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# RETHINKING DEVELOPMENT ASSISTANCE FOR RENEWABLE ELECTRICITY

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*K.K.*
*O.S.*



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# FOREWORD

Technologies that tap sunlight, wind, running water, the Earth's heat, and vegetation for electricity can supply an increasing share of developing countries' demand, while delivering environmental and economic boons—to the countries themselves and to the world at large. Besides curbing greenhouse gas emissions, renewably-generated electricity would reduce the air pollution that is damaging human health and the crops, forests, rivers, and lakes downwind from power plants.

On the bottom-line question of costs, some applications are already competitive with their fossil-fuel counterparts if one calculates life-cycle costs, not merely up-front outlays. Countries that harness renewables to meet electric capacity requirements—which are growing faster than 5 percent a year in much of the developing world—can solve several economic problems simultaneously. For one thing, renewables' modularity makes it possible to tailor them to the particular needs and circumstances of any setting. What's more, a widespread shift from imported fuels to renewably-generated electricity would stem existing hard currency outlays, while insulating nations from any future price shocks.

When renewably-generated electricity offers so many benefits, why hasn't it gained more of a foothold in developing countries? One reason is that renewables have long gotten short shrift in development assistance—whether from individual nations or from the World Bank and other multilateral banks—even though all these players have invested a great deal in boosting the developing world's energy supplies. As recently as 1991, renewables garnered only 5 percent of the $4.5 billion in official development assistance funds earmarked for energy projects.

Worse yet, what little money *has* gone to renewables has failed to stimulate sustainable markets for them. The "parachute" approach that prevailed from the 1970s to the mid-1980s provided one-time funding for renewable energy installations that hadn't a prayer of being commercialized because donors then moved on to other projects, neglecting follow-up. In addition, many renewable projects were too small to generate a critical mass of interest and support among the host nation's policy-makers. By the time the most egregious mistakes were acknowledged, renewables' prospects in developing countries looked dim, as disillusionment set in among donors and world oil prices plummeted.

Now that environmental concerns are rising—along with the recognition that billions of people are unlikely to be hooked up to a conventional power grid anytime soon—the development assistance community is once again interested in renewables. How can lenders and donors avoid repeating the mistakes of the past? Answering this question is crucial since, as Keith Kozloff and Olatokumbo Shobowale stress in *Rethinking Development Assistance for Renewable Electricity,* the direct leverage the assistance community can wield is waning, thanks to shrinking budgets and growing needs in other sectors besides energy.

Of course, a transition to renewable energy will depend at least as much on private-sector actions—and actions taken by developing-country governments—as it does on international donors and lenders. Kozloff and Shobowale note that electricity services in developing countries will increasingly be privately financed and managed, a trend that development assistance agencies are encouraging to make up for their own funding short-falls and for the inadequacies of government utilities. Drawing from a dozen case studies of diverse renewable electricity projects, as well as from their research on overall trends in development assistance, the authors describe lessons that lenders and donors can learn from the successes and failures of the past and present:

- Assistance that is part of a comprehensive commercial development strategy is likelier to lead to technology diffusion than "one-shot" projects are. To encourage widespread adoption of a particular renewable power application, assistance agencies must not just demonstrate that it works, but also address the institutional and financial factors that sap its market potential.



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- The growing private-sector role in financing and managing the electric power industry puts a premium on stepping up demand for renewables since multilateral loans will be dwarfed by the private capital flowing into developing-country power sectors—capital that renewables must attract if they are to gain significant market share.
- Involving local people in commercializing renewable technologies is critical to stimulating sustainable markets. Wherever possible, local entrepreneurs should be involved in adapting technologies to suit conditions, meet service needs, or reduce system costs—activities that not only produce local income and employment but also raise the odds of technology diffusion.
- Decisions about which local partners to work with in disseminating a given technology should be made on a case-by-case basis: no one institution—whether a utility, cooperative, government agency, nongovernmental organization, or private developer—is universally the best choice.

Kozloff and Shobowale's research into how development assistance interacts with the private sector and with public policy has led them to recommend principles that can help the development assistance community leverage its limited funds to the best effect:

- International lenders should "mainstream" renewable technology applications that are already cost-competitive with their conventional counterparts by ensuring that renewable options are thoroughly evaluated in project prefeasibility studies and that planning processes and investment criteria fully account for renewables' potential benefits.
- Multilateral agencies, bilateral donors, and developing countries should develop cooperative strategies for technology commercialization. OECD countries should take the lead in crafting and implementing such strategies. Where cost is a barrier, all three groups should work together to design and carry out coordinated programs to expand market volume, standardize design, or provide more experience in manufacturing and installation.
- Multilateral and bilateral assistance agencies should target countries whose policies allow renewables to compete fairly with other technologies. Even if renewable energy projects are well-designed to breach other barriers, project funds may be squandered in countries with severe energy price distortions.

*Rethinking Development Assistance for Renewable Electricity* extends the policy recommendations set forth in such previous WRI studies on energy in the industrializing world as *Growing Power: Bioenergy for Development and Industry, Money to Burn? The High Costs of Energy Subsidies,* and *Energy for Development.* Future reports will map out the public policy shifts needed to spur use of renewables in developing countries, just as WRI's 1993 book, *A New Power Base: Renewable Energy Policies for the Nineties and Beyond,* did for the United States.

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# I. BACKGROUND

Electricity is a vital ingredient in economic development. Between now and 2010, the developing world's electricity requirements will grow more than 5 percent a year (EIA, 1993). Much of this escalating demand could be served by power from renewable energy resources: the sun, wind, running water, underground hot water and steam, and biomass (energy crops and organic waste from farming and forestry). *(See Box I-1.)* These renewable resources offer a far more environmentally and economically sustainable supply of energy for electricity generation than expanded reliance on fossil fuels does.[1] But the shift toward renewable resources has yet to occur because of capital constraints, institutional inadequacies, and price distortions.

The hundreds of millions of dollars spent by the international development assistance community promoting renewable energy resources over two decades (OECD, 1993) have accomplished little (Foley, 1992). In many early projects the technologies were immature. (*See*, for example, Waddle et al., 1989.) But recent technological improvements make it easier to separate this factor from other determinants of success.

Making this critical distinction, this report draws lessons from past development assistance experience and offers recommendations for overcoming market and policy barriers to the greater use of renewables. The lessons are extracted from a general review of multilateral and bilateral assistance for renewables and the power sector in developing countries. Several assistance projects are also examined to see how much they have stimulated markets for renewable technologies. Although the diversity of renewable technologies and applications—as well as developing-country needs—make broad generalizations difficult, changes in development assistance priorities can be identified.

Because of several emerging opportunities and constraints, now is an especially good time to see that donor programs are designed and implemented effectively. The local, regional, and global impacts of development assistance policy on sustainability are a growing concern—witness rising pressure on development assistance agencies to get environmentally sound technologies adapted and dispersed. Offering to deploy renewables can help Northern donors meet their national obligations under the Climate Convention to reduce carbon emissions through so-called "joint implementation" schemes (U.S. State Department, 1994). Then too, using development assistance to leverage private resources to build sustainable markets has never been more important. Financial resources for multilateral lending are being stretched as the gap widens between the capital needed for power sector infrastructure and the amount that international donors can mobilize. The power-sector lending policies of multilateral development banks (MDBs) are also changing, but not necessarily in ways that will stimulate deployment of renewable power sources. Bilateral aid programs in the post-cold war era are shrinking as domestic economic concerns grow.

By itself, development assistance will not determine the market share of renewable power technologies in developing countries. National and local public policies as well as domestic and international private interests play more important roles—which will be the subject of subsequent research at WRI. But findings to date show where and how development assistance interacts with the private sector and national policy to shape markets for renewables.

## BENEFITS OF RENEWABLE POWER GENERATION IN DEVELOPING COUNTRIES

Two recently prepared electricity-supply scenarios show the difference that a shift toward renewables could make in the developing world. Under a "business as usual" scenario, competition among well-established technologies results in a net decrease in the market share of renewables (including hydropower).[2] *(See Figure I-1.)* But with supportive public policies, strategic private investment, intensive

**Box I-1. Renewable Resources for Power Generation**

The diversity of renewable electric technologies makes them suitable for providing bulk power to existing electric grids; electrifying isolated villages, households, and islands; or supporting utility transmission and distribution systems.[a] Some renewables can be used by themselves; where dispatchable power is required, intermittent renewable technologies are usually combined with storage or back-up generation.

*Hydropower.* Micro- (<100 KW), mini- (up to 5 MW), and small hydro (about 5-30 MW) turbines are among the most mature renewable technologies and have been used for many years to power rural areas. Only about 10 percent of the developing world's potential small hydro capacity has been exploited. Unused capacity is greatest in China and Latin America (World Energy Council, 1993).[b]

*Biomass.* Direct combustion of agricultural and forestry residues for combustion in turbines is growing rapidly. The processing of sugarcane, rice, coconut, and other tropical foods creates organic waste that can be burned directly or gasified. Bagasse, the residue from sugarcane processing, can be burned in cogeneration facilities whose surplus electric power output can be sold to the grid. While such resources are available throughout Asia, Latin America, and Africa where agricultural and forest products are processed, growing crops for energy production would greatly expand potential capacity. Aeroderivative turbines, when coupled with gasifiers, are expected to make biomass generation more efficient.

*Wind.* Wind has long been used for pumping water and other mechanical uses. Now wind turbines are springing up in many countries to generate either grid-connected or "independent" power. Wind resources (though generally stronger in temperate regions) are sufficient to produce thousands of megawatts of power in Asia and Latin America, and are especially strong along coasts, western China, parts of India, northeast and south Brazil, the Andes, and North Africa. India alone is estimated to have 20,000 MW of potential wind capacity.

*Geothermal.* Untapped geothermal resources can be found on both sides of the Pacific Rim

development, and commercial deployment, renewables' share of the power generation market rises dramatically.[3] *(See Figure I-2.)* While the first scenario covers a shorter time period, it would entrench fossil fuels' market share since the physical infrastructure of power generation turns over so slowly. Moving toward the second scenario would offer several economic and environmental benefits.

***Economic Development***

To confer development benefits, any power-generation technology must provide comparable energy services at lower lifecycle costs than existing energy sources. The cost of generating power from renewable resources has dropped significantly over the past decade to where several technologies are now cost competitive not just for off-grid applications (enormous markets in developing countries) but for grid-connected power as well (Ahmed, 1994; Larson et al., 1992). Whether any particular renewable technology application is attractive depends on the costs of competing energy sources in the same area. *(See, for example, Table I-1).* Of course, potential users must also be willing to pay the price. For instance, even if the unit cost of irrigation water is less with photovoltaics (PVs) than with diesel pumps, the market price of the crop output will still determine whether the expense is justified.

A significant economic advantage of renewable resources is their broad geographic distribution.

(especially Bolivia, Chile, Costa Rica, Guatemala, and Thailand) and in the East-African Rift Valley. Installed geothermal capacity in developing countries is projected to grow from about 2,000 MW in 1993 to about 5,000 MW in 2000 (Dickson and Fanelli, 1993; DiPaola, 1992). Because of their large scale and baseload operation, the output of geothermal plants resembles that of conventional generating technologies.

*Photovoltaics.* Photovoltaic (PV) installations already serve tens of thousands of household and other uses in rural Asia, Latin America, and Africa. At present costs, PV installations are used primarily to supply individual users far from electricity grids, although interest is growing in using central PV power stations for remote villages. The strength of sunlight in most developing countries is sufficient for PVs to operate economically.

*Solar Thermal.* Solar thermal technologies generate electricity by concentrating sunlight onto a line or point where heat is transferred to a fluid that drives a turbine. This technology is little used outside the United States, where a 360 MW hybrid solar parabolic trough/natural gas system is operating in California. (Among developing countries, only Mexico and India are currently considering such projects.) Other types of solar thermal technologies (parabolic dish, central receiver) have some advantages, but solar trough/gas hybrid technology is the most commercially mature. Much of the developing world has strong enough direct radiation to eventually make low concentrator trough technologies competitive with conventional power sources (Anderson, 1994).

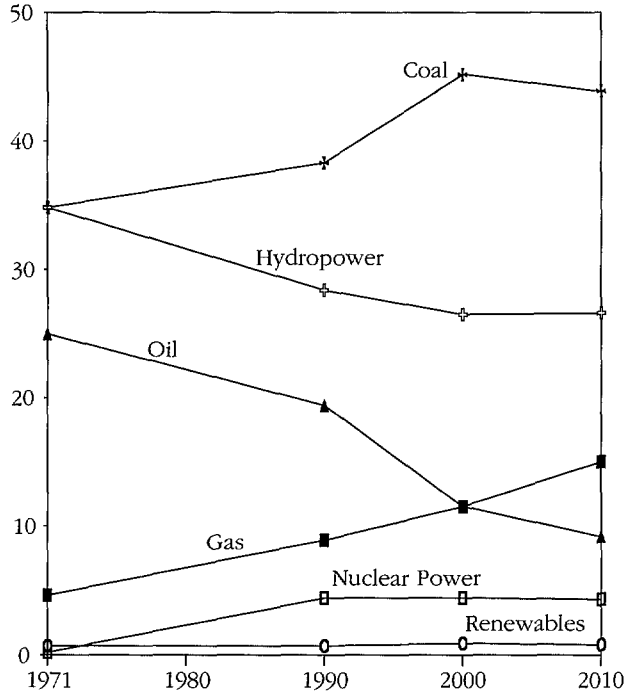
a. Detailed assessment of these and other renewable energy technologies and developing-country applications can be found elsewhere (*See*, for example, Sayigh, 1994; Johansson et al., 1993; Kristoferson and Bokalders, 1991).

b. These hydro technologies are distinguished from large hydro by their capacity size, required elevation, and environmental implications. Large hydroelectric dams, while avoiding the air emissions of fossil fuels, have serious ecological and social impacts. Moreover, they inundate large tracts of land whose decaying vegetation may release greenhouse gases. Such projects (as in Brazil and China), not only account for most hydro capacity, they also constitute a major source of all power in the developing world. Small hydro requires less land for facilities, and "run-of-river" technologies do not require impoundments.

