silicon plant, and at the Tash-Kumyr polycrystalline plant, offer promising opportunities for supplying the rapidly expanding international PV market. Both, however, need financial and technical backing.

3.68 The recommendations for **solar water heating**, **solar photovoltaic units** for nomadic populations, **biogas energy**, and **geothermal power** are the same for the Kyrgyz Republic and Kazakhstan and will be described jointly in the following section.

Conclusions and Recommendations for Kazakhstan and the Kyrgyz Republic

3.69 **Solar water heaters** and **solar photovoltaic units** for nomadic populations should be considered for contingent development. In the case of small water heaters, a pilot project should be launched to investigate cost-cutting solar water heating designs, to characterize the target market, and to determine market size prior to developing this option. Fuel and district heating prices also must be rationalized for this option to become viable. Concerning **photovoltaic units**, the cost per lumen hour of a pressurized kerosene lantern is 46 percent higher than that of a 20 W solar home system, which also provides greater amenity and sufficient surplus power for a small radio. The capital cost of solar equipment is much greater, however, meaning that the market must be adequately characterized and tested via surveys and pilot projects to verify the viability of full-scale investment in this technology, and the availability of financing resources.

3.70 The potential of **biogas energy** is too low to merit its exploration as a resource for for power generation, given the enormous concentrations of livestock required for biogas to be economically competitive with grid-based power. It nonetheless has market potential for the provision of cooking fuel and fertilizer, and this should be explored and quantified in future studies.

3.71 Kazakhstan and the Kyrgyz Republic offer no high-temperature **geothermal resources** suitable for large-scale power generation. There may be, however, possibilities to use existing geothermal fields for small-scale binary generation. Low-heat resources are in some cases suitable for direct heating purposes in small industry or tourist facilities.

3.72 In addition to these specific recommendations for RE resource assessment, certain general recommendations also are applicable to both countries, as follows:

3.73 As a paramount recommendation, it cannot be overemphasized that market distortions, particularly tariff subsidies, must first be rationalized if either country is to realize economic exploitation of its renewable resources. Unless a rational tariff framework is in place, private power capital will remain unavailable for investment in RE infrastructure. It is also essential that both countries establish a proper legal and institutional framework in which the various players can perform their respective roles with confidence and effectiveness. The process of reform that already is in progress needs to be accelerated, but in an orderly fashion, and it needs also to take into account the specific needs of the RE sector. Government could play a more proactive role in coordinating activities, simplifying procedures, and setting clear policies that can be translated directly into practical measures. Government also could set priorities and organize effective coordination of bilateral and multilateral technical assistance programs.

3.74 Regarding institutional strengthening, the study recommends the following measures:

- Establishment, with a clear government mandate, of a dedicated agency or group for the coordination, facilitation, and promotion of RE resources.
- Clarification of roles, to eliminate overlapping and conflicts and to simplify procedures in licensing projects.
- Creation of a special fund with favorable funding procedures for RE projects and with the ability to implement creative financing mechanisms, especially on the small and local level.
- Emphasis on the participation of the private sector. Private sector participation would be greatly encouraged by incentives that are carefully designed, targeted, timebound (i.e., put in place for a designated period of time), and not distortionary. It would also be encouraged by price incentives (a higher level of prices for energy derived from RE resources, justified on the basis of the environmental benefits that are not fully reflected in current energy prices) and other incentives, such as investment credits, tax holidays, and import duty equalization.

3.75 The effective and successful introduction of RE in Kazakhstan and the Kyrgyz Republic would be greatly aided by technical assistance from bilateral and multilateral assistance programs. Particular areas in which assistance is needed, as identified also by local authorities, include:

- strengthening of policymaking, institutional structures, and RE promotional activities
- improvement of RE resource databases and analysis
- information dissemination
- completion of the legal and regulatory framework
- raising expertise in investment promotion and financing mechanisms
- enhancement of local entrepreneurial skills
- strengthening and refocusing R&D centers and programs
- establishing standards and certification procedures for equipment and systems

Armenia

Renewable Energy Resource Assessment

3.76 The mission made a very brief visit to Yerevan in Armenia to meet with local authorities and to begin the discussion on RE development, mainly as a background to future work, should the opportunity arise. The mission was able to (a) make initial contacts and obtain an impression of the local potential and interest; (b) make a presentation on the World Bank's Solar Initiative and the role it could play in RE development in Armenia; and (c) familiarize itself with the various parties, both local and international, that are involved in the sector.

3.77 The mission was informed that extensive measurements of RE resources exist and have been documented at the Center for Renewable Energy at the Yerevan State Polytechnic Institute (the time available to the mission did not allow discussion or perusal of these data). An active collaboration of Armenian authorities with the U.S. National Renewable Energy Laboratory (NREL) is proceeding to update the measurements as a basis for selecting the most promising sites.

Work to Date

3.78 Considerable experience, gained during the Soviet era, exists in the manufacturing of solar devices. The production by government institutes of **photovoltaic** (PV) panels and hot water systems ended after the breakup of the FSU, however, due to a lack of financing and disruption of the FSU internal markets. PV panels, purchased from Italy, nonetheless continue to be assembled for local applications, with export also envisaged. A **wind turbine** with 1,000 ampère-hour batteries and inverter additionally provides power to a theological seminary at Akhtamar.

3.79 **Solar water heaters** (SWHs) are manufactured by the government in Armenia, but the total installed SWH surface area in the country is only 4,000 m^2.[17] The government is looking to transfer its manufacturing plants to commercial partnerships set up with the private sector. Armenia's interest in and potential for SWHs seems to be strong, given: (a) the country's good insolation; (b) the need to find a substitute for the imported fuel or electricity used for hot water production; and (c) the existence of a capability to produce SWHs at low cost (the figure was quoted of US$ 50–60 per square meter, but this is unrealistically low in comparison to costs elsewhere). It is possible that, through joint ventures with foreign firms, local production could supply affordable SWHs to the local market and possibly competitive products to the export market.

3.80 **Wind**. Three large sites have been identified for wind development: the Pushkin Pass, where a network of anemometers has been installed and where the average windspeed is reported to be of the order of 8.5 m/s; the Sisian Pass; and Lake Sevan. Additionally, a wind/solar hybrid unit at Karahatch Pass has been pumping water at a rate of 8 liters per second at nominal windspeed.

3.81 A number of wind turbines are installed and operated in Armenia. One 15 kW turbine made by Sumitomo Heavy Industries was obtained by U.S. benevolent organizations and installed alongside five smaller 5 kW turbines. Wind turbines have been installed for water pumping on a peninsula in Lake Sevan, and a U.S. firm is planning to install wind turbines of a total capacity of 27 MW in the Pushkin Pass.

3.82 **Geothermal resources** have been examined in Armenia: specifically, a preliminary assessment was performed by the consulting firm Lahmeyer International. One borehole found water at a depth of 350 m that had a temperature of about 83°C and high salinity, and another in the Sisian region produced at a depth of 920 meters a flow of water at 99°C. The study postulates that at a depth of 2,000–2,500 m there potentially could be steam at a temperature of 200–300°C—enough to generate 200 MW of power for the next 30 years. Most other studies consider the possibility of using geothermal

[17] Compare with about 2 million m^2 installed in Greece, which has three times the population of Armenia.

resources for district heating systems. One such study, at a total investment cost of US$ 3 million, was performed for the city of Martuni on Lake Sevan, to investigate the feasibility of providing heat to a local hospital, greenhouse, and apartment complexes. The project subsequently was dropped. The general conclusion is that geothermal resources are of low grade and high salinity, and that their potential for development seems limited to their injection only into district heating systems in the immediate vicinity of the resource.

3.83 **Biogas energy**. A factory that reconstructs motors has diversified into the manufacture of biogas digestors, several of which have been installed in five villages and reportedly are operating well. The feed material is animal waste, which is plentiful in the countryside. Considerable interest exists for the purchase of the factory's 5 m^3 biogas digestors, the use of which is supported by local environmental groups.

3.84 **Small hydro**. The potential for small hydro exists in several rural locations, with the total potential for the country estimated at about 400 MW. The number of sites identified as suitable for small hydro stations is 317, but scant information is available for most of these sites. Armenia has about 25 existing small turbines, only 15 of which are currently operating. Approximately 20 local entrepreneurs have expressed interest in procuring more small turbines, probably from China, proposing to sell surplus power to the grid at a price of US$ 0.025 /kWh. (This price may not be adequate for a reasonable rate of return.) The U.S. Overseas Projects Insurance Corporation and Electricité de France also have shown interest in supporting a program of small hydro development, including the rehabilitation of existing small hydro stations. Based on the potential, local entrepreneurial interest, and the need of the country to increase the contribution to overall electricity generation of local resources, Armenia's Department of Energy plans to encourage the local production of small, 50 kW hydro systems.

Institutional Structure and Framework

3.85 Armenia is the first country of the FSU to proceed quickly with the reform of the energy sector. Owing to its extreme dependence on imported energy, Armenia was designated during the Soviet era as the republic to lead the development of advanced, nonfossil energy sources, including nuclear power and RE. In accordance with this policy, Armenia undertook the manufacture of solar water heaters and set up other institutes to research RE development. (Armenia also was the only country in the Caucasus to acquire nuclear power, a two-unit reactor using VVER-440 technology at Medzamor.)

3.86 The local authorities realize that a package of incentives is necessary to stimulate the development of indigenous RE resources. A draft law is under discussion, and bilateral and multilateral donors, particularly USAID, through the National Renewable Energy Laboratory, are assisting in drafting and installing the institutional framework that is necessary for the energy sector. This framework will depend heavily on the participation of the private sector, since the financial resources of the government are severely constrained. Existing institutions additionally are forming joint ventures to undertake the development of commercial projects.

Local Capabilities

3.87 The Center for Renewable Energy is the focal point for RE study and development in Armenia. It employs about 20 staff and comprises four sections:

- solar energy laboratory
- monitoring and resource assessment
- siting and site evaluation
- design and construction

3.88 The center is active in the collection, documentation, and analysis of RE data. In collaboration with U.S. groups, it also has been monitoring and measuring RE resources and the performance of RE systems. Most of its experience is at the theoretical level, but some practical experience also exists. The center thus represents a repository of knowledge, technical skill, and data that could be useful in future RE development.