(Swisher, 1993; WEC, 1993; Johanssen et al., 1993; Dessus et al., 1992.). All developing regions consequently have access to electricity generation from renewables at stable cost for the long-term future. Fossil fuels are another story. In 1993, eight countries held 81 percent of all world crude oil reserves, six countries had 70 percent of all natural gas reserves, and eight countries had 89 percent of coal reserves (EIA, 1994b). In 1991, more than half of all Latin American, Asian, and African countries had to import over half of all the commercial energy they used (WRI, 1994). Aside from other macroeconomic risks, the drain on foreign exchange earnings from importing energy is particularly painful for some countries because their traditional exports (i.e., crops) fetch low prices in international markets. If power generation expansion increases import dependence, this problem will worsen.

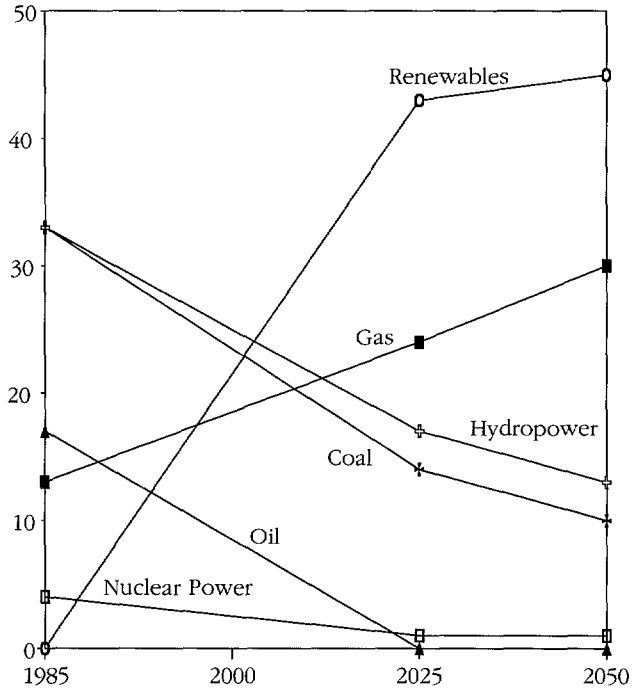
Constructing and operating many small power generators offers economic benefits over relying on more monolithic conventional generation facilities. Renewable generating equipment ranges in size from household to utility scale, but is on average smaller than fossil fuel facilities. The financial risks associated with mismatches between project construction schedules and power demand are lower with modular units since central station plants take longer to build. Whether on or off the grid, modular generation sources can also be located closer to customer loads, thus reducing the need to invest in transmission and

**Figure I-1. Business-as-Usual Projected Fuel Shares in Developing Countries for Electricity Generation (Percent)**




*Source:* International Energy Agency, 1993.

**Figure I-2. Renewables-Intensive Projected Fuel Shares in Developing Countries for Electricity Generation (Percent)**




*Source:* Johansson et al., 1993.

distribution systems. *(See Box I-2 and Figure I-3.)* Pioneered in the United States, this so-called "distributed utility" model holds even greater promise for countries with far-flung rural populations and low per-customer demand (Khatib, 1993). In addition, because the physical infrastructure of many developing-country power systems is far from complete, distributed generation units can be planned and added on more easily than in the U.S. system. In some regions, off-grid renewable or renewable/nonrenewable hybrid systems might make it possible to defer transmission and distribution investments until rising demand levels justify investment in a central grid.

Adding renewables to a utility's generation portfolio can also promote financial stability since renewables aren't vulnerable to some of the risks—such as fuel price spikes—faced by other generation types. In some cases risk reduction may be worth sacrificing some economies of scale. Whether any particular diversification strategy is worthwhile, however, depends on its incremental costs (Crousillat and Merrill, 1992).

### *Environmental Protection*

Shifting developing countries' reliance from fossil fuels to renewables would confer major environmental and health benefits. If, as projected for Latin America, the market share of coal-fired generation increases (at the expense of hydropower's current dominance), air emissions per KWh will also increase, despite improved pollution controls (Suarez, 1993). Much greater use of coal for power production is also projected for India and China. In southern Africa, where little coal is now used, it could edge out hydro as the dominant source of electric power (Hall and Mao, 1994). With increased coal use in developing countries since the 1970s, urban ambient particulate and $SO_2$ levels have risen even as air quality in higher-income cities has improved (World



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**Table I-1. Estimated Cost Competitiveness of Representative Renewable Power Technologies in California[a]**

| | Levelized Cost Ranges (1989 cents/KWh) | |
|---|---|---|
| | Renewable Technology | Fossil Fuel Alternative |
| Baseload (60–75% Capacity Factor) | | |
| Hydroelectric (New Sites) | 0.7–28.5 | 4.0–7.4 |
| Biomass Gasifier w/Engine | 6.0–8.2 | 4.0–7.4 |
| Geothermal Binary Cycle | 6.6–12.0 | 4.0–7.4 |
| Intermediate Load (20–35% Capacity Factor) | | |
| Solar Parabolic Trough/Gas Hybrid | 9.0–12.1 | 5.3–11.9 |
| Intermittent (Capacity Factor and Cost of Fossil Alternative Vary) | | |
| Utility-Scale Wind | 4.1–4.7 | 5.3–9.8 |
| Utility-Scale Photovoltaic Flat Plate | 15.7–21.8 | 7.0–11.9 |

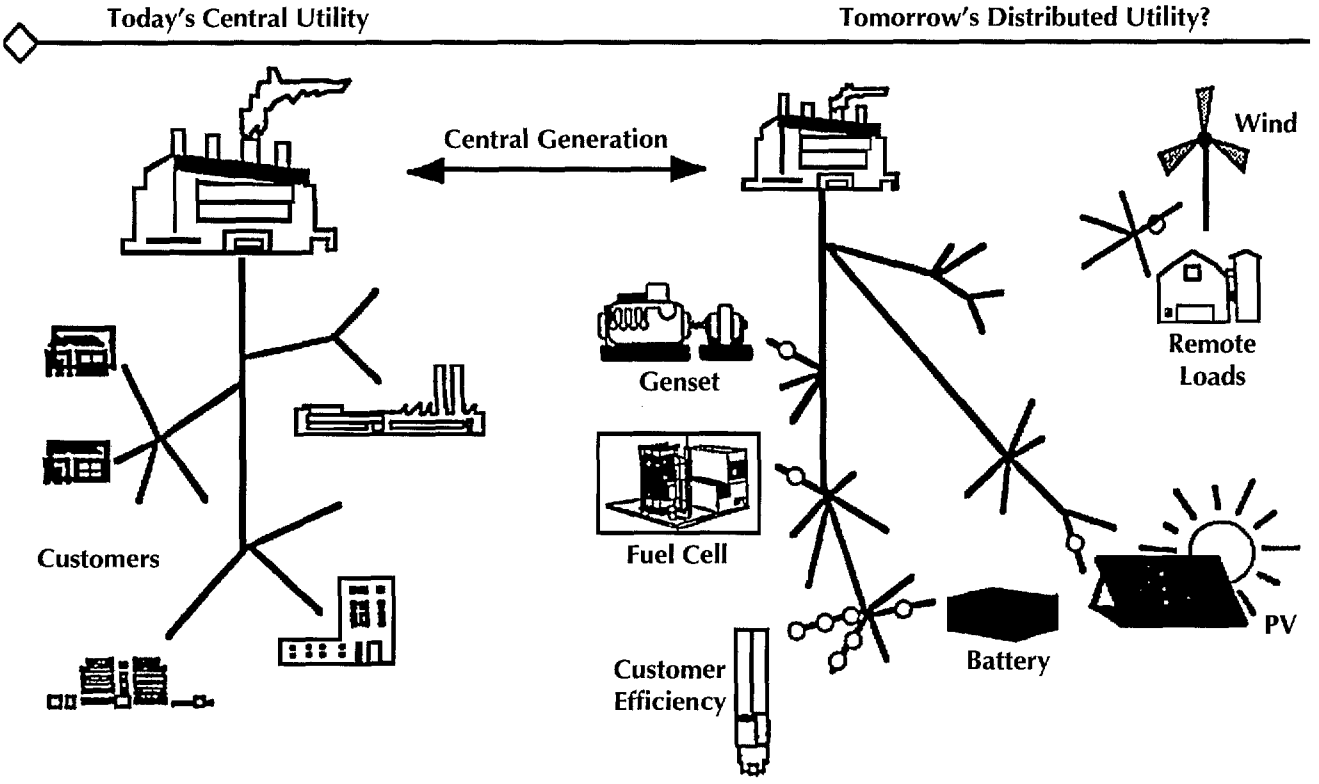
a. Fossil fuel generation costs are based on gas-fired combined cycle plants at the stated capacity factors. Levelized cost ranges are based on projects owned by private utilities in California. Comparable data for government utility ownership show improved competitiveness of some renewable technologies, which are favored by lower costs of capital. The relative cost of fossil fuel alternatives would be much higher in off-grid than in these grid-connected applications.

*Source:* California Energy Commission, 1992.

Bank, 1992a). Indeed, while total emissions of $SO_2$ and $NO_x$ are projected to decline in North America and Europe between 1990 and 2020, these emissions are expected to more than double in the rest of the world over the same period and increase by as much as eight fold by 2030, even if major efficiency improvements are made (Anderson, 1993; World Energy Council, 1993a; World Bank, 1993a). Controlling such emissions using "end-of-stack" strategies would stress scarce financial, organizational, and other development resources. Air pollution control investments could increase developing countries' capital requirements for capacity expansion by as much as 16% (Fernando et al., 1994). Deploying inherently clean generation technologies in the first place is far preferable if power consumption is to rise exponentially without increasing air pollution. Even indoor air quality improves when soot-spewing kerosene lamps are replaced by PV powered electric lights. Although no electric generation fuel cycle is completely benign, renewables' impacts also pale beside those associated with extracting and transporting coal.

A shift to renewables would also curb $CO_2$ levels. Under current trends, by 2010 increased fossil fuel combustion will cause total $CO_2$ emissions from developing countries (not including the former Soviet Union and Central and Eastern Europe) to exceed those from all countries in the Organization for Economic Cooperation and Development (OECD) (IEA, 1994). Indeed, the balance has already shifted for energy-related $CO_2$ emissions (EIA, 1994a). Because $CO_2$ emissions usually grow rapidly in expanding economies, holding developing-country emissions at current levels through greater efficiency alone would be very costly (Grubb et al., 1993). Even with efficiency improvements in electricity generation, transmission, distribution, and end use, replacement of most fossil fuels with renewables in both OECD and developing countries is necessary to stabilize global atmospheric $CO_2$ concentrations.

**Figure I-3. Comparison of Central Station and Distributed Utility**




*Source:* Pacific Gas and Electric, 1992

## BARRIERS TO GREATER RELIANCE ON RENEWABLES FOR POWER GENERATION

If the future of renewables is left to energy markets as they are currently constructed, their benefits will never be fully realized. Unequal access to investment capital, distorted energy markets, and inadequate institutional capacity to commercialize immature technologies all prevent renewable power applications from achieving their potential market shares.[4]

### *Unequal Access to Investment Capital*

Some characteristics of renewable power technologies deter investors. First, renewables usually cost more per kilowatt than fossil fuel power sources to install—even when low operating costs make them cost competitive on a lifecycle basis. Because of higher first costs, renewable power sources provide fewer energy services (whether pumps installed or villages electrified) per dollar of initial investment. All else equal, developing-country planning ministers have an incentive to choose a fossil fuel option over a renewable one that will require additional concessional financing (Bergey, 1993). Private power developers, whose discount rates are generally higher than those used by the public sector, also try to minimize the up-front investment to be financed.

Second, *per unit of capacity*, the smaller the project, the higher the transaction costs (those for plan-



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**Box I-2. Benefits of the Distributed Utility Model**

By strategically locating small generation units at critical points within the grid (often close to customer loads), less central station capacity, less fuel, *and* less investment in transmission and distribution systems are needed (Shugar, 1992b). The costs of upgrading transmission and distribution system capacity are particularly high in places within a utility's grid where local peak demands are much sharper than those experienced across the system as a whole. Installing "distributed" generation units allows transformers, substations, feeder lines, and related assets to be sized for more efficient use or investments in such assets to be delayed. Where their output is closely matched to local load curves, PV, wind, and other renewable generators fit well into distributed applications. The application and economics of renewables to distributed generation is only beginning to be studied in the United States, where a large utility (Pacific Gas and Electric) is currently field testing a 500-KW PV project (Lamarre, 1993), and in developing countries (Shugar, 1992a).

ning and developing project proposals, assembling finance packages, contracting with the utility) (Bhatia, 1993). Renewable power projects will probably get bigger as countries move beyond the pilot phase with new technologies, but they are unlikely to ever grow as large as conventional power facilities and systems (which, as noted earlier, is an advantage in other respects).

Third, capital markets for conventional central station projects are better established than those for off-grid power equipment. Many countries set loan conditions, repayment schedules, limits on access to foreign exchange and concessional rates, and equipment requirements for their banking systems, all of which may favor finance of conventional electrification projects in lieu of small off-grid systems (Mendis and Gowan, 1992). In addition, some renewable technologies are classified as consumer goods, which makes them subject to up to twice the interest rates utilities pay for capital. In some countries, financing for renewable power applications for households, businesses, or villages in unelectrified rural areas isn't even available.