3.89 The preparation of comprehensive proposals of viable projects will require both technical studies and economic, financial, and environmental analysis. The capability to perform such analysis is being enhanced through the introduction of new university courses and through the work of consultants employed by bilateral and multilateral donors.

Technical Assistance Programs

3.90 Armenia’s energy sector is the subject of several TA programs, due to the priority that the government attaches to the sector but also to the existence of the Medzamor two-unit nuclear plant. International political support for Armenia’s efforts to change to a market-oriented economy also is strong, resulting in the influx of substantial foreign aid. Most noteworthy are the TA programs of the EU’s Technical Assistance for the Commonwealth of Independent States (TACIS) program, USAID, and of German, Russian, and other donors.

Conclusions and Recommendations

3.91 Armenia urgently needs to diversify its energy profile to reduce its dependence on imports. A primary strategy of the government is to encourage the development of indigenous energy sources, notably the renewable resources of solar, wind, biomass, geothermal, and hydro. Although rehabilitation of existing assets has priority, the Bank’s mission obtained the impression that considerable potential in RE development exists and that the interest of local authorities is strong enough to warrant a closer examination of the situation.

3.92 Studies indicate that windpower has good potential; small hydro also presents potentially viable opportunities that have attracted the interest of entrepreneurs. Solar water heaters could substitute for imported fuels, and biomass could provide energy to rural populations. Local PV manufacturing would have to compete with international producers and costs, other than in a few specialized cases, probably would be prohibitive. For a rational selection of the most promising technologies, applications, and sites, an RE resource assessment would be invaluable. The technical assistance of donor agencies likely would be available to support any such assessment.

Georgia

Objective of the Report

3.93 The World Bank performed a preliminary assessment in Georgia to evaluate the RE sector and the potential of different renewable energies. Most of the work was performed in tandem with a project preparation effort for the rehabilitation of the power sector and alongside the preparation of an Energy Sector Review. Work performed under the Energy Strategy Study, sponsored by the European Union's TACIS program, and the work of Icelandic consultants who prepared an overview report on geothermal resources also was taken into account.

The Energy Sector in General

3.94 Following the breakup of the Soviet Union, Georgia's energy sector had to deal with numerous problems: gas supplies were curtailed, long electricity blackouts occurred with alarming regularity, large numbers of households resorted to the use of fuelwood for cooking and heating, petroleum product prices skyrocketed, and energy supply organizations went bankrupt and their staff became demoralized. The main reasons for this concentration of problems are the heavy dependence of Georgia on imports of fuel and the dramatic deterioration of its electricity generation system. Within the central planning regime of the former Soviet Union (FSU), Georgia's primary role in the regional Transcaucasus Interconnected Electricity System was the development of hydro resources. These sources are seasonal and served as peaking capacity and as a source of energy during the summer months. Many hydro plants have suffered through years of neglect and lack of maintenance, and the operation of one large hydro station at Inguri was seriously hampered by the political problems with Abkhazia, where the plant is located. The major thermal power station at Gardabani also suffered from neglect before being destroyed in 1994 by an explosion widely attributed to sabotage. The situation nonetheless has improved in recent years, and loans have been obtained for the rehabilitation of power plants.

3.95 Georgia has been dependent on imports of electricity (and energy, in general) to balance supply and consumption. The development of national resources to reduce this dependency has become a national priority.

Renewable Energy Resources and Development Potential

3.96 The **hydro potential** of the country has been estimated at about 85 TWh/y, of which only about 10 percent has been exploited. Large hydropower projects such as the 30 percent-completed Khudoni (700 MW) and Namakhvani hydro projects could, if completed, provide large additional amounts of electricity. However, discussion on completion of these projects is premature as electricity generation by the existing hydro plants is only about 600 MW of an installed capacity of 2,800 MW—rehabilitation of existing plants is the least-cost solution and therefore merits the highest priority. In addition, environmental issues that were disregarded under the FSU regime but that likely would generate public opposition today would have to be fully addressed. There exist also a large number of **small hydro plants** that need either rehabilitation or development.

A preliminary study for small hydro development cites the existence of about 150 units of less than 10 MW, with the potential to produce 1,000 MW and 4.5 TWh annually. Bilateral aid agencies are working with local authorities to begin development of a limited number of candidate sites, with emphasis on ownership and the identification of a market for the generated energy.

3.97 One of the most potentially important forms of RE in Georgia is **wind energy**. Karenergo, the national wind energy institute, has identified the three wind fields that it believes are most suitable for the installation of windmills for connection to the grid; one of these is at Mtha Sabueti, which has average wind speeds of 9–10 m/s and autilization factor of more than 40 percent. Another important factor that favors the installation of windfarms in Georgia is the complementarity between wind and hydro. The existence of a sizable hydro generation system provides a natural energy storage system, enabling hydropower to serve as backup for windfarm generation when the wind does not blow. Such a hybrid system would be all the more effective in Georgia since the maximum wind energy output would occur during the winter months when hydro is at its lowest. Given the favorable conditions prevailing in Georgia and the cost reductions that have been achieved in this technology in recent years, wind energy could play an important role in the future expansion of the electricity system. Local groups already have performed significant preparatory work in wind energy development, and the Georgian authorities have already contacted a wind turbine manufacturer at Dniepropetrovsk in Ukraine. The new manufacturer is a joint venture between a U.S. firm and a former defense sector factory, and produces wind turbines that it claims generate energy at a cost of less than US$ 0.03/kWh.

3.98 **Geothermal** springs have been used since ancient times in Georgia as health spas. More recently, geothermal fields have been exploited for space heating and hot water. In the Tbilisi region, two geothermal fields at Lisi and Saburtalo supply hot water at temperatures of 50–60°C and the field at Zugdidi produces water at 90–100°C that is used for hot water and space heating. A recent study by Iceland’s Virkir-Orkint has concluded that the total geothermal resource of Georgia is in the range of 600 to 12,000 MW (thermal), sufficient to provide hot water and space heating for 500,000 to 1 million people. An estimate of the cost of geothermal heat indicates that considerable savings could be obtained from the use of geothermal heat as base load, with small boilers providing peaking load and with mixing performed at substations. For example, the estimated cost to supply hot water only to Tbilisi for six months would be US$ 0.0029 /kWh (thermal); for a 12-month operation, the cost would be about one-half of this figure. This compares well with imported gas, which costs about US$ 12 per Gcal, or about US$ 0.01 /kWh (without taking into account the capital costs for gas transmission and distribution systems). A prefeasibility study has been performed by consultants from Iceland, and a multilateral bank is considering financing a geothermal project in the area of Zugdidi.

3.99 The conditions for the use of **solar energy** are reasonably good, warranting the further development of the solar heating industry. Georgia once supplied solar hot water panels to the entire former Soviet Union (FSU), but the factory is now idle owing to the general economic downturn in the FSU and to the technical deficiencies of the technology used.

3.100 **Biomass** has been used in Georgia in the past, mainly in the form of biodigestors, but with little success. However, fuelwood now is being consumed in large quantities as household fuel, owing to the shortage of hydrocarbon fuels and electricity. A survey covering about 650,000 households and completed in the summer of 1994 revealed that about 50 percent of households use fuelwood. The total amount used in the period mid-1993 to mid-1994 is estimated at about 5.6 million m^3 of stacked wood (4.5 million m^3 in rural areas and 1.1 million m^3 in Tbilisi and other urban areas), with fuelwood therefore accounting for 12–15 percent of total primary energy consumption. The fuelwood used is equivalent to 1 million tonnes of standard coal, and the consumption of fuelwood energy is 50 percent higher than the energy produced by hydro resources. The amount of fuelwood used and, more importantly, the way in which it is used may not be consistent with the national objectives of preserving the national forests for their functions as protection against soil erosion, maintenance of water and other resources, and recreational and tourist development. It is estimated that only 1 million m^3 of stacked fuelwood is officially authorized for household use, and the rest constitutes illegal use. Official usage figures furthermore are based on the low price of 40,000–50,000 Georgian coupons[18] per cubic meter—the actual cost of fuelwood may be as much as 20 times higher: 1 million coupons (approximately US$ 0.70) per cubic meter.

Recommendations for Further Work

3.101 The main obstacle to the development of **wind energy** is the absence of a viable electricity company that either could invest in, own, and operate such a plant or could purchase the generated power at a price that would allow a reasonable rate of return to private investors. The situation has changed since the RE mission, with the unbundling of the electricity sector and new government policy to privatize existing generating plants and to allow new generation by the private sector. Given the difficulties and priorities of the system, it is suggested that a pilot project be launched, preferably using grant funds, that would employ a small number (four or five) of commercial wind turbines of 100 to 500 kW each, coupled with a systematic network of anemometers. Such a project could introduce the technology to Georgia, provide reliable measurement of wind resources, and confirm the performance of the turbines under the conditions of the chosen site.

3.102 Concerning **geothermal,** it is suggested that tests be performed, including reinjection tests, for one year and that careful monitoring be undertaken to obtain histories of temperatures and chemistry effects. The utilization of geothermal water in district heating (DH) systems assumes that the DH networks are in or can be brought to a satisfactory condition with a modest investment. A study to determine to what extent the DH systems in the major cities of Georgia can or should be rehabilitated is yet to be performed.

3.103 The commercial development of **solar water heaters** could be led by the private sector and enabled by the apparent low local production costs. Following privatization of the industry, partnerships with foreign companies and technical

[18] At the time of the mission, coupons were in use at an exchange rate of about 1,430 coupons per U.S. dollar. A new national currency has since been introduced, the Georgian lari, at an exchange rate currently of 1.3 lari : US$ 1.

assistance could help the industry become a competitive, quality supplier in the regional market.

3.104 **Biomass** resources do not seem to be adequate for large-scale applications, and the current extensive use of fuelwood furthermore is unregulated and possibly damaging to the forests. The Georgian authorities are keen on securing technical assistance—the EU Commission is planning to provide such assistance—to establish a forestry management plan for the protection and rational utilization of forest resources. Small biogas digestors, of limited success in the past, may continue to play a small role in rural areas where livestock and agricultural waste is available. Local use of forest waste materials and industrial and agricultural waste (for example, papermill waste) may be possible and economical in cogeneration mode.

3.105 The conclusions of this assessment are that there exist considerable RE resources in Georgia that could make a significant contribution to the energy balance of the country. The most substantial RE resources are hydro, wind, and geothermal. However, a number of institutional and economic issues first must be resolved before the intensive exploitation of RE resources can be undertaken.

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Renewable Energy Potential in Selected Countries

Volume II: Latin America

Energy Sector Management Assistance Program
(ESMAP)

1

Regional Overview

1.1 Latin American countries recognize that efficient, reliable, and financially viable electric power sectors are critical to their continued economic and social development. Over the next 10 years, the need for new electricity generating capacity in Latin American and Caribbean (LAC) countries is expected to grow by 50 percent, an increase of about 90 gigawatts (GW). More than half of this capacity will need to be financed with private investment, as well as with the support of multilateral and export credit agencies.

1.2 In response to these needs, many LAC countries have begun major structural reforms of their electric power sectors to support economic development and social progress. The reforms are characterized by de-monopolization and privatization designed to attract private investment, increase efficiency, improve system reliability, and promote technology diversification.

1.3 Linked to the overall reform process, many countries in Latin America are concerned with expanding the availability of electricity services, particularly to rural and remote areas. In this regard, there is emphasis throughout the region on renewable energy (RE) technologies and on innovative delivery and financing mechanisms, both of which are expected to be important to sustainable development strategies and to the economic development of rural areas. Carefully conceived and properly developed programs can provide economic, environmental, and health benefits as electricity displaces traditional energy supplies, such as kerosene for lighting, in rural and remote areas.

1.4 RE technologies offer LAC countries the opportunity to obtain cleaner, more sustainable energy from indigenous sources, particularly for electrification. While they generally are more costly than conventional systems in applications connected to the main network, RE technologies already are economically competitive in off-grid situations, both for individual homes and for isolated mini or micro grids.

Rural Electrification Issues in the LAC

1.5 Rural electrification levels vary widely throughout Latin America, from less than 15 percent to more than 95 percent in some countries. As a result, the needs and corresponding approaches to electrification vary tremendously. In some countries there remain many densely populated communities that lack power, while in other countries the necessity lies exclusively in electrifying dispersed, isolated villages or homes. Regardless of current conditions, the challenge throughout Latin America is to significantly accelerate the pace of electrification in a manner that is cost-effective, reliable, environmentally sound, and sustainable. To do this, the key issues outlined below, among others, clearly need to be addressed.

1.6 **Resource information and policies**. The development and implementation of economically attractive policies promoting rural electrification in the LAC region is hampered by the lack of essential information. In the past, few of the countries in the region had accurate information on the appropriateness of various generation options for the unelectrified population, user willingness and ability to pay, or the availability of renewable natural resources. In such an environment, policies and planning tended to be politically based rather than based on any economic or financial rationale. Given the overall reform process, including the emphasis on rural electrification, this situation is changing. For example, in Guatemala the national utility is now basing its decisions on line extensions on cost-benefit analyses and demand assessment methodology. In Bolivia, the master rural electrification plan is being developed with the use of a geographical information system (GIS).

1.7 Rural electrification nonetheless presents a significant challenge to energy planners. In many countries in the LAC region rural energy policies are weak, per capita electrification of rural areas is viewed as expensive, and cost recovery is seen as difficult, technically challenging, and politically divisive. While privatization is occurring throughout the region, one of the great challenges confronting governments is how to attract private capital to invest in rural electrification projects. In order to provide an attractive investment environment, the private sector at a minimum will require clear and transparent guidelines under which investments will be recovered, such as tariff provisions, depreciation incentives, and, in most cases, co-investment by the government to reduce the overall investment cost of the projects.

1.8 Regarding the latter, progress is being made in certain countries. In Argentina, the federal government has established a national electrification strategy wherein it will cost-share subsidies provided to off-grid rural areas that will be served by private electric utilities. The utilities will be granted long-term concessions to protect their investment and will receive income from their customers as well as from the Argentine government.

1.9 **Subsidies and other incentives**. In most rural electric systems, some form of subsidy is required to ensure that electric rates can be offered at reasonable and affordable levels, in order to promote economic development and to allow the rural electric utilities to recover the cost of their investment. Subsidies have taken the form of low-cost loans, fiscal incentives (accelerated depreciation incentives and other tax breaks), and direct transfers, in the form of lower rates offered at the wholesale and retail levels. When not conceived carefully and insulated from political interference, such subsidies have led to economic inefficiency and waste in many LAC countries. There now seems to be greater awareness of the appropriate role of subsidies, and more care is being taken to ensure they are directed at the proper targets.

1.10 In Brazil, for example, the 1995 National Action Plan called for the diesel subsidy fund for Amazonian electrification to be made available to finance the replacement of existing diesel systems with renewable energy technologies. The fund, originally intended to allow for lower-cost power generation with diesel, was to be made available to renewable energy technologies, enabling them to provide service in an economically and environmentally sustainable manner to areas that cannot be served with other electrification systems.

1.11 Excessive import duties and other trade barriers can also serve to distort the market for electricity generation technologies, leading to inappropriate technology choices. Renewable energy systems face such trade barriers in several LAC countries, making them uncompetitive with fossil-fueled generators. As a result energy planners may select technologies, such as diesel generators, that turn out to be much more costly, unreliable, and environmentally damaging in the long run.

1.12 In 1988 the Dominican Republic passed a law exonerating all electrical generators from import duties. This led to a steady flow of imported, high-quality photovoltaic modules, sold by local distributors on a commercial basis. This market has thrived, without the input of government subsidies, on what is essentially a cash/consumer credit scheme. In Guatemala, government Decree 20-86 allowed renewable energy technologies to be imported tax- and duty-free. This has been a key step in fostering the development of this industry throughout Guatemala.

1.13 In Argentina, the privatized model (see Section II) was created so that private concessionaires would have exclusive rights to provide for rural electrification services in province-wide service areas. The government would provide subsidies to the concessionaire to support installation, maintenance, and operation of the systems for the dispersed market. However, the subsidies will decline over time, and the bulk of the cost recovery is expected to come from end users.

1.14 **Cost recovery**. Cost recovery through rate collection has historically been problematic for many rural electricity providers. Costs of metering, billing, and collection are high, and, if not controlled vigorously, theft can become a problem. Losses, largely administrative and nontechnical, can run as high as 40 percent in some rural systems. Proper administrative, financial, and technical controls must be installed to ensure that collection is efficient and effective and losses are minimized. This one factor can lead more quickly than any other to the failure of rural electric utilities, whether they use conventional or renewable energy technologies.

1.15 **Project selection**. Selecting communities to receive electricity has often been a highly politicized process. With privatization of state-owned systems, central planning and selection are becoming a thing of the past. However, the state is likely to continue to be involved in cofinancing rural electrification projects, particularly for "missionary electrification." It is important that pragmatic methods of planning rural electrification schemes be implemented that incorporate criteria such as the needs of communities, costs and benefits, productive end uses, and the environment.

1.16 Selecting the most appropriate technologies for rural electrification requires assessment of many factors, including resource availability, lifecycle cost analysis, quality profiles of demand, environmental considerations, and other key criteria. It is key that the institutions making decisions in this sector have the technical capacity to perform such analyses.

1.17 Bolivia has established a national policy that mandates that the power to allocate infrastructure resources be directly in the hands of the communities themselves. Each community is given monetary resources on a per capita basis from the federal government to implement what they consider priority activities.

1.18 **Institutional capability**. In all rural electrification scenarios in Latin America, institutional capacity will be a key variable to successful projects. Often technical capacity building can be achieved through institutional linkages. Local implementing institutions generally have a fundamental knowledge of the local market, but they often require that outside institutions furnish hardware, technical assistance, and capital at the initial stages of project/program development. International linkages have been particularly effective in providing scarce capital, management techniques, and newly commercialized technologies. These include linkages between local institutions and technical laboratories, bilateral aid agencies, product suppliers, project developers, and international nongovernmental organizations. Such linkages can be used as a means of promoting technology transfer and developing local skills in implementing countries.

1.19 Human and infrastructural capacity can also be supported through targeted training activities. Tremendous opportunity exists throughout the LAC for training at all levels of the sector, from utility leaders to system users. By targeting training in implementing countries, the necessary skills can be transferred to local implementers.

1.20 In Honduras and the Dominican Republic, Enersol, a private Energy Service Company (ESCO), provides training, technical assistance, and financing for the establishment of local enterprises that sell, install, and maintain solar electric systems in local communities. The U.S. Department of Energy-supported Renewable Energy and Energy Efficiency Training Institute (REETI) recently supported a series of targeted workshops at the *Conferencia Latinoamericana de Electrificaci¢n Rural* in Argentina. These workshops covered wind energy applications for rural electrification, renewable energy financing for community development, and renewable energy applications for productive uses.

Enhanced Role for the Multilaterals

1.21 Access to long-term, low-interest capital is restricted normally to large, low-risk generation projects and is generally unavailable to rural electrification projects. However, successes in renewable energy rural electrification projects mean that the question of longer-term financing is again being revisited by the multilateral development banks, as they weigh the risks against the obvious economic and environmental benefits these projects will yield. As experience is acquired in aggregating numerous small, dispersed electrification plans, financing has taken the shape of conventional large projects.

1.23 As Chapter 2 outlines, the multilateral banks now are playing a role in financing rural electrification projects in the region. To attract more support from these entities, client countries must be able to demonstrate that a project is technologically viable, will produce sufficient economic returns, and, fundamentally, that the institutional capacity exists to implement and monitor project development. Grants from the Global Environmental Facility (GEF) can be instrumental in contributing to World Bank financing for renewable energy systems, both by buying down the cost of capital and by providing funds for technical assistance.

1.24 National commercial and development banks also have an important potential role to play as second-tier financial institutions. They have thus far been relatively minor players in the area of rural electrification, however. These institutions typically have perceived the risks of investment in this sector as being too high and the rates of return as being too low for their involvement. Such perceptions can be overcome through a variety of mechanisms, including preinvestment study support, loan guarantees, education and training efforts, the development of efficient infrastructures, and the use of least-cost technologies.

1.25 In sum, progress in the use of renewable energy for rural electrification is being made in select countries in the LAC, with other countries in the region anxious to learn from and follow successful development models. Recent efforts in Argentina, where the World Bank is now working in coordination with the government and with the domestic and international private sector, could provide valuable lessons for the region as a whole. Chapter 2 highlights the in-depth efforts underway in Argentina, as well as the vast market potential for renewable technologies and rural electrification throughout Mexico. Finally, while smaller in scale, the case of Panama offers an insight into a country committed to providing a framework and implementation strategy that focuses on both renewable energy and rural electrification.