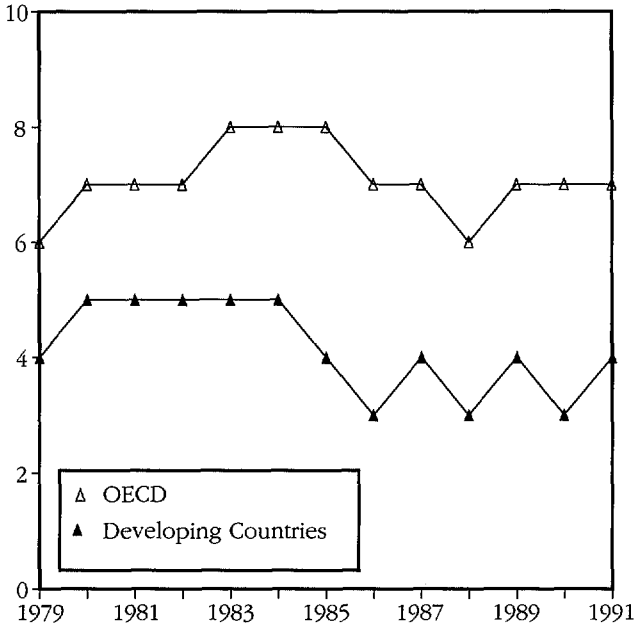
### *Energy Market Distortions*

Energy price distortions pose well-recognized barriers to renewable power development (Bates, 1993). Production and consumption subsidies lower the price of competing fossil fuels relative to renewable electric generators connected to a grid. Similarly, they bias decisions away from off-grid applications of renewables that compete with diesel fuel, kerosene, or power-line extensions. Besides skewing energy-supply choices, subsidized electricity prices also encourage wasteful consumption and discourage demand for efficient electric appliances. Since shortages of capital can limit renewable electric capacity, inefficient use patterns make it less likely that renewables alone can fully meet power demands.

In many developing countries, the prevailing electricity tariffs are not based on the often high long-run marginal costs of providing electric services. Between 1979 and 1984, average electricity tariffs among 60 developing countries recovered only about 75 percent of the costs of providing service (Schramm, 1993). 1990–91 electricity sales revenues in four Indian states covered only an estimated 40 percent of long-run marginal costs (RCG/Hagler-Bailly, 1991). At the same time, electricity prices in developing countries averaged less than 60 percent of those in OECD countries from 1979 to 1991—even though providing service to the dispersed loads found in developing countries generally costs relatively more. *(See Figure I-4.)* Among 40 rural electrification projects, the sum of capital costs of distribution, the long-run marginal cost of energy supplied, and operating and maintenance (O&M) costs averaged $0.20 per KWh and ranged from $0.084 to $0.35 per KWh. (All dollar amounts in this report refer to U.S. dollars.) Not even these high costs always reflect low load factors or high losses (Schramm, 1991).

Subsidized rural tariffs can make renewable power sources (typically priced at full marginal cost) uncompetitive when a household, business, or village is choosing between a grid extension or an off-grid renewable power source. And the same country that

**Figure I-4. Trends in Electricity Tariffs of OECD and Developing Countries for 1979–91 (cents per KWh 1986 Dollars)**




OECD = Organization for Economic Cooperation and Development
*Source:* Heidarian and Wu, 1994.

subsidizes conventional electrification may impose high import duties on renewable power equipment—a double whammy (van der Plas, 1994).

Some countries also subsidize fossil fuel consumption in markets where renewables compete. Defined as the difference between consumer prices (including those paid by utilities) and world prices, estimated 1991 world fossil fuel subsidies exceeded $210 billion—20 to 25 percent of the value of fossil fuel consumption at world prices. Of this total, coal and natural gas subsidies for power production amounted to about $38 billion. In eight countries, fuel subsidies totalled as much as 5 percent of GDP. (Granted, some oil-importing countries do tax such petroleum products as kerosene, which may compete with PV for household lighting.) Eastern Europe and the former USSR are responsible for the bulk of total fossil fuel subsidies, as well as just those for power production. Nonetheless, as of 1991, India, China, Indonesia, and other developing countries maintained significant fuel subsidies (Larsen, 1994).

Finally, because fuel prices do not fully reflect their relative environmental costs, and renewables in most cases entail far lower costs of this sort, conventional energy options look deceptively good compared to renewables. Indeed, environmental costs from conventional coal-fired power plants in the United States have been estimated at $0.006 to $0.10 per KWh (Chupka and Howarth, 1992).

The relative stability of world energy prices since the mid-1980s has afforded the chance to set realistic electricity prices with low political fallout, but most countries have instead maintained the status quo (Kosmo, 1989). Although pressure from multilateral donors or desire to attract private capital has recently prompted some countries (notably in Latin America) to reduce their subsidies, others are reluctant to act. India and a few other countries have taken a more expensive approach: in lieu of removing entrenched subsidies for other energy sources, they have subsidized renewables.

Distorted price signals aren't the only miscues in energy decision-making. Utility planning processes and power-project acquisition procedures may overstate the costs and understate the benefits of alternative technologies. In the United States, power sector planning and analysis co-evolved with centralized power generation, so new technologies that don't fit the mold are hard to assess by old rules. Renewables' environmental benefits, modularity, lack of fuel dependence, and supply-diversification aren't on the credit side of the ledger, even though the intermittency of some sources is on the debit side. Some of renewables' selling points become apparent only when decision-makers compare the degrees and types of financial risk associated with various electric generation technologies (Awerbuch, 1993). Frequently, for instance, utilities overemphasize the risks of uncertain power output per hour or over lifetime[5] (a problem with some renewables) and underemphasize the risk of future fuel cost increases (a problem with most conventional fuel sources).

Finally, subsidies to other sectors can influence the competitiveness of alternative generating options. In India, for example, the heavily subsidized rail sys-



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tem devotes 24 percent of its freight capacity to moving coal to power plants (Monga, 1994). China also subsidizes coal transport.

***Weak Institutions for Commercializing Renewable Electric Technologies***

In many smaller developing countries, scientific, engineering, manufacturing, and marketing capabilities are weak. The private sector—the most likely source of technological innovation and transfer—may in these nations be dominated by multinational companies that conduct little R&D through local subsidiaries. Even in countries with a strong R&D establishment, connections among researchers, local firms that manufacture or market equipment, and consumers can be tenuous (Butera and Farinelli, 1991; Davidson, 1991), and poor communication may slow word of new technologies and applications.

Trade policies can also hamper the flow of technology. In some countries, indigenous manufacturers of renewable energy equipment (as in Brazil and India) are protected from foreign competition through import tariffs. Trade protection for infant industries, common throughout the world, can commit developing countries to older, less efficient designs if it extends beyond the early stages. This danger is especially great if a technology is rapidly evolving and capital to upgrade manufacturing plants is tight.

Utilities often have more technical capability for delivering off-grid electric services than other existing organizations, however, few utilities view this as part of their mission. Many who might be interested lack strong internal R&D capabilities or run up costs by being inflexible on engineering design standards. Moreover, utilities' agendas are filled with more urgent operational or financial problems than developing, acquiring, or maintaining unfamiliar generating equipment.

Commitment to service is an equally important issue. Regardless of whether the utility or another entity installs the renewable equipment, it will fall into disuse unless someone is there to maintain, repair, and replace it. Local people without specialized training rarely have the necessary skills to carry out even routine maintenance, much less to diagnose problems and carry out repairs (Eskenazi et al., 1986). For example, a recent audit of public PV systems in eight Indian states revealed equipment failure rates ranging from 33 percent to 100 percent for street lighting, 25 percent to 94 percent for domestic lighting, and 41 percent to 100 percent for domestic water pumping (Maycock, 1993). High failure rates typify some public PV systems in Africa as well (Essandoh-Yeddu and Akorli, 1993).

## REMOVAL OF BARRIERS NEEDED TO ACHIEVE BENEFITS

The above barriers can cast long shadows on any renewable power technology's competitiveness, but inadequate capital and institutional capacity for commercialization are especially problematic for technologies whose costs could be cut the most. Recent estimates for various technologies suggest that substantial cost-reduction opportunities remain—for example, 20 to 60 percent for wind and 20 to 40 percent for solar thermal troughs (Pertz, 1993; Aitkin, 1992). PV's are thought to offer the greatest potential—from about $0.25 per KWh to $0.06 per KWh (Williams and Terzian, 1993.) Cost cutting of this magnitude will require sustained movement along learning curves in manufacture and operation, greater production economies, and technical innovations. For some technologies, the problem is one of chickens and eggs: producers are reluctant to invest the capital needed to reduce costs when demand is low and uncertain, but demand stays low because at current costs the technology isn't competitive in large markets. Here, institutional capacity is lacking not so much within developing countries but internationally, in the coordination of supply-push and demand-pull activities. Some technologies—notably, PVs—can progress from small, high-value applications to successively larger markets, but this path is rocky when initial markets are thin and geographically fragmented. Other technologies depend for market growth on their attributes being fully valued by potential users. In any case, renewables must gain market share if their large potential benefits are to be realized.

# II. TRENDS IN DEVELOPMENT ASSISTANCE FOR RENEWABLES AND POWER SECTORS

Financial and technical assistance has been used since the 1970s to adapt and adopt renewable energy technologies in developing countries. At the same time, donors have promoted initiatives and reforms in developing countries' power sectors that affect renewables' prospects. Both experiences are reviewed in this chapter.

## MULTILATERAL AND BILATERAL ASSISTANCE FOR RENEWABLE POWER SOURCES

Development assistance for renewables was first recognized as an international priority at the 1981 United Nations Nairobi Conference on New and Renewable Sources of Energy.[6] The conference produced an action plan for five broad areas: energy assessment and planning; research, development, and demonstration (RD&D); transfer, adaptation, and application of mature technologies; information flows; and education and training. The Nairobi program called for $5 billion (1982 dollars) for nonhydropower renewables just for feasibility studies, RD&D, and other pre-investment activities (Committee on the Development and Utilization of New and Renewable Sources of Energy, 1991). Unfortunately, falling energy prices and oil gluts—already the subject of speculation when the conference opened—subsequently weakened the political resolve to implement the plan. As a result, funding levels, projects completed, increases in the share of renewables in global energy consumption, and institutional coordination all fell well below early expectations.

From 1980 to 1987, investments in renewable electricity projects in developing countries (other than large-scale hydropower) totaled an estimated $5 billion. Approximately equal contributions were made by United Nations (UN), bilateral, and intergovernmental sources. Developing countries followed through on financial and institutional commitments more consistently than did industrial countries (Committee on the Development and Utilization of New and Renewable Sources of Energy, 1992; Miller, 1992). These financial commitments were inadequate, and they were more often focused on hardware than on capacity-building. Between 1979 and 1991, most official development assistance for renewable energy funded fixed capital assets. Much smaller amounts were used to meet such recurrent costs as maintenance, and less than 10 percent was spent imparting the technical and managerial skills needed to build national capacity (Organization for Economic Co-operation and Development, 1993).[7] Although capital goods, services, design specifications, and operating and maintenance skills are all needed to build a developing country's electricity-generation capacity, the neglected need to develop human and organizational capacities for generating and managing technical change (a long term and complex process) is just as vital.

> ***Donors lack incentives to fund capacity-building.***

Donors lack incentives to fund such capacity-building. It doesn't immediately benefit a hardware-oriented project, and capacity-building poses significant managerial challenges. Moreover, because associated manpower requirements are often too large to be absorbed into overall project costs, explicit financing must be found—an uphill struggle when the resulting assets are both intangible and mobile (Bell, 1990). Even when there is a willingness to pay, the timing and duration of investment projects focused primarily on equipment and engineering services often don't mesh with those of the learning components. Training is often tagged on as a low-priority effort, limited to what equipment suppliers can provide.

Also lacking in most hardware-oriented projects is a comprehensive approach to technology commercialization, one that encompasses research, develop-

ment, demonstrations, and market diffusion and that can require over a decade to complete (Jhirad et al., 1993). (Piecemeal efforts also typified the early domestic renewable energy programs of donor and developing-country governments.) Too often, immature technologies have been promoted and too little attention has been given to developing the indigenous institutional capacity to commercialize and deploy them. One observer characterized such projects as "little more than technical research exercises masquerading as energy assistance" (Foley, 1992). Rural projects often focused on a single technology, with no attempt made to match energy end-use needs with local energy resources and institutions.

Often, even efforts to build local technological capacity have not been tied to commercial development plans. In many countries, renewable energy research centers without any connection to the country's private sector have been established. Not surprisingly, few commercial technologies have emerged from solar research centers in several West African countries, despite years of operating experience (Bassey, 1992).

By the late 1980s, many donors had become disillusioned and many aid recipients had come to view renewables as second-class technologies that industrialized countries were unwilling to adopt themselves. High capital costs also made them inappropriate for their development status. Nonetheless, the 1980s saw major improvements in reliability, efficiency, and cost in several renewable technologies that were commercialized and deployed in industrialized countries.

Under the rubric of sustainable development, the 1992 United Nations Conference on Environment and Development breathed new political life into assistance for renewables, even though energy issues were not specifically addressed. Once again, renewable energy technologies are being recognized as appropriate components of development assistance and cooperation (Committee on New and Renewable Sources of Energy, 1994).

### *Recent Multilateral Initiatives*

In their official policy statements, the World Bank, the regional development banks, and numerous U.N. agencies advocate a place for renewables in (primarily rural) power generation. (*See*, for example, Asian Development Bank, 1994.) Within the U.N. system alone, about 25 agencies have promoted renewable energy. The United Nations Development Programme (UNDP) has been among the most active, spending about $50 million in grants from 1990–93. But rarely has multilateral agency rhetoric been matched by resource commitments, nor are funded activities well-coordinated.

#### *The World Bank*

During the 1980s and early 1990s, the World Bank financed large hydro and geothermal projects, but provided little financing for other renewables. *(See Figure II-1.)* The Bank is on record stating that "renewable energy is an abundant resource that can be increasingly harnessed" in response to environmental concerns, but until recently, it had not elaborated a clear role for itself in promoting renewables (Saunders, 1993; World Bank, 1993a and 1992a). In 1994, Bank staff developed an initiative for financing near commercial technologies whose implementation should clarify the Bank's role (World Bank, 1994a).

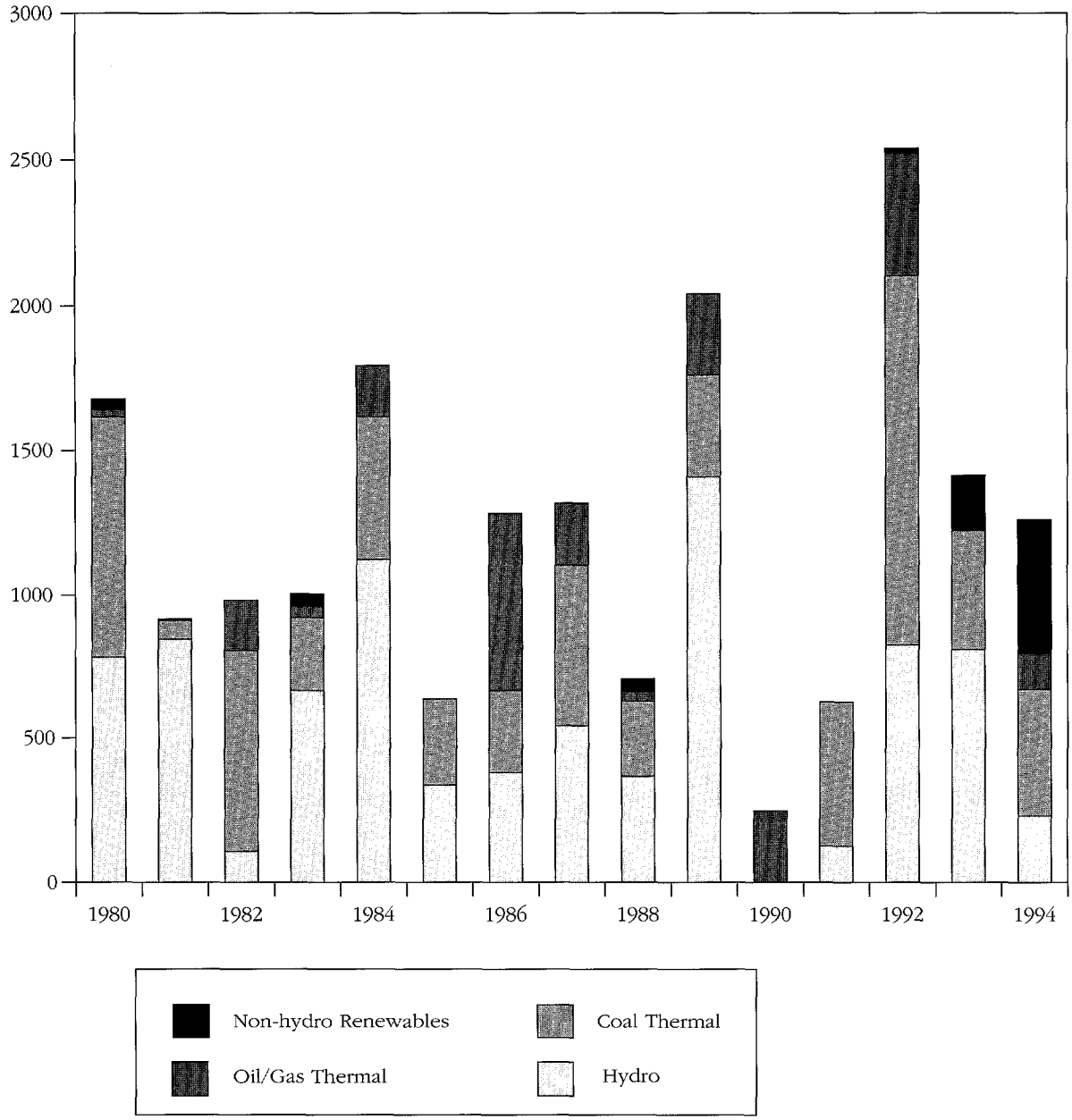
Still, the Bank's traditionally low emphasis on technical assistance puts renewable projects at a disadvantage. Small and unfamiliar, these projects require comparatively more pre-project data and analysis, given pressure on project managers to minimize loan-related costs. Moreover, the Bank's loan-financed technical assessments (which could provide such data and analysis) are expensive for recipients relative to U.N. grant–supported technical assistance. In addition, incentives to ensure that projects are properly implemented are weak among the Bank's loan officers compared to incentives to get project designs approved by the Board of Directors (Feinstein, 1994; Williams and Petesch, 1993).

In 1991, the Bank created the Asia Alternative Energy Unit (ASTAE) in its Asia Technical Department to help to prepare renewable energy and energy-efficiency components for Bank operations in the region. ASTAE identifies and prepares alternative energy components for Bank projects; designs and implements training in energy efficiency and renewable energy options (for both Bank and developing-country staff); helps formulate alternative energy policy and strengthen institutional capabilities within developing countries; collaborates with donor agen-

*Errata Sheet for Page 13*

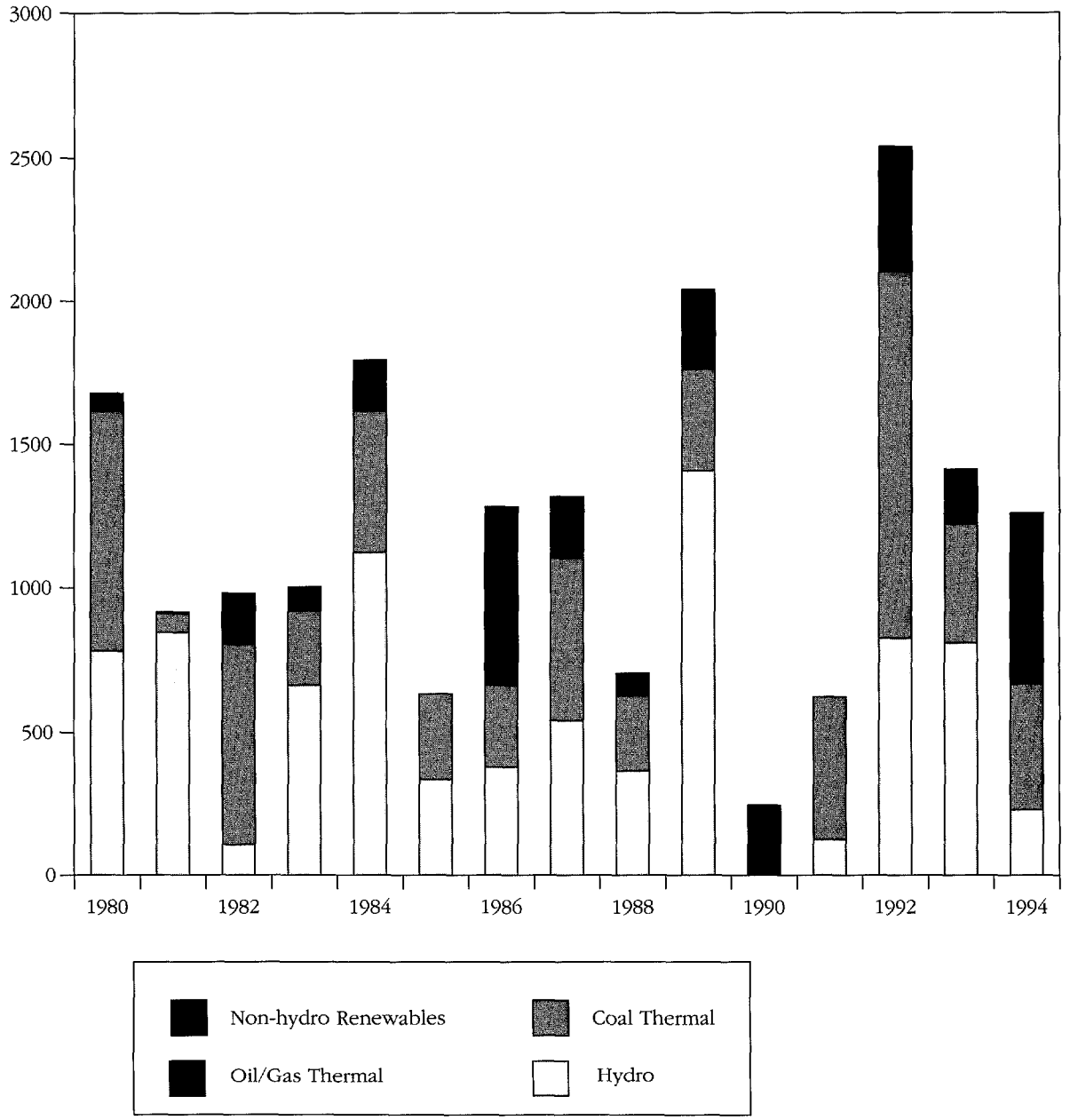
(This corrects Figure II-1, in which the distinction between Non-hydro Renewables and Oil/Gas Thermal is unclear.)

**Figure II-1. World Bank Financing for Power Generation Projects (U.S. $Millions)**




Other than in 1993, virtually all non-hydro renewables financing has been for geothermal projects.
*Sources:* World Bank, 1989; World Bank Annual Reports, 1994b, 1993b, 1992b, 1991a; Hemphill, 1993.

**Figure II-1. World Bank Financing for Power Generation Projects (U.S. $Millions)**




Other than in 1993, virtually all non-hydro renewables financing has been for geothermal projects.
*Sources:* World Bank, 1989; World Bank Annual Reports, 1994b, 1993b, 1992b, 1991a; Hemphill, 1993.

cies, and mobilizes technical assistance funds in support of these activities.[8] During its first two years of operation, ASTAE identified, appraised, prepared, or evaluated household photovoltaics (PV), grid-connected micro-hydropower, and other renewable components of projects in India, Sri Lanka, Indonesia, and China. Working with the India country department manager, ASTAE was instrumental in obtaining

approval for the Bank's first major renewables project. ASTAE also conducted several training seminars and workshops, provided technical assistance to both Bank staff and developing-country utilities, and promoted various energy-efficiency investments (Schaeffer, 1993; ASTAE, 1992). It has also promoted renewable private power sales to public grids by drafting power-purchase agreements and establishing guidelines and standards for project bids (Messenger, 1994). With two years left in its pilot phase, ASTAE has not yet been formally evaluated. The ultimate success of this modestly funded group depends on whether both project preparation and financing activities for renewable projects fully enter the mainstream of the Bank's Asian operations.

Initially, bilateral donors funded ASTAE with little financial or in-kind staff support from the Bank. Recently, the Bank has begun to pay for ASTAE's project-related services, but financing for renewables will not be fully "mainstreamed" within the Bank as long as the Global Environment Facility (GEF) or other donors are involved in the Bank's renewable projects—the case in two out of ASTAE's five ongoing and proposed projects. In the meantime, ASTAE's limited resources will constrain its influence. This group's 2-person renewable energy staff contrasts with the Bank's total Asia energy staff of 35, and the unit has low visibility. Operations staff aren't required to either involve ASTAE in sector work or solicit ASTAE support in preparing investment projects (Bhatia, 1993). The World Bank has no plans to replicate ASTAE in other regional divisions, though the Inter-American Development Bank is implementing a similar program with bilateral funding.

*Global Environment Facility*

Created in 1991 to help developing countries address climate change and other global environmental threats, the GEF funds mitigation projects, technical assistance, and, to a lesser extent, related research. UNDP, the United Nations Environment Programme (UNEP), and the World Bank jointly administer the GEF. Individual donor countries may add grants or highly concessional loans to GEF grants. Project success is measured in part by subsequent willingness of conventional sources to finance the commercial development of targeted technologies.

During its pilot phase (which ended in 1993), the GEF approved $281 million for greenhouse gas reduction, divided among renewable energy projects, improvements in conventional energy supply efficiency, and demand-side efficiency. GEF seeks to increase the menu of technologies available for reducing greenhouse gas emissions by promoting technology commercialization through demonstrations, economies of scale, marketing demonstrations, and institutional development. GEF project criteria are based on the notion of "incremental cost" embodied in the climate convention: potential projects might be supported if economically attractive from the global perspective of reducing greenhouse gas emissions, even though from the recipient country's perspective they make sense only with GEF funding (Ahuja, 1993). Some observers argue that, because many energy-efficiency projects should be attractive to developing countries without GEF support, renewables should dominate GEF projects in the global warming arena (Anderson and Williams, 1993). In early 1994, the GEF was restructured and its core budget replenished at $2 billion for three years. If early projections hold, about 50 percent of this budget will be allocated to address global warming. Even leveraged at five to one, however, this budget will be swamped by the incremental costs of imposing climate constraints on electric capacity expansion plans. Indeed, for just one small country (Colombia), electric capacity expansion through 2009 would cost an estimated $400 million more than without carbon contraints (Ahuja, 1994).