2

Opportunities in Selected Countries

Argentina

Background: PAEPRA

2.1 The goals of the Government of Argentina (GoA) for the continued development of energy are to continue the expansion of private sector participation in the power business, to diversify the use of primary energy resources, to minimize the negative impacts of energy use on the environment and society, and to make energy services available to the population at large. As part of these goals, the GoA is making serious efforts to consolidate power sector reform throughout the country by:

- strengthening the power sector regulatory frameworks and institutions in the provinces;
- promoting enhanced private investment throughout all areas of the sector, including rural electrification.

2.2 The GoA has nearly completed the macro reform of the power sector. The power market has been unbundled (generators, transmitters, distributors, and large users) and the main power utilities and power plants have been privatized. Now the GoA and the provincial governments are gradually progressing in the transformation of the provincial power systems. To accelerate the entry of private investors, provincial electricity service has been divided into two markets:

- the concentrated market, or grid-connected market
- the dispersed, rural off-grid market

2.3 Consequently, most of the provincial concentrated markets have been privatized.

2.4 In its approach to service provision in the dispersed markets, the GoA, through the *Secretaria de Energia,* initiated in 1995 the implementation of the *Programa de Abastecimiento Electrico de la Poblacion Rural Dispersa de Argentina* (PAEPRA). Overall, the program aims at supplying electricity to about 1.4 million inhabitants (300,000 households) and more than 6,000 public services (schools, first aid medical centers, police stations, civil services) through private concessions. It is estimated that full implementation of PAEPRA will require about US$ 314 million.

2.5 The rural residents and public service centers targeted by the program are located in remote areas of low population density that (in general) do not have the possibility to be served through traditional grid extension. In such areas, small-scale renewable energy technologies, such as solar home systems and hybrid diesel and renewable systems become important options for individual hones and isolated mini or micro grids. However, the concessionaire in each province is free to choose the technology or system that is the most financially viable, given the tariffs set by the province for the particular type of service. The concession is awarded by competitive bidding to the private company that requires the least subsidy. This public-private partnership for the provision of electricity service to remote, low-income areas is unique and is internationally perceived to be a highly innovative approach to the problem.

The World Bank Project: PERMER

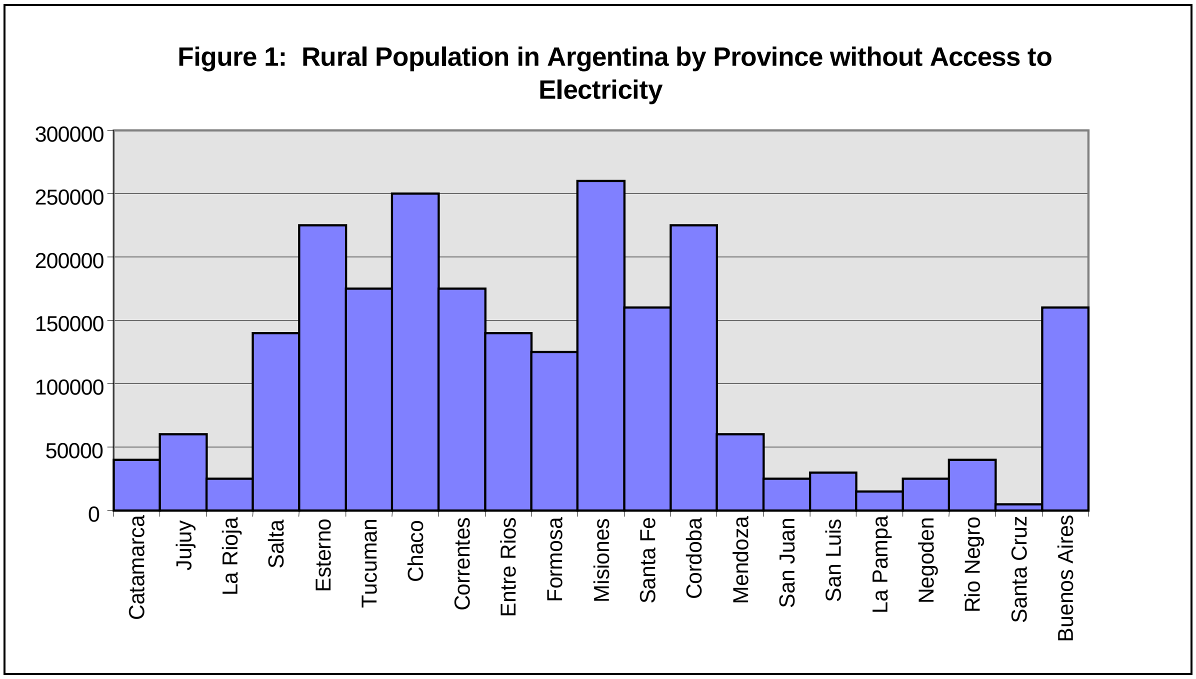
2.6 In 1997, the GoA requested financial assistance from the World Bank to implement the PAEPRA program in several provinces. Known subsequently as the Renewable Energy in Rural Market Project (PERMER), the Bank project can be regarded as a subset of PAEPRA, combining regular loan funds with grants from the Global Environment Facility (GEF). PERMER is designed to reach approximately 65,500 individual customers and to provide energy service to approximately 3,500 households in agglomerated villages by means of collective energy systems (primarily RE systems), as well as to about 2,800 public service centers (all with RE systems). The financing plan for PERMER is shown in Table 2.1.

Table 2.1

Source	Total (US$ millions)
Government (national and provincial)	*26.5*
Customers	*10.8*
International Bank for Reconstruction and Development (IBRD)	*30.0*
Global Environmental Facility (GEF)	*10.0*
Concessionaires	*43.2*
Total	*120.5*

2.7 The GoA indicated that the Bank/GEF involvement was needed not only for financing considerations but, equally important, for the expertise and international experience that are vital to pioneering projects of this type. The Bank's presence can help ensure transparency in the awarding of concessions and compliance with contractual obligations, and can ensure that the overall project is designed and implemented within a framework of the reformed power sector. Finally, it was envisioned that GEF financial involvement would permit more rapid implementation and penetration of RE technologies than would normally be the case, including broader provincial coverage, as well as more intensive monitoring and evaluation of the project. The present ESMAP activity extensively assisted LAC staff in the design of PERMER, particularly in determining the appropriate catalytic role that GEF grant financing can play in reducing market barriers for the introduction of RE systems.

Figure 2.1: Rural Population in Argentina



Sources: *Secretaria de Energia y Transporte de Argentina. Programa de Abastecimiento Electrico de la Poblacion Rural Dispersa de Argentina*, 1995.

Characteristics of Off-Grid Markets

2.8 According to data from the Energy Ministry in Argentina, approximately 2,360,000 (approximately 8 percent of the country population) of Argentina's 4 million rural inhabitants lack access to electricity service. The rural population by province without electricity is depicted in Figure 1. The overall target provinces for PAEPRA fall into five distinct socioeconomic and geographic regions. The different socioeconomic and natural resource characteristics of these regions affect the overall design of PAEPRA, including household income and ability to pay for new individual systems, dispersion of the population and cost of delivery of electrical services, solar insolation, and the output achieved by given systems throughout the different regions. The five regions, with the inclusion of the target provinces, are briefly profiled below:

- **Noroeste**. Mixed economy based on agriculture, cattle raising, mining, forestry, tourism, and some industry. The less developed rural zones are dependent on a traditional agricultural economy. Santiago del Estero and

Jujuy are located in this region. Santiago del Estero contains the largest number of unelectrified households, which are characterized by relatively high levels of poverty.

- **Sierras Pampeanas**. Diverse geography with mountains, valleys. and plains. Area is characterized by widely scattered population settlements along with scarce water resources. La Rioja, San Luis, and Rio Negro are in this region.
- **Mesopotamia**. Eastern region with unique geography that includes forests. Distinct economic activities include subtropical agriculture, as well as grain production and cattle. Corrientes, Misiones, and Entre Rios are in this region.
- **Noreste**. Characterized by agriculture, silvoculture, and cattle industry. Subtropical agriculture and forest exploitation are also characteristic. Represents region of country most recently populated. Highest levels of poverty nationally. Formosa is in this region.
- **Cuyo**. Western region characterized by irrigated agriculture and vineyards. Other important economic activities include mining, petroleum, and tourism. Mendoza is in this region.

2.9 Eight provinces were selected for PERMER. Each province has privatized or is in the process of privatizing its power sector, or at a minimum has made a legal commitment to privatize. The composition of the dispersed market in each province is shown in Table 2.2.

Table 2.2

Province	Customers	Capacity (kWp)	Households	Public Service	Collective Service
TOTAL	*70,247*	*6,658*	*65,584*	*1,136*	*3,547*
Chubut	*4,346*	*519*	*4,110*	*20*	*216*
Corrientes	*21,560*	*2,043*	*20,140*	*380*	*1,040*
Entre Rios	*16,190*	*1,425*	*15,200*	*190*	*800*
Jujuy	*2,514*	*248*	*2,280*	*114*	*120*
Mendoza	*2,376*	*208*	*2,128*	*19*	*229*
Rio Negro	*2,905*	*370*	*2,660*	*105*	*140*
San Luis	*3,677*	*385*	*3,268*	*238*	*171*
Tucuman	*16,699*	*1,460*	*15,796*	*70*	*831*

2.10 Although a significant number of isolated micro grids using small hydro plants, small wind turbines, diesel plants, or hybrid plants (diesel/wind, diesel/solar, or solar/wind) will also be installed under the project, the largest component of each market is dispersed individual households. Depending on current expenditures for lighting by kerosene, liquid petroleum gas (LPG), and other fuels, these households could get equivalent lighting service from solar home systems of between 50 and 400 watts. The lower service levels represent potential customers whose shift from traditional lighting fuels to solar home systems would generally require additional expenditures, due to the still high cost of photovoltaic systems. The magnitude of this incremental cost depends on the household's willingness to pay (which at the minimum is indicated by current lighting expenditures).

Ability and Willingness to Pay

2.11 A study carried out in seven small communities in the provinces of La Rioja, Catamarca, and Jujuy—provinces targeted for RE systems—have determined that the monthly expenditure by rural families on lighting and communications varies from area to area, from US$ 4 to US$ 38 per month. The average expenditure on lighting and communications in these areas is approximately US$ 13.50 per month.