In GEF's pilot phase, the cost effectiveness of various $CO_2$-reducing options did not drive project selection (UNEP et al., 1993).[9] In some of GEF's renewable energy projects summarized in Table II-1—mainly those based on wind, hydropower, and bagasse cogeneration—only relatively modest cost reductions are needed to make them competitive for many power applications that currently emit large volumes of carbon emissions. Others, including photovoltaic projects, can't achieve the economies of scale needed to become competitive with grid-connected power. Moreover, solar thermal troughs were not included in the GEF's pilot phase, even though their current cost is closer to competitiveness than PV's cost. Cost effectiveness in reducing carbon emissions also depends on whether a project can be repli-

**Table II-1. Global Environment Facility Renewable Electricity Projects (2nd Quarter, 1994)**

| Country | Project Name | Implementing Agency Approval Date | Duration | Total Cost ($millions) | GEF Share of Cost ($millions) | Status |
|---|---|---|---|---|---|---|
| Brazil | Biomass Integrated Gasification/Gas Turbine (BIG/GT) | 9/92 | 2.5 years | $7.7 | $7.7 | Subcontracts issued to implement the required modifications to the gas turbines, feedstock tested for suitability. Terms of Reference for both short-term and long-term environmental assessments finalized. |
| Costa Rica | Grid-Integrated Advanced Windpower | 12/93 | 5.5 years | $38.9 | $3.3 | Signed by Costa Rican government. Under implementation. |
| Côte d'Ivoire | Crop Waste Power | 11/94 | — | $40.0 | $5.0 | Project Document in preparation. |
| India | Optimizing Development of Small Hydel Resources in the Hilly Regions | 1/94 | 5 years | $7.5 | $7.5 | UNDP approval in January 1994. Awaiting signature by government. |
| India | Bio-energy from Industrial, Municipal and Agricultural Waste | 1/94 | 3 years | $5.5 | $5.5 | UNDP approval in January 1994. Awaiting signature by government. |
| India | Renewable Resource Management | 12/92 | 7 years | $430.0 | $26.0 | Grant effective 4/93. Wind energy component fully subscribed. |

*continued on next page*

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**Table II-1. (continued)**

| Country | Project Name | Implementing Agency Approval Date | Duration | Total Cost ($millions) | GEF Share of Cost ($millions) | Status |
|---|---|---|---|---|---|---|
| Mauritania | Wind Electric Power for Social and Economic Development | 6/94 | 5 years | $4.0 | $2.0 | Project approved by UNDP review committee 6/94. |
| Mauritius | Sugar Bio-Energy Technology | 11/94 | 5 years | $10.5 | $3.3 | Grant effective 12/93. Implementation underway. |
| Pakistan | Integrated Community Waste-to-Energy Systems | 5/95 | 5 years | $14.0 | $11.0 | Project appraisal scheduled for 1/95. |
| Philippines | Geothermal Energy Development | 5/94 | 5 years | $1,334.0 | $30.0 | Associated Bank loans approved by Board 6/94. |
| Tanzania | Electricity, Fuel and Fertilizer from Municipal Waste in Tanzania: A Demonstration Biogas Plant for Africa | 12/93 | 3 years | $3.9 | $2.5 | Project beginning implementation. |
| Zimbabwe | Photovoltaics for Household and Community Use | 2/92 | 5 years | $7.0 | $7.0 | Project under implementation. |

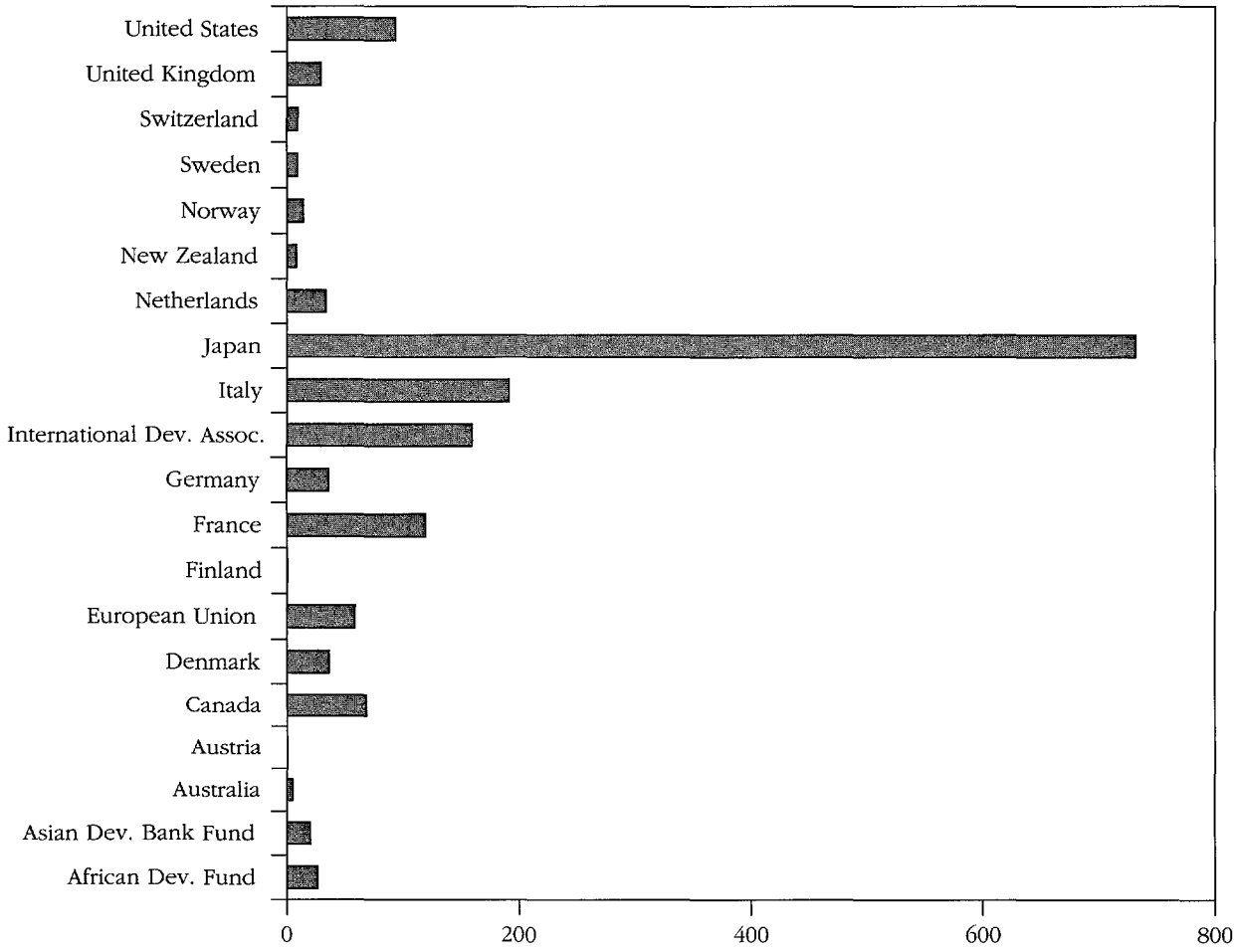
IDB = Inter-American Development Bank; UNDP = United Nations Development Programme.
*Source:* GEF, 1994.

cated or can catalyze other initiatives. For example, if the GEF's bagasse projects ultimately lead to "closed-loop" biomass feedstock systems, much larger scale greenhouse gas reduction benefits are possible. The potential for replicating GEF's wind project in Mauritania depends on upgrading in-country capability to assemble and fabricate wind generator components.

### *Trends in Bilateral Assistance*

As with multilateral assistance, bilateral assistance for renewables has been modest. *(See Figure II-2.)* Over 1979–91, renewable projects totaled about $1.3 billion—only about 3 percent of total reported bilateral energy assistance. Geothermal received the most funding, followed by small hydropower. Solar, wind, and other renewable technologies have each received no more than a tenth of the resources allocated to small hydro, even though their ultimate market potential is probably larger. *(See Figure II-3.)* Funding for renewables reported by donors has been erratic *(See Figure II-4)*, paralleling the rapid increase in the 1970s and subsequent decline in the 1980s of domestic spending for renewables in several donor countries. In some years, spending spikes were caused by large individual projects. Bilateral donors tend to focus assistance on certain countries. Al-

**Figure II-2. Individual Donor's Official Development Assistance for Renewable Energy, 1979–91 (1991 US$ Million)**




*Source:* OECD, 1993. Some multilateral assistance sources are included in this database.



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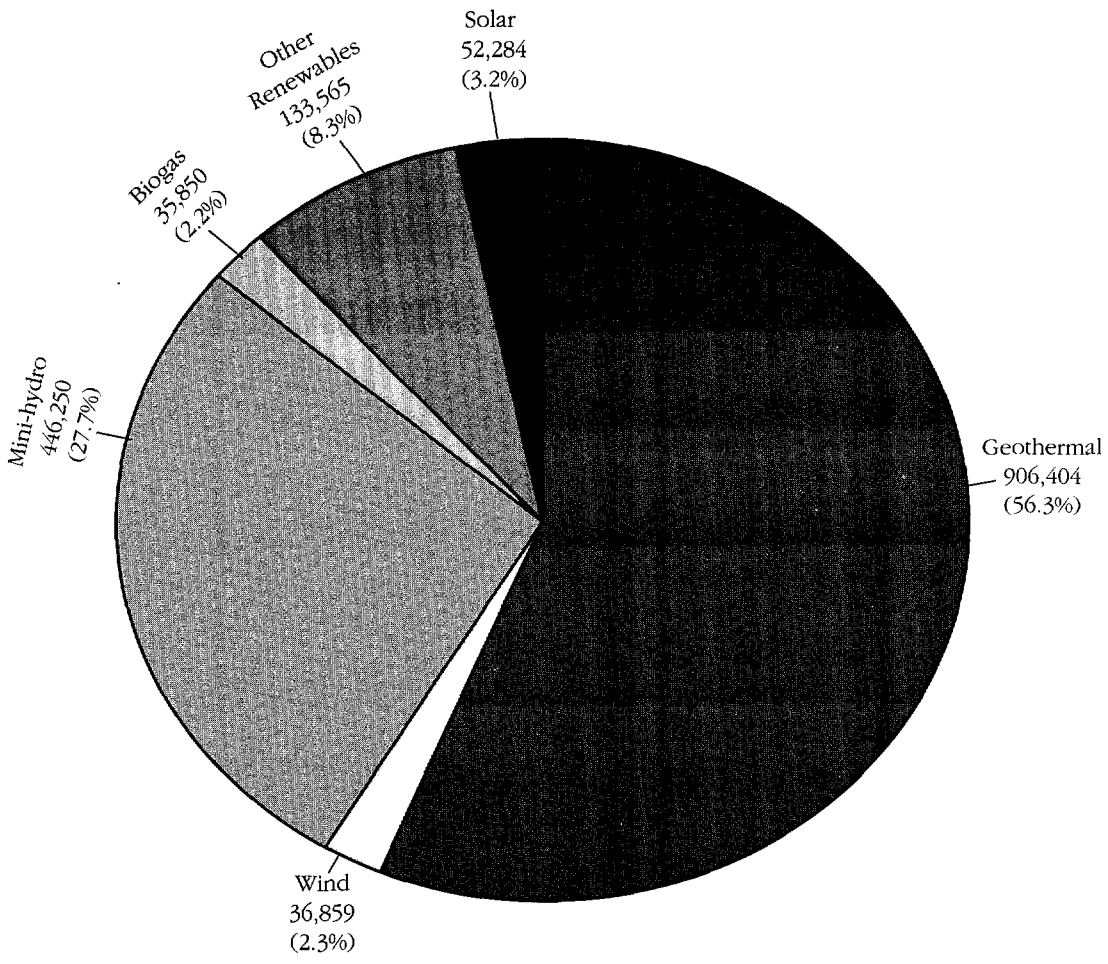
**Figure II-3. Official Development Assistance for Renewable Energy by Technology 1979–91 (1991 US$)**




*Source:* OECD, 1993.

though details of Japan's aid program are not readily available, most of its support has gone for hydro projects in the Philippines and India (OECD, 1993). Although Japan's program is largest in absolute terms, small donors (New Zealand, Switzerland, and the Netherlands) rank highest in terms of the percentage of total energy assistance allocated to renewables from 1979 to 1991 (OECD, 1993).

An important objective of many bilateral (and less explicitly, multilateral) aid programs is to promote donor country exports of goods and services.[10] Although the distinction between development assistance and export promotion is frequently blurred, it is no accident that bilateral donors often direct assistance to technologies and products in which they have a comparative advantage in domestic or world markets. (For example, the Danes have focused on wind turbines and the Italians on geothermal equipment.)

Tied aid credits ensure that aid recipients will use a donor's goods or services. These credits may be given either as a pure grant or provided in conjunction with a loan in order to enable more exports per dollar of aid expended.[11] Because competition is



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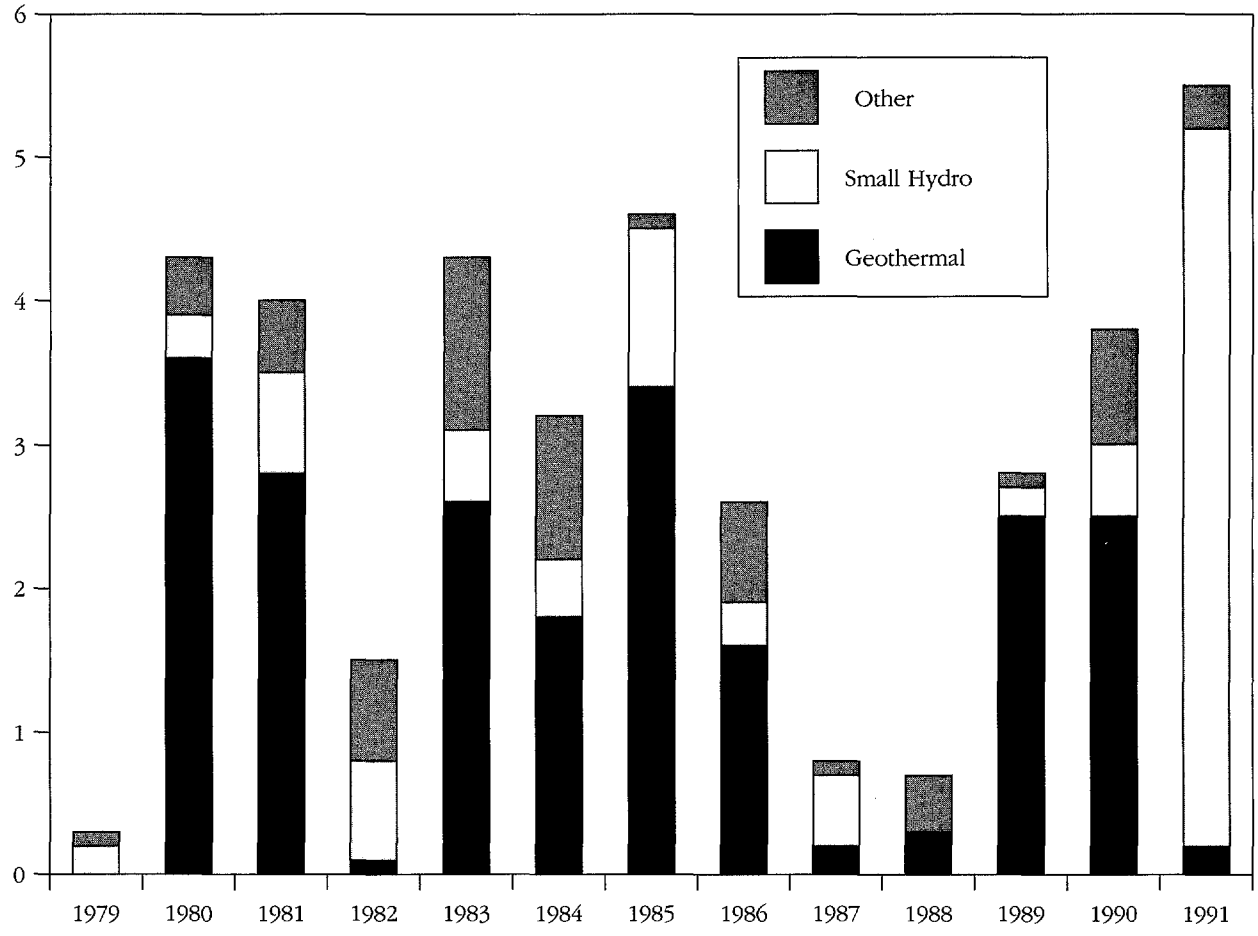
**Figure II-4. Percent of Total Energy Official Development Assistance Devoted to Renewables**




*Source:* OECD, 1993.

keen among OECD donors for shares of the burgeoning developing-country markets for power and environmental technologies, pressure is high to use tied aid for energy projects (U.S. Office of Technology Assessment, 1993).

Each donor's experience in providing assistance for renewables reflects its overall assistance and export-promotion policy. Because comparable evaluations of the 18 OECD bilateral assistance programs for renewables are not available, a comprehensive review is not feasible. But the conclusions reached by the United States and Germany about their experience appear broadly consistent with reviews of other bilateral energy assistance (Barnett and Bharier, 1988).

*United States*

The U.S. Agency for International Development (USAID) helped fund over 200 renewable energy projects between 1975 and 1988. USAID assistance did not result in wide-scale diffusion of renewables because technology R&D was emphasized at the expense of dissemination. Institutional weaknesses in recipient countries and policy barriers also posed problems. According to an internal review of this experience:

- Only commercially mature renewable technologies should be used in projects not explicitly designed to promote technology development.
- Only commercially competitive renewable technologies—those that are affordable, easy to service, and reliable—will succeed, and user involvement/market testing should be required as part of project design, implementation, and evaluation.
- USAID should address fuel subsidies and other unfavorable policies that hamper the diffusion of renewables.
- Applications should be fitted to local social, economic, physical, and institutional conditions.
- "After-sales" service must be adequate or renewable energy promotion will fail.
- Local private sector production, marketing, sales, and service are needed to sustainably disseminate renewables and make a significant impact on a developing country's energy sector.
- Improved documentation of past experience could increase the rate of future success (U.S. Agency for International Development, 1990b).

Partly as a result of these findings, USAID now emphasizes private sector programs to stimulate market-driven applications of renewable energy sources in developing countries (U.S. Agency for International Development, 1990a). For example, USAID funds the Export Council for Renewable Energy (US/ECRE), a consortium of renewable energy trade associations that works with the inter-governmental Committee on Renewable Energy Commerce and Trade (CORECT)[12] to coordinate governmental renewable energy export activities. Together, CORECT and US/ECRE identify market opportunities around the world for U.S. renewable energy products and services and facilitate their cost-effective use (NREL, 1992). CORECT encourages member agencies to fund renewable energy projects, reverse trade missions (in which foreign officials visit U.S. renewable energy installations), pre-investment studies, technical assistance, workshops, and other informational activities for foreign officials. Coordination of bilateral support has helped leverage multilateral initiatives, as evidenced by the creation of FINESSE and, subsequently, ASTAE.

Another U.S. bilateral effort to help open foreign markets to domestic firms is the private nonprofit International Fund for Renewable Energy and Energy Efficiency (IFREE), created to "catalyze U.S. public and private financial resources" to leverage international lending for U.S. renewable energy,[13] energy conservation and efficiency, and natural gas products and services. IFREE shares costs for project pre-feasibility studies and provides technical assistance to lending officers in multilateral development banks and their clients in developing countries.

Finally, USAID provides technical assistance to several countries for specific technologies. It also supports the creation of renewable energy support offices in several developing countries so as to help U.S. firms enter local markets.

*Germany*

The German assistance agency Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) has promoted renewable energy since the late 1970s. A current program seeks to "improve the energy supply situation in developing countries through the development and use of renewable energy sources...in combination with the exploitation of all possible means of energy conservation" (Wagner, 1988). Over the years, GTZ efforts have shifted from a supply-driven emphasis on technologies to a demand-driven emphasis on strengthening local institutions and planning capabilities and, most recently, to bringing together the necessary players for market-based development (Suding, 1994). Accordingly, GTZ now emphasizes advisory and extension services and "leans much more heavily toward the provision of technical assistance than of financial assistance (5-to-1 ratio)." Based upon experience during 1982-88, GTZ concluded that purely technical solutions fail without a commercial infrastructure, access to capital, and regional planning. Future projects will focus on proven technologies and on promotion of local institutional capacity.

Looking back at ten years of assistance for the dissemination of small-scale photovoltaic systems, GTZ has recently framed other objectives pertinent to renewable energy assistance too:

- Facilitating large-scale dissemination by establishing long-term marketing and distribution systems

that are sustainable without continuing external assistance.

- Designing finance mechanisms for poor people.
- Designing commercially viable, nongovernmental dissemination processes that make maximum use of private entrepreneurs acting in self-interest.
- Promoting only systems that offer economic and social benefits.
- Maintaining strict quality control of well-tested systems (Bierman et al., 1992).

Schooled by experience, both GTZ and USAID now profess to focus support on technical assistance, more mature technologies, and coordination with the private sector. German assistance is still more likely to finance physical infrastructure (Perret, 1993), though several USAID activities are linked to the U.S. renewable energy industry.

## OVERALL POWER SECTOR ASSISTANCE

To understand more fully why renewable energy assistance has had only mixed success, the challenges facing developing-country power sectors and the response by aid agencies must also be examined. In many cases, donors have provided assistance for financing and management of power production, rationalizing electric tariffs, and reforming national power laws and planning procedures but failed to adequately address the implications of this aid on the choice of generating technology.

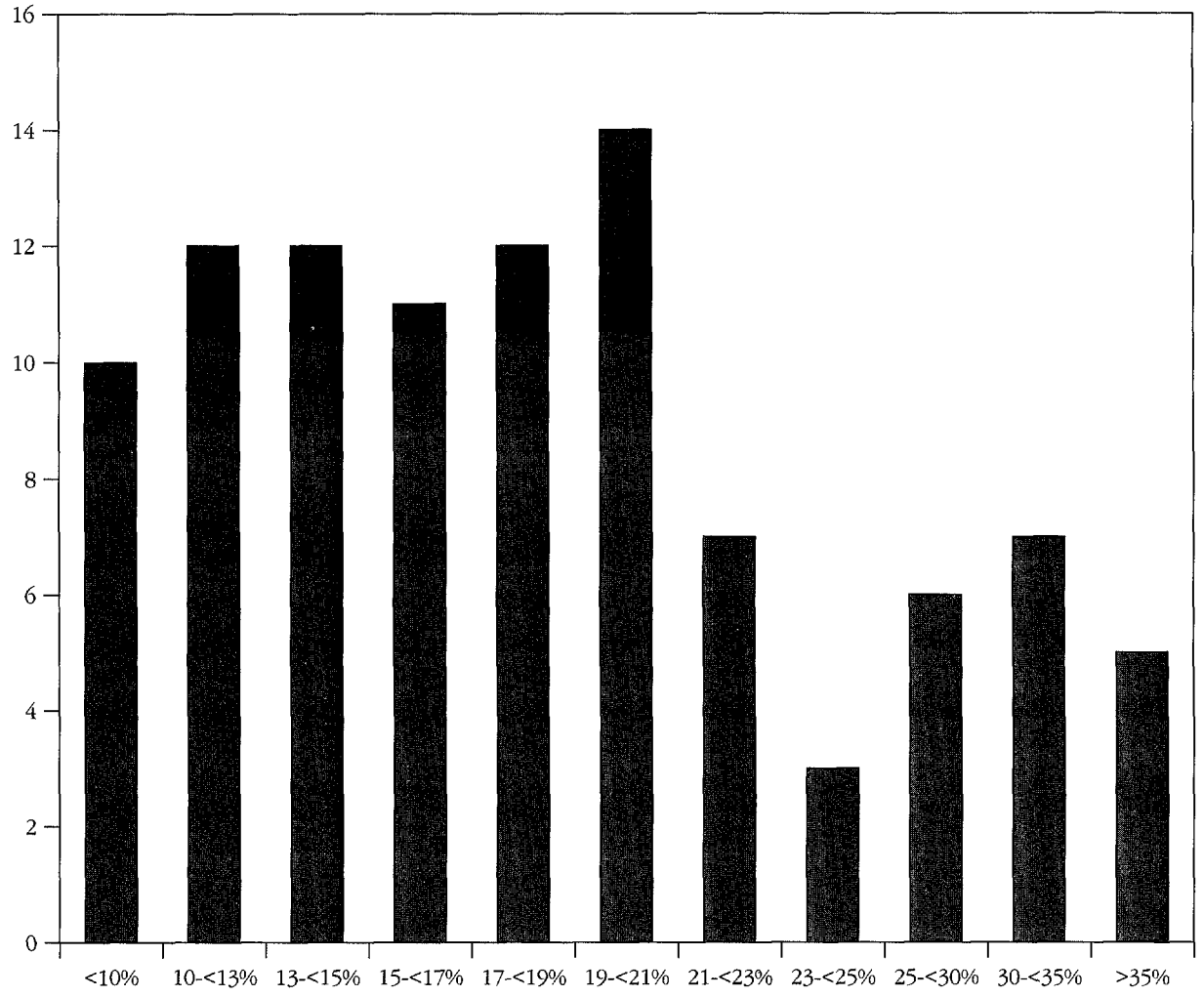
Multilateral donors have historically supplied substantial capital for developing-country power sectors, and public utilities have invested the lion's share partly because electric generation projects are so large and risky that only governments are willing to invest in them. Private financial markets have remained small in this capital-intensive industry (Khatib, 1993). Indeed, one reason for creating the World Bank fifty years ago was to compensate for the commercial financial markets' failures to provide such infrastructural lending. Future expansion of power sector infrastructures depends on developing countries' ability to mobilize sufficient capital. Needs are projected to total about $100 billion a year for the next 10 years, of which 40 percent will need to be externally financed. In light of growing assistance needs in other sectors, however, only about $10 billion a year is expected to be available for power sector projects from concessional sources (Saunders, 1993).

***"In many cases, donors have provided assistance for financing and management of power production, rationalizing electric tariffs, and reforming national power laws and planning procedures but failed to adequately address the implications of this aid on the choice of generating technology."***

On top of the financial pressures they face in expanding capacity, utility managers are forced to address the poor operating performance of the existing system. In most countries, electricity services have been provided by state-controlled utilities untrammeled by competition or public oversight. Lack of autonomy from government surfaced in a recent study of 60 diesel power plants in 36 developing countries as one of nine factors that adversely affect plant performance independent of technology.[14] The other eight are conflicts between economic efficiency and social objectives (e.g., providing electricity to all), lack of management accountability for plant financial performance, insufficient training for plant operation, poor management quality, lack of financial "transparency" in procurement processes, insufficient revenues to cover costs, lack of timely access to foreign exchange (especially for maintenance), and donor policies and procedures that do not promote efficient operation (Central Project Team, 1991).

Other problems arise when utility managers are interested only in the centralized utility structures and generating technologies common in donor countries, but not well suited to their countries. Partly for political reasons, utilities have extended their grids into low-density, high-cost rural areas.[15] Many developing-country utilities are plagued by capacity factors of only 40% or less, poor power reliability, and large

**Figure II-5. Distribution of Power System Losses in Developing Countries (Number of countries and percentage losses)**




*Source:* Heidarian and Wu, 1994.
*Note:* Ninety-four countries made up the sample.

transmission and distribution (T&D) system losses. *(See Figures II-5 and II-6.)* While some energy losses result from theft, others are caused by underinvestment in T&D systems relative to generation (Schramm, 1991). T&D system components cause a 15 percent energy loss in Kenya, compared to a target of 8 percent (USOTA, 1992). In addition, if a few large central generation units are relied on to serve the grid, investments in new generation can be poorly matched to demand increases. While many developing countries have capacity shortfalls, total excess capacity among others is estimated to be 43,000 MW—even with an assumed 30 percent reserve margin. Thanks partly to a commitment to long-gestation, large hydropower projects, excess capacity in Colombia reached 24 percent in 1989 and over the period 1986–92 cost the Colombian economy 3.5 times more than the losses incurred from



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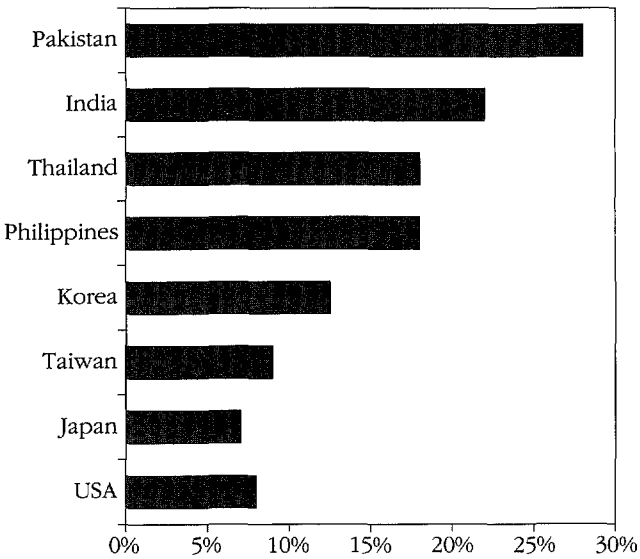
**Figure II-6. Transmission and Distribution Losses in Several Countries (Average percentage losses for 1981–85)**




*Source:* Jhirad, 1990.

earlier power outages (World Bank, 1991b). The shortcomings of the centralized utility model are more apparent in countries where power loads are geographically dispersed and load factors are low, or where demand for power isn't great enough to fully exploit the economies of central station generation.