2.12 Recent surveys show that for the province of Misiones, more than 50 percent of the rural inhabitants without electricity pay US$ 15–20 per month for service that could be provided by a 50Wp solar home system. The average income of a family without electricity service in this case is US$ 460–640 per month for land-owning families and US$ 230–260 per month for non-land-owning families.

2.13 Similar findings were also revealed through a recent survey in a small town in the province of Santa Fe, where monthly expenditures on lighting and communications averaged US$ 19.50. The arrival of basic electric service was greeted with a high level of acceptance (75 percent) by those interviewed. Interviewees showed a willingness to pay US$13–20 per month for the basic level of service that could be provided from a 50Wp solar home system.

2.14 Based on the GoA surveys from dispersed areas in five provinces, the unelectrified households can be categorized into essentially four levels of energy expenditure. These levels are presented in Table 2.3. Energy expenditures are for kerosene, candles, dry cells, and battery charging. The values presented are levelized monthly expenses:

Table 2.3

Income Type	Income/Month	Percentage of Households	Approx. Energy Exp./Month
I	*<$150*	*19*	*$10*
II	*$150 to $250*	*40*	*$15*
III	*$250 to $400*	*27*	*$25*
IV	*>$400*	*14*	*$38*

2.15 Again, current energy expenditures by household is considered the best indicator of the household’s capability and willingness to pay. It is believed that consumers cannot afford monthly payments higher than their current energy expenditures, regardless of the technology and institutional arrangements used to supply them. In the particular case of Type I consumers (see 2.3), their monthly energy expenditures are roughly similar to the monthly lifeline tariff provided to urban markets.

2.16 The survey data revealed that Type I and II households use Petromax, wick lamps, and some candles for lighting, plus dry cells for powering simple radios. There is little or no car battery charging. Taking into account the normal life of these appliances, typical costs in the rural areas, and surveyed hours of usage, the net present value of energy expenditure by Type II households over 15 years is estimated at US$ 1,245. This figure includes equipment replacements over time.

2.17 A Type III household uses Petromax or LPG lanterns and wick lamps for lighting. For powering radios and black and white television sets, the household typically uses a car battery charged at a central station about twice a month, as well as some dry cells. The net present value of Type III household energy expenses over 15 years is estimated at US$ 2,070.

Cost of Solar Home Systems

2.18 The cost of solar home systems is still high in comparison with the ability and willingness of rural customers to pay for such systems. In the fee-for-service scheme, the concessionaire must be paid a monthly tariff that in effect is the amortized value of the system over 15 years plus the cost of replacements and operating and maintenance costs (see Table 2.4). Comparing the monthly payments with the willingness-to-pay levels in Table 2.3 (as approximated by the current monthly fuel expenditures for lighting), it is seen that Type I and II households would require subsidy in order to meet the incremental costs of shifting to a solar home system.

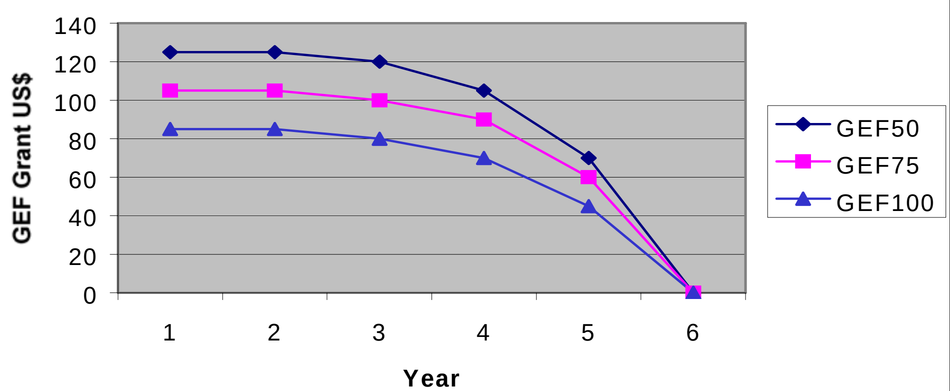
Table 2.4

SHS size	Investment	O&M	Replacement	Total	Monthly
50Wp	*764*	*390*	*216*	*1,370*	*16.80*
70Wp	*1,074*	*390*	*299*	*1,763*	*23.10*
100Wp	*1,347*	*390*	*418*	*2,155*	*26.70*

Assumptions: all economic costs; 15 years life; 14 percent discount rate; 20,000 household market size.

2.19 In the PERMER project, part of the subsidy is provided through the GEF through a buydown of the investment cost, in effect reducing the monthly payments. The GEF subsidy is provided at a level that starts with the estimated incremental cost for the particular system size and declines to zero at the end of the PERMER project. At that time, the expectation is that there is sufficient reduction in system costs—mainly through reduced operation and maintenance (O&M) cost per unit as the consumer base expands—to obviate the need for the GEF subsidy (see Figure 2).

Figure 2: Declining GEF Grant



2.20 The subsidy provided to each market segment is summarized in Table 2.5.

Table 2.5

Market Segment	System	Subsidy*
Agglomerated customers	*Centralized system: diesel, etc*	*Partial subsidy*
Dispersed lowest-income households (Type I)	*SHS (50W)*	*Partial subsidy*
Dispersed low-income households (Types II and III)	*SHS (50W,75W, 100W)*	*Partial subsidy*
Other dispersed households (Type IV)	*SHS (>100W)*	*No subsidy*
Public service centers	*PV (>100W)*	*Full subsidy*

* Subsidies are from the GoA and from the GEF. There is no GEF subsidy for diesel systems, Type IV households, or public service centers.

2.21 Type I households, as outlined in Table 2.3 (lowest income level at less than US$ 150 per month), are to be subsidized in full by the GoA and are not considered for GEF assistance. The GoA wants this segment of the population to be provided electricity for basic lighting, radio, and so on by means of the 50 Wp solar home system. The GoA is prepared to subsidize this segment to the extent similar households in the grid-connected markets are being provided with lifeline tariffs. Type IV households also are not considered for GEF assistance because their incremental costs are estimated to be negligible or negative.

2.22 Type II and III households earning less than US$ 450 per month have energy use patterns considered suitable for systems ranging from 50 Wp to 100 Wp. The incremental costs estimated by the Energy Ministry and the Bank match this range of income with solar home systems of 50 Wp, 70 Wp, and 100 Wp. The GEF grant will decline to zero at the end of the initial five years of the concession contract.

2.23 GEF assistance to these system users will effectively bring system costs to roughly the same level of the user’s current energy expenditures. The support is designed also to stimulate the creation of an initial consumer base. It is expected that households will choose system sizes in rough relation to their income levels.

Lessons from PERMER

2.24 Since the PERMER project only became effective in June 1999, no observations can yet be made as regards experience with installed systems, performance of concessionaires, or the adequacy of the tariff scheme. However, the preparation of the project has identified the key issues that must be addressed in designing an approach to the provision of electricity services to dispersed rural areas, particularly to individual low-income households.

2.25 Although in this context renewable energy systems such as the solar home system are often the least-cost option, there are important market barriers, including the following:

- Insufficient information for prospective private investors to compete for investment in a concession system based on renewable energy. This includes information on market size and characteristics, the costs of operation and maintenance of systems in dispersed and difficult terrain, adequacy of the proposed tariffs, and potential difficulties in tariff collection, for example.

- The need for substantial investment resources at the front end, due to the high capital cost and low recurring cost nature of renewable energy investments. These capital resources are at risk from potential consumer default or termination of service, although these risks are partially mitigated through the consumer connection fee.

- Market reception of a relatively new technology: Will clients accept it, and will they be able and willing to pay for the system or service? (In surveys, for example, many unelectrified rural people in Argentina express a preference for alternative current (ac) service or are not interested in a solar home system, thinking it will reduce their chances of being selected for grid connection in the future). The reasons for resistance on the consumer side include inadequate information on the benefits of the new technologies and high set-up costs.

2.26 The fee-for-service concession approach addresses the important barrier of affordability by spreading out consumer costs over the long term. The granting of exclusive rights over a large area additionally ensures a market of sufficient critical mass for business: this in turn attracts larger, better-organized private companies with their own sources of financing, or leads to the creation of such companies in the country. Economies of scale are achieved by reducing unit costs of equipment (through volume discounts), transactions (for example, selling and collection), and operation and maintenance (one vehicle serving 200 customers instead of 20), and by spreading the fixed administrative costs of the provider over a large number of customers. The obligation-to-serve characteristic of a concession furthermore creates a greater likelihood that a large number of customers will be covered within a reasonable period of time.

2.27 This is not to conclude that the concession system is the only effective approach to large-scale commercial deployment of RE systems. The approach implemented in earlier Bank projects in Indonesia and Sri Lanka—seeking competitive operations by individual solar home panel dealers—has many advantages as well, given the particular situation in these two countries. As more experience is gained of these different delivery mechanisms, it is anticipated that not one but several approaches will be found effective, according to the country or even the local context.

Future Investment Opportunities

2.28 There remains a significant opportunity to expand the PERMER project, not only within the targeted provinces but also throughout rural Argentina. Based on the costs associated with PERMER and data related to the unelectrified population, it is estimated that potentially another US$ 200–500 million in project financing could be focused on rural electrification throughout the provinces. As experience is gained in the service delivery mechanisms pioneered by PERMER, the Government of Argentina hopes that a large proportion of these financing requirements will increasingly be borne by the private sector.

Mexico

Introduction

2.29 Recent studies have concluded that the greatest immediate potential for the economic exploitation of renewable energy in Mexico lies in small-scale systems for rural use. A KPMG Peat Marwick national study commissioned by Sandia National Laboratories identified three major market segments:

- rural households
- potable water applications
- agricultural applications

2.30 The survey estimates that these segments have an investment potential ranging between US$ 500 million and US$ 1 billion. These potential rural users are found in dispersed locations and require relatively modest amounts of energy, their needs thereby fitting well the supply characteristics of modular renewable energy systems. About one-half of the total investment potential is in the rural residential market, primarily for the lighting of dispersed households situated in areas more than 7 km from the main networks.

2.31 According to the *Comision Federal de Electricidad* (CFE), the 12 states with the largest portion of off-grid localities appropriate for the residential market would be, in the south, in Veracruz, Chiapas, Oaxaca, Puebla, Campeche and Guerrero, and in the north Chihuahua, Tamaulipas and Sonora, and in the central states in Michoacan, San Luis Potosi and Jalisco. At an estimated average per household cost for a renewable energy system of US$ 950, the overall market potential for off-grid residential electrification for the 12 states alone exceeds US$ 500 million. This size of investment for remote electrification targets is not likely to be included in the Government's regular rural electrification program. The challenge is to find ways to attract the private sector into a public/private partnership that puts some of the risks out of government hands without totally removing the government's responsibility for providing basic services to the poorest sectors of the population.

Power Sector Context

2.32 In 1998, Mexico had a total installed capacity of 36,000 MW. Power demand is expected to grow at an average rate of 5 percent per year in the next decade, with total gross generation reaching some 230,000 GWh by the year 2007. Approximately 66 percent or 24,000 MW of capacity is thermal, powered by fossil fuels (fuel oils and natural gas) and coal. The GoM has established policies to reduce or mitigate the emissions of thermal generation through energy conservation programs, substitution of coal and fuel oils by natural gas, as well as by the development of renewable energy projects.

2.33 Institutionally, the Energy Ministry (Secretaria de Energia, SE) is responsible for establishing sector policies for the energy sector as a whole, which includes both the oil/gas and the power sectors. The Energy Regulatory Commission (*Comision Reguladora de Energia*, CRE) is responsible for the supervision of the operations of the overall sector and for granting permits for private generation. Tariffs are set by the Ministry of Finance (*Secretaria de Hacienda y Credito Publico*) with the participation of the SE and the CRE. In the power sector, the CFE and *Luz y Fuerza del Centro* (LFC) are responsible for the provision of electric service for public consumption. Since 1992, however, private generation can be installed in Mexico for self-consumption, mainly by medium and large size industries and by Independent Power Producers (IPPs) for sale to CFE and LFC. As of October 1998, a total of 80 permits have been granted for the installation of approximately 4,000 MW. It is expected that the majority of new generation capacity in Mexico will involve the significant participation of the private sector.

Rural Electrification

2.34 Mexico's national electrification rate is 95 percent of its 100 million population and is considered high by regional and international standards. However, in absolute terms the remaining unelectrified segment of the population still comprises more than 1 million households, with approximately 80 percent of these in rural areas. These households also constitute the poorest segments of the population. While the GoM is targeting an electrification rate of 97 percent by 2000, the sharp cuts in CFE budgets, along with other priorities of the SE, cast doubt on the attainment of this goal. Furthermore, the connections that are made likely will be in areas close to the existing grid. For the foreseeable future a substantial number of unserved rural inhabitants are not likely to have access to even the most basic electric service due to the high costs of conventional solutions, such as grid extension or installation of isolated diesels and mini grids. The situation presents a special challenge to the GoM's overall development agenda of improving the level of human welfare not only in urban areas, but in all parts of the country.

2.35 Due to budgetary constraints, rural electrification does not play a priority role in the overall energy policy of the SE. Higher priority is placed on the objectives of improving energy efficiency and promoting switching from fuel oil and coal to natural gas. Of resources allocated by the CFE to rural electrification, only 10 percent are dedicated to off-grid areas, while 90 percent are focused on traditional grid extension.

2.36 Recent efforts on the part of the GoM to support off-grid rural electrification initiatives were promoted primarily through the *Programa Nacional de Solidaridad* (Pronasol), which focused on rural infrastructure. The Zedillo administration, however, replaced Pronasol with the *Programa de Educacion*, *Salud y Alimentacion* (Progresa) and Salud 2000, which focus on alleviating extreme poverty through the provision of basic services and infrastructure, with an emphasis on education, health care, and nutrition. It is expected that with Progresa, and through the *Secretaria de Desarollo Social* (SEDESOL—Progresa's main implementing agency), less emphasis will be placed on rural electrification initiatives and priority emphasis will be on education, health, and nutrition projects.

2.37 Federal efforts to support rural electrification are also diminished by the GoM's commitment to decentralization. In a break with tradition, the GoM is trying to decentralize political power away from Mexico City, and is placing more emphasis on state and regional authority and autonomy. State and municipal governments are becoming better positioned and more interested in supporting rural electrification efforts, but generally lack experience and resources.

2.38 While the states are allocated 16 percent of the federal budget, they have generally allocated only a small portion of their budgets (approximately 13 percent) to public works projects. While the *municipios* have even less money than the state governments, a higher portion of their budgets (approximately 25 percent) is dedicated to public works projects. Recently, state and municipal initiatives with pilot projects in small-scale, off-grid rural electrification using renewable technologies, including solar lighting systems, solar pumping, and windpower, have been undertaken with varying degrees of effort and success in the states of Chihuahua, Sonora, Baja California Sur, Chiapas, Oaxaca, Quintana Roo, Veracruz, and San Luis Potosi.

2.39 While the municipal governments lack financial and human resources, they are more familiar with rural communities. Overall, it is expected that they will play a more important role in the design and implementation of, among other projects, rural electrification projects that can serve local, off-grid needs. In addition to being prospective stakeholders in such projects, the states and municipals also offer the prospect of partnerships with the donor community and the private sector, and represent prospective sources of funds for the leveraging of rural electrification efforts.

Characteristics of Off-Grid Areas

2.40 Mexico has a rural population—"rural," as defined by the GoM, implying communities of less than 2,500 inhabitants—of an estimated 23 million. Of these, an estimated 800,000 to 1 million rural households lack basic services, including electricity. These households generally are found in the poorest southern and central states, such as Chiapas, Oaxaca, Veracruz, Guerrero, Hidalgo, Campeche, and Puebla. They furthermore typically are dispersed in remote locations, and generally are removed from national economic life. According to the CFE, more than 5,700 villages of 500 inhabitants or less are not connected to the power grid. Income statistics indicate that an estimated 2.8

million rural households in Mexico subsist on an average household buying power of less than US$ 2,000.

2.41 The incidence of poverty, which is highest in the central and southern states, has been rising. These states account for about 15 percent of Mexico's population but contain more than half of those classified as "extremely poor." The poverty rate in indigenous communities is alarmingly high, at around 80 percent. According to the World Bank's recent Country Assistance Strategy (CAS) on Mexico, despite the relatively high levels of public expenditure in recent years, deficiencies in the design and implementation of government programs have led to disappointing results on the ground, with the result that the government has failed to make these states fuller participants in national economic growth. In addition, rural Mexico is characterized by high birth rates, which in turn are balanced out by high migration rates to urban areas. The government recognizes and articulates that the solution to urban migration rests in improving conditions in rural Mexico.

2.42 Rural inhabitants in Mexico without electricity generally can be separated into two broad groups:

- residents of on-grid villages who do not have access to power
- residents of off-grid villages—i.e., homes and ranches

2.43 In the former category, data indicate that under current pricing regimes it is usually more cost-effective to extend power lines to those residents that lack connection to the grid. The subsidized prices of electricity in these on-grid areas also tend to make small-scale renewable systems impractical (the average residential user rate in Mexico covers only 42 percent of the cost of generating electricity). For off-grid users, however, on a long-run cost basis data indicate that renewable energy systems often are more affordable than grid extension or temporary solutions such as the use of car batteries or diesel generators.

2.44 Whether it is used to provide higher quality lighting for rural homes accustomed to kerosene lamps, to power small vaccine refrigerators in clinics, or to pump water for irrigating small plots, the availability of even small amounts of electricity can make dramatic changes in the lives of rural inhabitants. The benefits from rural electrification are also consistent with the goals of the national efforts of Progresa and Salud 2000.

Prevailing Barriers to Off-Grid Electrification and Possible Approaches

2.45 Although renewable energy systems may be the least-cost option for providing basic electricity supply to off-grid areas, many barriers stand in the way of promoting a sustainable program. These include:

- general poverty in rural areas
- high system set-up costs
- lack of financing mechanisms

- subsidized pricing for conventional energy sources
- a federal policy emphasizing grid extension over renewables
- lack of local institutional capacity
- lack of familiarity with renewable systems
- lack of trained technicians for maintenance

2.46 These barriers are not insurmountable, as has been demonstrated in various cases elsewhere. Despite the low income levels in rural areas, worldwide evidence indicates that the poor are willing to pay more than are their urban counterparts for reliable energy services. The benchmark that is important in this case is not the cost per kilowatt hour, but the cost to households per month of obtaining basic energy services. If appropriate financing schemes can bring this key figure close to the willingness-to-pay level, significant market penetration can be achieved. As has been experienced in the Dominican Republic, Kenya, Morocco, Argentina, Indonesia, and other countries with significant private involvement in off-grid electrification, there are legitimate business opportunities for the private sector in the provision of basic electricity services to households in remote areas. The mechanisms that have been tried have included direct sales, fee-for-service, leasing, and other schemes. All incorporate consumer financing schemes and some means for aftersales service or ongoing maintenance.

2.47 Depending on the size of the population that it is hoped to reach, government subsidies to these efforts can range from zero to modest. In many cases, government can be most effective as provider of the proper environment for private business operation and by assisting with the public education and promotion activities that otherwise could be a substantial drain on the budgets of private investors. In Mexico, prospective private investors in off-grid electrification should focus their efforts at the level of the *municipios*, and should seek to leverage their investments with funding from related national, state, and municipal programs. Private companies initially may target higher-income households and local commercial enterprises, before gradually expanding to lower-income households. They may also initially target states that, in addition to having large market potential, have populations with relatively high purchasing power, such as Chihuahua, Jalisco, Tamulipas, Sonora, and Campeche. Two states, Veracruz and Chiapas, constitute nearly 33 percent of the total market potential identified in the KPMG study. However, the populations of these states also have low income levels, and some form of partnership that combines private investment with public subsidies will need to be forged.

Proposed World Bank Project

Objectives and Scope

2.48 In early 1999, the Mexican Government requested the assistance of the World Bank in developing an off-grid electrification project. The specific activity proposed is the design and pilot implementation of an approach to the electrification of off-grid that maximizes the participation of the private sector, extends the reach of available public resources for improving social welfare, and has the potential for replication in all parts of the country.