### *Donor Responses to Managerial and Capital Problems*

In response to the problems just noted, donors have promoted various sectoral reforms. Power tariff reform has met with some success. Some 19 structural adjustment loans were provided by the World Bank for this purpose from 1988 to 1992 (Warford et al., 1994). The World Bank also strongly favors introducing competition to developing-country power sectors and "vertically unbundling" generation, transmission, and distribution services (World Bank, 1994c). Both bilateral and multilateral agencies have encouraged power-planning reforms.

*Private Power*

The gap between the foreign exchange needs of developing-country power sectors and aid flows from abroad implies that total investment will have to be reduced, foreign aid increased, domestic finance increased, or private foreign investment increased. All these options may play a role in power sector expansion, but the last is the most likely to dominate (Barnett, 1992). Currently, the status of private power markets ranges widely among developing countries. *(See Box II-1.)* As of 1992, privately financed power projects under development totaled over 100 GW (Meade and Poirier, 1992), which will increase installed capacity in developing countries by about 10 percent.

The ultimate effects of private involvement on renewables' market share of developing countries' power output remain to be seen. But some advantages are already clear. If private investors are to earn acceptable returns, utility revenues will have to be collected more carefully from customers, and tariff structures will have to be based more closely on costs. Renewables become more competitive in off-grid applications when utilities charge customers the full costs of serving rural areas with grid extension. Greater energy efficiency resulting from cost-based rates will also help developers match local power demand to available renewable resources. Opening the grid-connected generation market would allow those nonutility renewable developers offering dispatchable electric power and agro-industries that produce excess electricity to compete for market share most readily.

Private involvement and competition in power generation also poses some disadvantages for renewables. Given the high capital and low operating costs of renewables and the market discount rates available to the private sector, renewables are less likely to be cost competitive in private generation markets than in publicly-developed projects. If the U.S. experience with nonutility power generation is any indication, renewables' competitiveness also depends on national and state policy. *(See Box II-2.)* In the United States, public utility commissions exercise oversight over resource acquisition, but few developing countries have independent public bodies to address market distortions while opening up generation to private developers.

**Box II-1. Private Power in Developing Countries**

Developing countries are at various stages in allowing private investment in power production. Brazil, Chile, Costa Rica, the Dominican Republic, India, Jamaica, Mauritius, Mexico, Pakistan, Philippines, Tanzania, Thailand, and Turkey all have legislation governing the private production of power either pending or in force. Depending on the specific legislation in each country, industries may be allowed to generate their own power and sell the excess to the grid. Elsewhere, independent power producers may compete with utility projects to provide new generating capacity or may sell power to privatized distribution utilities. Few countries require their utilities to provide wholesale power wheeling. Relative to Asia and Latin America, private power lags in many African countries, where venture capitalists are reluctant to invest in projects because little beyond verbal commitments protects their investment.

Laws allowing private power sales are no guarantee that generation markets will develop. In some countries, monopsony power by utilities remain barriers, along with high investment risks and transaction costs. For example, though Brazil allows the sale of private power, the generation utility Electrobras will buy power from cogenerators only at the weighted average long-term cost of power from its current generation portfolio—not at the higher marginal cost of new capacity. India's sugar industry is similarly disappointed with low purchase tariffs recently offered by one major state utility (Mathur, 1994), though another state has offered attractive rates (D'Monte, 1994b). The charter of the Indonesian utility PLN was amended in 1979 to allow the Ministry of Mines and Energy to license private utilities and cooperatives, but the move produced no immediate results. In Costa Rica, where private power legislation has been on the books since 1990, contracts to bring proposed independent renewable capacity on line were not signed until 1993. Most developing countries that allow private power transactions don't require utilities to consider project characteristics other than lowest near-term cost—and only Thailand and the Dominican Republic explicitly mention renewables in enabling legislation.[a]

a. In 1989, Thailand issued regulations defining qualifying facilities for power sales as those that are less than 60 MW and derive at least a third of their annual energy input from agricultural residues. The regulations list requirements for responding to the utility's power solicitations and propose a standard contract with energy payments for peak and off-peak periods. In 1990, the Dominican Republic authorized contracts between private generators and the state utility with priority to nonconventional generating technologies (USAID Private Power Database, undated).

As part of broad macroeconomic reform packages, multilateral donors sometimes require such sectoral reforms as greater private involvement in financing or managing power generation projects. The International Finance Corporation (IFC, the World Bank's private sector lending division) has made direct loans to private power developers totaling about $2 billion. Yet, only about $200 million for small hydropower projects and no nonhydro renewable projects have been approved (Wishart, 1994; Glen, 1992).

Bilateral assistance promoting private power generation has covered project prefeasibility studies, conferences, and other activities. USAID has sponsored programs to encourage nonutility generation in India, Pakistan, the Philippines, the Dominican Republic, and Costa Rica. A primary goal of the Indian private power assistance program is to improve local utility officials' ability to evaluate proposals by private developers. The U.S. Export-Import Bank, which now has a project finance group, authorized in FY1994 about $1.5 billion in power generation loans and guarantees. Two geothermal projects constituted 23 percent of this total and a biomass project received another 3 percent.

**Box II-2. Competition and Renewables' U.S. Market Share**

The 1978 Public Utilities Regulatory Policies Act (PURPA) required U.S. utilities to purchase power from qualifying renewable power and cogeneration facilities (QFs) at prices based on their avoided costs. Renewables fared well in the ten states that had favorable buyback policies and contractual incentives and these states now account for 73 percent of the nation's QF capacity (Hamrin and Rader, 1993).

By 1991, concerns about cost effectiveness and overcapacity prompted 36 states to implement competitive bidding among all power sources. Some utilities began purchasing power to avoid investing in new capacity themselves. But, given the near obsession in competitive bidding on lowest cost per KWh, only 2 percent of all capacity acquired under such schemes was renewable during 1993. To improve the percentage, several states require utilities to consider characteristics other than cost when developers submit bids for power purchases or, alternatively, to limit some competitively bid capacity to renewables (Kozloff and Dower, 1993). National legislation in 1992 further boosted competition for power generation by relaxing ownership requirements for nonutility generators and requiring utilities to provide independent developers with access to transmission lines. Further restructuring of the power sector to allow retail competition is being proposed in several states.[a]

Increased wholesale and retail competition in the U.S. power sector is likely to have several effects on renewables. QF status still confers benefits to developers of renewable power, but because of heightened competition from natural gas project developers, is unlikely to result in the high level of renewable capacity added during the 1980s. To retain customers, utilities strive to keep rates down by reducing investments in new generating capacity particularly if it's unfamiliar or capital-intensive, regardless of whether such investments might improve their position in the long run. Also to cut costs, R&D staffs in some utilities have been downsized, particularly in power generation. If generation, transmission, and distribution services are unbundled, distributed generation opportunities that provide grid support may not be readily evaluated because generation will be organizationally, analytically, and financially separated from transmission and distribution functions. Also, renewable power developers, whose projects must be sited where the resource is located, may not be able to find buyers for their power as easily as nonrenewable competitors. Finally, private projects using intermittent renewable resources are not considered by utilities that impose dispatchability requirements, even when the project's power output has some capacity value. In some cases, enhancing the capacity value of a project based on an intermittent resource may only require evaluating the project's output in combination with that of other intermittent generators or the utility's own generating portfolio (Kozloff and Dower, 1993).

a. Retail competition is already allowed in New Zealand, Norway, and the United Kingdom (Flavin and Lenssen, 1994).

Several avenues are possible for private financing, depending on project size (capital requirements and generating capacity) and other characteristics. A prominent mechanism is the build-own-operate-transfer (BOOT) scheme whereby at the end of a specified period, say 10–15 years, project ownership is transferred to the government. In other financing models, no transfer occurs at the end of a specified term, a government utility constructs a plant that it then sells to a private owner-operator, or a government utility leases a privately constructed and owned plant. In every case, investors must be confident of getting hard currency returns from their investments. That said, their typically high capital and low operat-

ing costs mean that renewable generating technologies may require different payment terms than nonrenewable projects.

What has been the net effect of increased private participation in power projects on market penetration by renewables? The preponderance of independent power projects and aggregate capacity proposed for developing countries between 1987 and 1991 has been nonrenewable. *(See Figure II-7.)* The same holds true for India in 1993. *(See Figure II-8.)* Less than 1% of the overseas capacity proposed by U.S. developers was renewable in 1993 (Hyman, 1993).

To their credit, donors have initiated programs intended to direct at least a small portion of private capital flows to renewable power options. A U.S. Government-backed private equity fund identifies renewable power projects as eligible, though it is limited to investments of $5 million to $10 million (*International Solar Energy Intelligence Report,* 1994). In 1994, the U.S. Export-Import Bank began to offer financing enhancements for renewable energy and other environmentally benign projects. Renewables would also be eligible for funding by a World Bank program proposed to attract venture capital to greenhouse gas mitigation projects (World Bank, 1993c).

The effectiveness of these efforts in garnering a share of private capital flows for renewables will depend on the extent to which developing countries' procurement policies stimulate renewable capacity proposals. So far, however, donors have not adequately recognized the connections among such policies, private power markets, and technology choices. For example, a World Bank/USAID manual for developing countries on evaluating private power proposals contains virtually nothing on this issue (World Bank and USAID, 1994), nor does a USAID report that discusses power sector restructuring as a response to the risk of climate change (USAID, 1994).

*Power Planning*

The choice of generating technologies for capacity expansion is deeply influenced by the planning tools that utilities have at their disposal. The World Bank's primary power sector planning tool was originally developed to cover large central station generation (specifically, nuclear power) and cannot readily be used to evaluate such modular or intermittent generation options as wind turbines. Yet, the Bank's planning processes and analytic tools for power infrastructure investments are often adopted by developing countries (Meier, 1990).

***"The choice of generating technologies for capacity expansion is deeply influenced by the planning tools that utilities have at their disposal."***

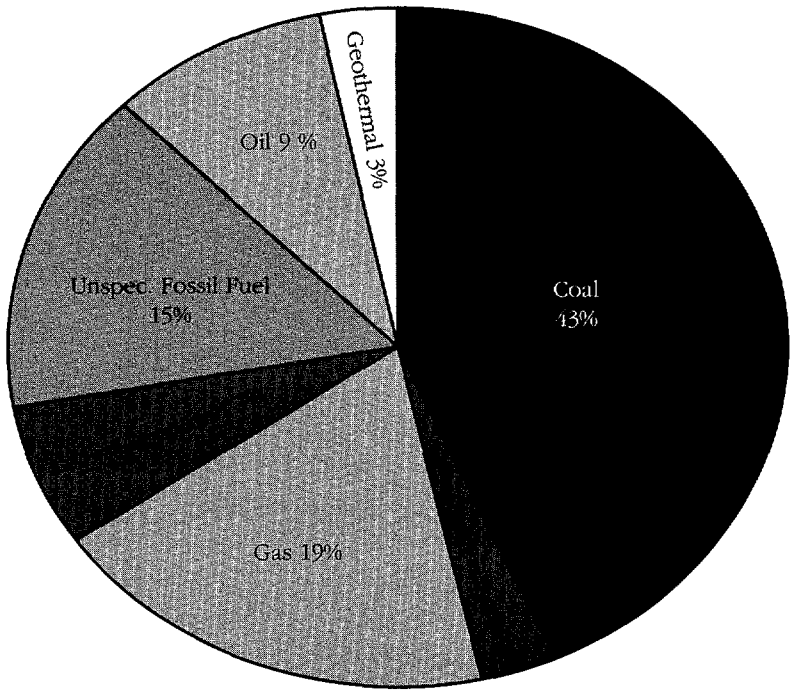
In addition, few planning processes adequately address load-forecast uncertainties, biasing the outcomes of these processes in favor of large increments of generating capacity.

> Power system expansion planning is subject to a considerable degree of uncertainty with respect to load forecast, time and cost-to-completion of new plant, fuel costs, and technological innovation. Many power system planners continue to use forecasts of these planning parameters as certainty-equivalent characterizations of the future, despite the generally poor concurrence between these *ex-ante* forecasts and actual *ex-post* situations. Such disregard of uncertainty greatly enhances the prospects of future imbalances between the demand for power and the system supply capability, as well as erroneously biasing the selection of plant types to meet demand at least cost (Sanghvi et al., 1989, abstract).

A review of some 200 electricity-sales forecasts made for 45 countries for 1960–85 reveals a strong bias toward overestimation, and accuracy deteriorates as forecast horizons lengthen. Even with the best analytical tools, the scope for reducing uncertainty in load forecasting appears limited (Sanghvi et al., 1989).

Partly in response to the poor or deteriorating performance of developing-country utilities, donors have offered technical assistance to improve planning capability. A primary multilateral vehicle for this aid is the Energy Sector Management Assistance Program (ESMAP), jointly sponsored by the World Bank and UNDP. While ESMAP is supposed to provide more

**Figure II-7. Generating Technologies' Market Share in Megawatts of Proposed Private Power Projects, 1987–91**




*Note:* Status as of 1992 ranges from inactive to operating.
*Source:* USAID Private Power Database, 1992. This database is representative but does not include all private power projects.