2.49 To achieve a critical mass sufficient to attract private sector participation, the project proposed a minimum total package of about 5,000 households, 100–150 public service centers (water supply, schools, and clinics), and 100 productive applications in unelectrified off-grid areas. The households would be provided with 50 W solar home systems for lighting and the communal and productive applications would be provided with photovoltaic, wind, or diesel systems, as appropriate. The households would be provided first-cost subsidy, probably from GEF or other public programs, but would be expected to pay monthly installments commensurate with willingness-to-pay levels. The community applications are expected to be financed from ongoing social programs. Productive applications by farms and small businesses would be expected to pay almost full cost, but with appropriate financing. The type of economic applications would depend on the needs and conditions of the chosen sites. All efforts would be made to ensure the project would be complementary to other ongoing or planned rural development programs such as PROGRESA, *Alianza para el Campo*, and other public-funded or bilateral donor-funded initiatives targeting poor communities. For example, if the pilot site chosen is also a beneficiary area for the Alianza project, concessional financing could be extended for solar pumping and other agricultural applications, and would represent additional business for the private service provider.

2.50 The mechanisms for private sector participation would be determined after analysis of the specific conditions in the chosen sites (for example, household density, income distribution, and presence of private operators). The mechanisms could range from simple independent dealerships marketing systems with financing to franchises, rural Energy Service Companies (ESCOs), and concessions. In all cases, the project would provide assistance in developing business plans, in training, market characterization studies, educational and promotional campaigns, and other activities designed to reduce market barriers. For productive applications, the project would assist in pipeline-filling activities, feasibility analysis, and financing of demonstration systems. In addition to improving the access of remote populations to modern energy, the project also aimed to induce the development of a private sector-based service infrastructure that would increase local employment and benefit local economies.

Estimated Financial Requirements

2.51 A new Bank lending instrument, the Learning and Innovation Loan (LIL), is being considered for the proposed pilot project. The LIL provides "structured support for small, time-sensitive projects to pilot promising initiatives based on a sound development hypothesis, or to experiment in order to develop locally based models prior to a larger-scale intervention." The successful implementation of the pilot project accordingly could lead to the preparation of a full-scale operation covering other off-grid areas.

2.52 Based on the above, highly tentative numbers for households and other market segments, the total investment requirement could be US$ 7–8 million, of which up to US$ 5 million would be the loan amount, with the rest provided from local private and public sources. In addition, GEF grant assistance would be sought to buy down the cost of necessary hardware and to finance studies and other activities aimed at reducing market barriers. This project is being prepared by the *Secretaria de Energia* of Mexico.

Other Investment Opportunities

Market Potential for Potable Water Application

2.53 The second target segment for renewable energy systems is potable water. It is estimated that approximately 15 million people in Mexico lack potable water. Of these, some 10 million live in rural areas. Surface water supplies are abundant in the southeast of Mexico, where the population is small. In the central and northern parts of Mexico, however, water is scarce and the population is greater. Much like surface water, the supply of underground water resources is dispersed: it is scarce in the center and north of Mexico and abundant in the southern and coastal regions.

2.54 As the decentralized branch of the Environmental Ministry, the *Comision Nacional del Agua* (CNA) is responsible for the administration and protection of water resources and for the construction, operation, and maintenance of hydraulic infrastructure. Working with the states, the CNA cost-shares (50:50) on the implementation of potable water projects. The actual responsibility for projects resides with the *municipios*. Diesel is the standard power source used in off-grid or rural projects: the CNA currently does not have any ongoing or planned potable water projects powered by renewable energy systems. CNA policy is to seek the least-cost solution for the projects it implements. In addition to working with the CNA and state and municipal governments, prospective interventions for renewable energy systems for water pumping would best be approached through Progresa and Salud 2000, as potable water is recognized as key to improving health and nutrition in rural areas.

2.55 The states in Mexico with the greatest absolute need for rural potable water systems, based upon 1990 census data, are Veracruz, Mexico, Chiapas, Puebla, and Guerrero. These states are concentrated in southern Mexico. In relative terms, the states of Puebla and Mexico have the highest percentages of households without potable water.

2.56 The KPMG study estimated that the per capita system costs, based on pilot projects, range from US$ 75 to US$ 110, depending on the size of the community. The total market potential for renewable potable water systems is estimated at US$ 135 million, based upon a projected 13,350 renewable energy-powered pumps. The market potential of the most economically viable market segment (rural villages of between 100 and 999 inhabitants), is calculated at US$ 73 million.

Market Potential for Irrigation and Livestock Watering

2.57 Prospective applications of renewable energy systems in commercially productive end-use activities in Mexico include:

- small-scale irrigation for agriculture

- livestock watering and fence electrification

2.58 In terms of small-scale irrigation, renewable energy-powered water pumps are most viable for use in small-scale (less than 5 hectares) irrigation. In the ranching industry, there are significant opportunities for the use of renewable energy water pumps and of renewable systems for electric fences. Key target states for the prospective application of small-scale renewable energy irrigation systems are Hidalgo, Mexico, Puebla, Chiapas, and Michoacan.

2.59 The agriculture sector is dominated by farms of less than 5 hectares and characterized by low productivity. With these stats it has been severely affected by drought and recent devaluations of the peso. Both factors have strained the ability of farmers to withstand cyclical downturns, prompting renewed and concentrated efforts on the part of the government to help farmers, particularly small-scale farmers, become more efficient. The drive to raise efficiency has been the focus of the government rural development program *Alianza para el Campo*, under the auspices of the Secretariat of Agriculture (SAGAR). The Alianza program that could potentially could best complement efforts at promoting renewable energy systems for irrigation is the Ferti-Irrigation program. This program, which focuses on attracting investment into rural areas, currently funds 35 percent of the cost of irrigation systems. Although the program is primarily designed for large-scale irrigation, it also calls for the use of renewable energy-powered micro irrigation systems. Based on system costs of US$ 8,000 and a market potential of more than 11,000 wells, the study projects an estimated market potential for small-scale systems of about US$ 90 million.

2.60 The government similarly supports the livestock sector through the Alianza program; specifically, the *Establecimiento de Praderas* component. This program funds approximately 40 percent of the cost of acquiring and installing pumps for livestock watering or electric fences. Through the program, individual "ranches" can receive federal support of up to 78,000 pesos and matching funds from state governments. The states with the greatest market potential for the application of renewable energy-powered pumps for livestock watering are Chihuahua, Sonora, Veracruz, Jalisco, Coahuila, Tamaulipas, Chiapas, Nuevo Leon, and Zacatecas. Chihuahua, Sonora, and Veracruz account for more than one-third of the prospective market. Assuming that one renewable energy pump is needed for every 200 head of cattle on classifying ranches, and that an average system (based on pilot project data) costs US$ 7,000, the KPMG study projects a market for renewable systems for livestock watering applications in the range of US$ 300 million.

2.61 As with the residential and potable water segments, the major market barriers are:

- lack of financing schemes for renewable energy systems
- lack of awareness among potential users of the benefits of such systems

2.62 It would be important for prospective private investors to work with state and municipal entities, as well as with the *Alianza para el Campo* program at the state level and with the Ferti-Irrigation and the *Establecimiento de Praderas* programs, to develop strategies to address these barriers.

Bank Initiatives in Mexico on Renewable Energy Applications for Agriculture

2.63 The Mexican government most recently developed the Agricultural Productivity Improvement Project (ALCAMPO) to support and improve Alianza's delivery of financing and technical services. The project was approved for a loan of US$ 445 million from the World Bank in December 1998 and began implementation in early 1999.

2.64 Operating within the context of ALCAMPO, the supporting GEF-financed Renewable Energy for Agriculture Project is being prepared with the following development objectives:

- to provide unelectrified farmers with reliable electricity supply for productive purposes in a sustainable manner using renewable energy technologies;
- to increase the productivity and income of unelectrified farmers by supporting the adoption of productive investments and improved farming practices;
- to improve the ability of local institutions to catalyze the penetration of renewable energy technologies in the agriculture sector.

2.65 The project would support the above objectives by removing barriers to the penetration of renewable energy technologies in Mexico's agriculture sector by:

- implementing a nationwide promotion campaign to increase farmers' awareness of renewable energy systems;
- building the capacity of technicians and agricultural extensionists through training;
- introducing technical specifications and certification procedures for farm-based renewable energy equipment;
- carrying out studies on the potential market and applications for renewable energy in Mexico's agriculture sector;
- installing renewable energy systems (solar- and wind-powered pumps and solar-powered refrigerated milk storage tanks) on selected farms as demonstration units to allay the perceptions that other farmers have of the risks involved;
- supporting the proper operation of these renewable energy systems through the provision by trained extensionists of ongoing technical assistance to participating farmers;
- testing innovative vendor financing mechanisms for farm-based renewable energy systems in four states.

2.66 The total cost of the project amounted to US$ 25.9 million (see Table 2.6).

Table 2.6

Source	Total
Beneficiaries	*5,805*
Government	*1,800*
IBRD[19]	*9,340*
GEF (grant)	*8,910*
Total	*25,855*

2.67 The project was expected to become effective in January 2000.

Panama

Background

2.68 There is approximately 922 MW of installed capacity serving the power needs of Panama. Of this, only 676 MW is considered effective due to the low availability of certain fossil fuel plants. Of the total installed capacity, 551 MW (60 percent) is accounted for by hydropower plants and 372 MW (40 percent) by fossil fuel-based plants.

2.69 According to government data, the power grid extends to approximately 65 percent of Panama's total population of 2.8 million. Half the population is considered as residing in urban areas and half in rural areas. Approximately 25 percent of the population resides in Panama City. The grid extends to basically all the Pacific side of the country, where the majority of the population resides (with the exception of the Darien), and to parts of the Caribbean side of the country, particularly Bocas del Toro and Colon.

2.70 The power sector in Panama is operated by the Institute for Hydro Resources and Electrification (IHRE). IHRE has historically operated all generation, transmission, distribution, and commercialization of electrical energy. Given the increasing demand for energy, however, coupled with the severe financial and institutional limitations that IHRE faces, the government recognizes the need to reform the power sector. According to the Bank's most recent CAS, power outages are increasing, connection delays are protracted, the price for electricity for industrial users is 40 percent higher than in the United States, and rural electrification coverage is approximately just 50 percent. Furthermore, according to Bank data only 47 percent of the population classified as poor and 29 percent of the extreme poor, who together constitute more than 55 percent of the total population, have electricity. Electrification in indigenous communities is virtually nonexistent.

[19] Via the federal government's *Alianza para el Campo* program, with financing from the Bank-supported Agricultural Productivity Improvement Project (Loan 4428, approved December 22, 1998).

2.71 **Sector reform**. With the approval of the new electricity reform law (Law of the Regulation and Institutional Framework for Public Services of Electricity), IHRE will be split into six companies: two hydropower generators, one thermal power generator, one transmission company, and two distribution companies. Isolated systems and small generation plants of less than 15 MW will be operated by the distribution companies. All six companies will be sold to the private sector, a transaction that is scheduled for no more than 24 months from the approval of the law.

2.72 Of special interest in the new reform law are those articles regarding rural electrification and renewable energy. The articles promote both rural electrification and renewable energy on a national level. Article 95 of the law calls for the creation of the Rural Electrification Office (REO), which would be responsible for promoting sustainable and appropriate rural electrification initiatives in targeted rural areas. Essentially, the REO will promote and support demand-driven private sector projects that foster sustainable rural electrification.

2.73 Article 155 of the reform law advocates that it is of special interest for the nation to promote the use of renewable sources of energy, for their positive environmental effects and for their ability to complement the national effort to reduce dependence on fossil fuels. As an incentive, the law also certifies that transmission and distribution companies must give preference to new and renewable sources of energy when soliciting for and buying energy on the market.

Ongoing Activities

2.74 The REO has been created to help the Government of Panama (GoP) realize its national goal of 95 percent electrification coverage by 2010. The creation of the REO was considered necessary in light of the GoP's movement to privatize the power sector's distribution entities without stipulation that those entities, once privatized, undertake rural electrification even to those areas that cannot be profitably electrified. Instead, the GoP has charged the REO with the responsibility of leveraging its funds and its expertise in the institutional and technical aspects of rural electrification to stimulate the private development of appropriate, targeted, and sustainable rural electrification programs and projects. The REO will in essence provide institutional, market, and technical oversight to, and through the provision of subsidies will be a financial catalyst for, the promotion of sustainable rural electrification. The REO will rely on a combination of shareholders, including nongovernmental organizations, private distribution companies, government entities, rural cooperatives, energy service providers, and equipment manufacturers, to develop and implement projects.

2.75 As outlined, national electrification coverage is approximately 65 percent. However, according to national survey data, rural electrification coverage is approximately 55 percent and only 7 percent of families in the indigenous communities have electric service. Given population figures and the established goal of the GoP to achieve 95 percent coverage within 10 years, this means that more than 133,000 rural connections will have to be realized.

2.76 IHRE projections for attending to this segment of the population indicate connection costs to be so high as to render most rural electrification projects unattractive. IHRE project data indicate that the cost of extending coverage to 45 percent of the rural population would average approximately US$ 1,250 per connection; to the next 29 percent, US$ 1,500–3,000 per connection; and to the next 16 percent, in excess of US$ 3,000 per connection. One reason for these high costs is the dispersed, decentralized nature of the projects, 70 percent of which are designed to serve just 15 families per project. Furthermore, analysis of the IHRE project data, as outlined in a recent study by AGB Deloitte & Touche, indicates that while there is a technical emphasis on standard project design (for example, grid extension and standalone generation) there is little analytical emphasis on the sociocultural attributes of prospective rural users, on the economic conditions and opportunities in rural areas, or on new and renewable energy technologies; nor is there appropriate consideration of environmental conditions and opportunities. All of these factors would influence both the costs of and the long-term viability and sustainability of rural energy strategies and projects.

2.77 Specifically, IHRE perspectives on decentralized rural electrification, which merit closer examination on the part of the REO, are summarized as follows:

- Small, decentralized, isolated projects cannot provide sufficient incentive for the active participation of the private sector in rural electrification.
- The lack of local providers of goods and services, in terms of rural electrification, results in elevated costs for the provision of rural electric services.
- Operation and maintenance costs for decentralized systems are relatively high.
- Energy consumption per consumer is relatively small.
- Sustained efforts are required to ensure that users adequately maintain decentralized systems.

2.78 Clearly, it will be critical that the REO develop new and innovative ways of assessing and catalyzing rural electrification initiatives. It is essential also that the REO use its own resources to encourage the participation of other potential shareholders.

2.79 The AGB Deloitte & Touche study outlines the prospective role and operational modalities of the REO. In general, the REO would be designed as a facilitator for market forces rather than a constructor or operator of rural electrification projects. It would concentrate on creating an environment that provides incentives to other entities to develop projects, including both technical and institutional guidance and initial subsidies to targeted projects that, as in the case of Argentina, would aim to assure their long-term success. The study points out that by creating this enabling environment the REO would ensure that projects are in fact implemented by market forces.

2.80 The success of the REO would depend on three critical factors:

- Successful relations with other institutions in Panama, including the national energy regulator (*Ente Regulador*), appropriate ministries, distribution companies, rural cooperatives, and NGOs, that play important roles in the rural sector.
- The internal capacity of the REO to effectively assess and deal with the rural sector and with rural energy. This would require development of the analytical, technical, and institutional capabilities necessary to develop viable strategies and programs for stimulating rural energy services.
- Possession of the operational capability to stimulate and provide proper incentives to market forces.

2.81 The REO will be charged with making rural electrification an attractive business for entities that are interested in developing and implementing sustainable projects. In carrying out this mandate, the REO will need to be flexible in the institutional approaches it supports in order to ensure that the framework of energy service providers, concessions, cooperative ownership, distribution entities, individual ownership, and so on that evolves is the one most appropriate to each rural area targeted.

Potential Investments

2.82 Aided by other entities involved in the rural sector in Panama, IHRE has identified preliminary target markets for rural electrification that merit further analysis by the REO. The IHRE information assumes grid extension to be the primary way to serve these markets, but further analysis may indicate that a portion of them would best be served by decentralized off-grid systems—mini or micro grids or individual household systems. This decision would be dictated by the distance of the specific locality from the main network, the load profile of the communities concerned, and the household density. In addition, it is important to assess through site surveys if there are local energy resources, such as small hydro, that can be economically harnessed.

Table 2.7: Prospective Rural Projects by Province - Panama

Province	*Projects*	*Households*
Chiriqui	*161*	*1,826*
Cocle	*63*	*1,705*
Colon	*39*	*346*
Darien	*8*	*516*
Herrera	*44*	*522*
Los Santos	*32*	*605*
Panama Este	*128*	*2,333*
Panama Oeste	*25*	*431*
Veraguas	*63*	*1,486*
Subtotal	***563***	***9,770***
Darien	*111*	*1,549*
San Blas	*59*	*3,048*
Subtotal	***170***	***4,597***
Total	***733***	***14,367***

Source: Deloitte Touche Tohmatsu

2.83 The information in Table 2.7, assembled primarily from IHRE data, provides a preliminary overview of prospective markets by province. For the first series of 563 projects, IHRE calculates that the cost to extend the grid to these 9,770 households would be US$ 14,290,683, or US$ 1,462 per household. It would be expected that for the other projects in Darien and in San Blas, where access is more difficult, that costs would exceed these figures. At this level of investment per connection, the need to explore other opportunities for decentralized interventions, including small-scale photovoltaic systems for individual households, becomes more pronounced.

Prospective Bank Assistance

2.84 The population data for Panama indicate that there are more than 750,000 rural inhabitants without access to electricity services. After sector reform, the challenge for Panama is how to leverage its small public resources for electrification with private and donor monies in order to extend service to a substantial part of this population. Through projects in India, Indonesia, Sri Lanka, China, Argentina, and Brazil, the World Bank and the GEF have accumulated experience in identifying approaches to the electrification of rural areas that involve strong participation by the private sector and the use, whenever feasible, of environmentally benign energy sources. Considering the high costs of connecting unserved areas of Panama to the grid, it is clear that new approaches are needed.

2.85 In terms of technology, what may be required is a two-pronged strategy involving an improved conventional grid extension and the adoption of decentralized schemes in areas that lie beyond the economic limit of grid extension. There are a variety of new approaches that can be used to reduce the cost of grid extension to rural areas. For example, savings of between 30 and 40 percent can be realized through the increased use of single-phase construction, which can satisfactorily meet the foreseeable needs of most consumers. It has also been shown that the correct sizing of transformers can considerably reduce the per customer cost of electrifying small rural population centers.

Even simple investment decisions, such as the use of superior quality poles, can lower lifecycle costs by reducing the need for maintenance, overhauls, and upgrades. Innovative grid extension schemes furthermore are not limited to technology and engineering improvements: systemic changes, such as the use of improved quality assurance programs, also can lower costs. Rural electrification efforts should take a fresh look at these and other options before rejecting grid extension as excessively expensive.

2.86 Second, developments in renewable energy technologies have expanded the range of options available for improving rural energy supplies. As an alternative to diesel generators, where the terrain is suitable inexpensive mini and micro hydro systems can be deployed. Recent developments in distribution technology furthermore allow the integration of many smaller systems into grid systems, which can improve performance and reliability in remote areas. Other mini grid options include windpower and electricity generated from biomass. Standalone photovoltaic (PV) systems also can provide electricity for domestic lighting and appliances, village water pumps, street lighting, health clinics (including refrigeration for vaccines), and schools. For small-scale applications in remote areas, PV systems in fact are often cheaper on a lifecycle cost basis and more reliable than electricity generated from either the main grid or diesel mini grids.

2.87 In the case of off-grid electrification, the larger challenge for the REO is how to devise incentives that are sufficient to persuade the private sector to absorb some of the investment risks. As cited in earlier sections of this report, several countries have succeeded in attracting private investment through the judicious leveraging of public funds and bilateral funds. While many households in off-grid areas cannot afford to shift from traditional fuels to electric lighting, powered either by conventional or renewable energy systems, experience shows that a large number typically are willing and able to pay if the right financing scheme is in place.

2.88 The market also can be made more attractive for private investors by combining the usually poor household segment with the community-center segment. Assuming that they are supported by public financing, schools, health clinics, police stations, street lighting, and so on offer a more or less guaranteed market. An effort should also be made to identify applications that promote economic activity, such as micro-irrigation systems, electric fencing for livestock, and water pumps for household supply and livestock watering. Applications such as these potentially can create a new sector able to generate the returns that can repay a significant part of the investment cost of providing electricity service.

2.89 As with similar Bank projects in other countries, an operation in rural electrification in Panama that uses renewable energy technologies could enable the REO to obtain GEF grant financing for activities that support capacity building, public education programs, standards and certification systems, and other activities that help reduce market barriers and make it easier for the private sector to operate.

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