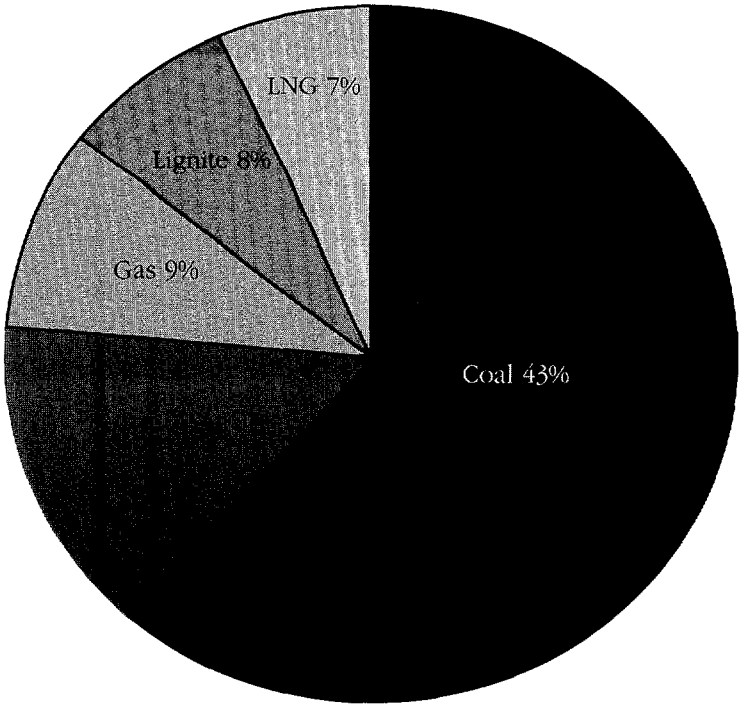
technical assistance for environmentally friendly energy options in the wake of the Earth Summit (World Bank, 1993a), power sector restructuring has dominated its recent activities (UNDP and the World Bank, 1993).

An example of bilateral assistance is the USAID-sponsored Utility Partnership Program, which has brought together U.S. and Eastern European utility personnel to address basic managerial and operational issues (USEA, 1994). In addition, under UNDP auspices a group of large electric utilities from industrialized countries has agreed to share their expertise with developing country utilities in integrating environmental considerations into planning. Even these assistance efforts, however, may not connect a utility's choice of generating technology to its environmental and financial performance.

One approach developed in the U.S. to improve utility planning is integrated resource planning (IRP) which analyzes the full range of supply- and demand-side resource options for providing electric services in a "least cost" context, and assesses the environmental and financial risks of these options. Some form of IRP has been adopted by most U.S. states (though the advent of competition-driven restructuring has clouded the further diffusion of IRP). In the last few years, bilateral and multilateral agencies, as well as NGOs, have begun to promote modified IRP in a few developing countries. Brazil, Costa Rica, Jamaica, Mexico, Sri Lanka, and Thailand have taken some steps already while China is considering adopting IRP for certain regions.

The primary purpose of international assistance in transferring IRP concepts and methodologies has

**Figure II-8. Generating Technologies' Market Share in Megawatts of Proposed Indian Private Power Projects, 1993**




*Source:* Payne, 1993.

been improved consideration of demand-side management (Phillips, 1993). This emphasis helps renewables because they complement improved energy efficiency and because improved end-use data and analysis can also identify potential renewable applications. However, adopting IRP as commonly practiced in the U.S. does not necessarily ensure that the distinguishing characteristics of renewables will be fairly considered when utilities decide what type of generation to add. Moreover, planning for generation, transmission, and distribution investments is not well integrated. For example, high transmission- and distribution-system costs imply substantial savings from end-use efficiency improvements, but may not lead utilities or donors to evaluate distributed generation options. And while tools exist for analyzing how modular generation projects with short lead times affect financial risk (Hirst, 1992), few utilities use them, even in the United States (Cadogan et al., 1992).

Whether IRP or otherwise, planning reforms have recently been overshadowed by privatization as the focus of technical assistance to developing-country power sectors, mirroring the ongoing power sector restructuring within some donor countries, notably the U.S and U.K. (*See*, for example, Elliott, 1993). Technical assistance that promotes competition and vertical unbundling may be premature, given that donors have only limited experience in resolving conflicts in their own power sectors between such restructuring and resource planning reforms.

# III. DEVELOPMENT ASSISTANCE PROJECTS AND PROGRAMS FOR RENEWABLE ELECTRIC GENERATION

Only part of the story is told by trends in financial and technical assistance for renewables and developing-country power sectors. To highlight more of the determinants of development assistance's effectiveness, 11 projects are examined in this chapter. They span a wide range of country settings, technologies, time periods, and types and levels of assistance. Technology-independent aspects of project design and implementation are pinpointed by drawing examples of photovoltaic (PV), wind, geothermal, mini-hydro, and biomass from at least two countries.[16] Unlike many early efforts in which installed equipment did not work, these projects all met with some measure of technical success and are assessed here in terms of their prospects for replication. For a few newer projects, replicability had to be inferred from their design rather than experience.

To the extent allowed by available data, projects are compared according to how well they address inadequate access to capital and insufficient local capacity for commercial development and deployment. Renewable energy assistance projects cannot by themselves overcome the third barrier discussed in Chapter I, energy market distortions, but can be located where market conditions are likely to allow project replication. In fact, only 5 of the 11 projects were implemented in countries where electricity revenues appear based on marginal costs. *(See Table III-1.)* When a utility's revenues do not recover its costs of service, attracting capital to finance capacity expansion (of any type) becomes more difficult. Moreover, replicating off-grid renewable projects is harder when potential recipients are promised subsidized grid extension.

**Table III-1. Recent Electricity Rates and Incremental Costs in Case Study Countries**

| | Average Electricity Revenue US cents per KWh[a] | 1987 Average Incremental Cost of System Expansion (US cents per KWh)[b] |
|---|---|---|
| Brazil | 6.00 (1994) | 7.34 |
| China | 1.62–3.29 (1991) | 6.02 |
| Dominican Republic | 11.0 (1992) | 8.50 |
| India | 3.14–8.80 (1990) | 8.04 |
| Kenya | 6.25 (1987) | 5.63 |
| Mauritius | 12.46 (1991) | n.a. |
| Morocco | 8.30 (1991) | 8.21 |
| Nepal | 3.70 (1991) | 10.53 |
| Philippines | 5.20 (1991) | 6.29 |

n.a. Not available
a. Ranges for China and India reflect tariff classes for one utility rather than average revenues.
b. Presumably, incremental costs increased between 1987 and when average revenues were calculated.

*Sources:* Heidarian and Wu, 1994; World Bank, 1990. Brazil revenue figure from Luis Vaca-Soto, World Bank. Dominican revenue figures from Hankins, 1993.

## PHOTOVOLTAICS FOR RURAL ELECTRIFICATION

Off-grid PV systems for household lighting, water-pumping, and other uses are proliferating in many countries. In Colombia, the Dominican Republic, Mexico, Sri Lanka, Zimbabwe, and Kenya, private sales of PVs are significant. In fact, more rural households in Kenya receive electricity from PVs than from the grid (van der Plas, 1994). In most projects, the amount of power supplied is sufficient only for lighting and other modest domestic uses.

### *Brazil*

The availability of off-grid electricity in Brazil has been constrained by the lack of institutions capable of financing and delivering it. To address this barrier,



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the U.S. Department of Energy (USDOE) developed a joint project with the state governments of Pernambuco and Ceará in northeast Brazil to install 750 home lighting and 14 larger PV systems and to train local personnel. USDOE is also providing technical assistance for program planning, implementation, and monitoring. Local utilities—which own, install, and maintain the systems—collect small tariffs from system users. The immediate project objective is to "establish and assess the efficiency, operability, and reliability of solar energy-based rural electrification in a pilot project" (Taylor, 1993). The ultimate goal is to attract multilateral finance for substantial project expansion.

The cooperative agreement between USDOE and the two states was announced during the 1992 United Nations Conference on Environment and Development in part to demonstrate U.S. commitment to sustainable development. USDOE subsequently contracted its National Renewable Energy Laboratory (NREL) to oversee the four-year implementation. In turn, NREL arranged for joint implementation, operation and maintenance (O&M), and evaluation with the Companhia Energetica de Pernambuco (CELPE), Companhia Energetica de Ceará (COELCE), and Centro de Pesquisas de Energia Eletrica (CEPEL), the research branch of the Brazilian utility holding company, Eletrobras (Taylor, 1993).

USDOE has committed some $855,000 to the project, including $677,000 for equipment and services (to be provided by Siemens Solar International) and $100,000 for a service subcontract with CEPEL. Brazilian parties have committed approximately $2,067,000 for balance-of-system equipment, installation, O&M, oversight, evaluation, and reporting. This sum includes $1,100,000 from Eletrobras (financing CEPEL's involvement), $150,000 from FINEP (the Brazilian finance ministry), $362,000 from CELPE, and $455,000 from COELCE.

Monitoring and evaluation is intended to provide the information needed to refine the project and inform utilities, policy-makers, and the public about the viability and characteristics of PV rural electrification. In addition, involving two state utilities, the national utility research organization and the national utility holding company, should develop these institutions' capacity to implement additional PV projects. COELCE has subsequently begun working with GTZ to deploy PV-driven pumps. Since 20 million rural Brazilians (23 percent of the population) have no electricity, PV's potential market is huge. In a second project phase now under way that includes wind power too, six additional states have expressed interest in similar pilot programs. USDOE will finance up to $250,000 in each state that meets several conditions. These include 50 percent state-utility cost sharing and a commitment to request large-scale financing if demonstrations succeed (NREL, 1993). CEPEL has established a PV working group to help other interested states learn about PV applications.

The project has enhanced capacity on the demand side of the market (Brazil's power sector) but not on the supply side. Siemens Solar is the sole equipment supplier—ostensibly because its modules are cheaper than those produced by Heliodinamica, a Brazilian PV manufacturer whose goods are protected by an import tariff. Nonetheless, bypassing an indigenous manufacturer already serving local markets caused a stir (*Energy, Economics and Climate Change,* 1992; *International Solar Energy Intelligence Report,* 1992)[17].

In addition, the project's design may not promote sustainable PV diffusion. Because end users make no down payment and pay for little more than O&M costs, participating utilities do not fully recover costs, which makes it hard to internally finance large-scale replication. Given the need for large amounts of foreign capital and a shortage of utility revenue to repay debt on previous power projects, international lenders are not eager to finance additional electrification in Brazil. Thanks to a recent law, Brazilian utilities may now charge cost-based tariffs, but the law's implementation has been suspended to help curb inflation.

***Dominican Republic***

Quite different from the public sector approach used by USDOE in Brazil is one used in the Dominican Republic to address capital and institutional barriers to PV deployment. Since 1984, Enersol Associates Inc., a U.S.-based nongovernmental organization (NGO), has supported the development of indigenous Dominican supply, service, and financing mechanisms and a market-driven demand for household PV systems. Enersol has used donor grants to train a network of local entrepreneurs to assemble, market,

install and service the systems; develop a community-based solar NGO to manage revolving loan funds for individual end-users; and help local community-development and financial NGOs develop full cost-recovery finance of the systems. Enersol is also using donor grants to replicate the Dominican entrepreneur/professional training and NGO loan model in Honduras and Guatemala. Enersol's immediate objective is to develop an "open-ended self-sustainable" program for solar-based rural electrification and, eventually, to integrate solar technologies with rural societies in Latin America.

Because a standard home PV system costs more than half the average annual per capita income in the Dominican Republic, credit is essential if PV is to penetrate its rural energy market. Accordingly, a key component of the Enersol model is a network of locally managed NGO credit programs to finance systems using revolving loan funds capitalized by external donors. Recipients must repay full capital, installation, and market interest costs with monthly payments over two to five years. The default rate for these credit programs is less than 1 percent, though late payments are not uncommon (Doernberg, 1993). Other rural Dominicans have purchased systems with cash or informal three- to six-month loans provided by system suppliers.[18] In addition to building capacity for household systems, Enersol created a program to help communities finance and implement PV water-pumping and community-lighting projects.

This program began in 1985 with 6 systems, grew to 100 in 1987, more than 1,000 in 1989, and 2,000 in 1993 (Hankins, 1993; Hansen and Martin, 1988). More capital for local revolving loan programs is needed for further expansion, but even so the total number of Enersol-associated systems is expected to surpass 2,400 in 1994, with the help of a $50,000 Global Environment Facility (GEF) grant. In addition, a $55,000 Rockefeller Foundation-sponsored "bridge fund" is being used to provide loan guarantees to Dominican banks, which in turn provide commercial loans for local NGOs to finance additional PV home systems. Since bridge fund monies remain in an interest-bearing U.S. account, the capital becomes available to leverage financing of new PV systems after current guarantees expire (unless the NGOs default). Including private sales outside the Enersol network, the total number of systems exceeded 4,000 in 1993—1 percent of all unelectrified rural households nationwide (Hankins, 1993).

Growth of the Dominican PV-home-system market has led to several related developments. First, fifteen commercial installation businesses, four equipment importers, and two balance-of-system (charge controllers) manufacturers now supply this market. Second, the infrastructure developed to support small systems has provided the basis for development of larger community lighting and water pumping systems. Third, building upon its Dominican experience, Enersol in 1992 opened a Honduran field office, through which it has conducted PV technician and professional training and established an additional $40,000 "bridge fund" that provides access to credit through local NGOs.

Enersol founder Richard Hansen attributes the program's success to several factors: simple, economical, stand-alone systems; emphasis on training and development of local human resources; village-level focus and control; local capital generation to ensure community responsibility and support for the projects; and parallel development of credit programs, service enterprises, and technical and organizational human resources.

The program has also benefited from demand for limited electrical services that was previously met by dry cells to power radio/tape recorders and car batteries to power televisions. The domestic supply of car batteries can now be used for PV systems.[19]

Use of locally fabricated PV panels is not an option in the Dominican Republic. Indeed, India and Brazil are the only two developing countries that currently manufacture PV cells. Most batteries and charge controllers are manufactured in the Dominican Republic, so, if installation is included, the local value added constitutes approximately 50 percent of the total value of the systems.

## GEOTHERMAL POWER GENERATION

Few enterprises in developing countries are large and diversified enough to assume the investment risks associated with geothermal exploration. Moreover, returns from the up-front investment in developing a geothermal field are more gradual than from

mineral extraction. Financial and technical assistance have thus been critical to enable developing countries to exploit their geothermal potential.

***Philippines***

Use of geothermal resources for power production is well established in the Philippines, which derived 21 percent of its national power supply from such resources in 1992 and which has targeted 1,675 MW of geothermal capacity over the next decade. National agencies have gained experience in geothermal development through past projects and bilateral training agreements with Iceland, Italy, Japan, New Zealand, and the United States. Access to capital, however, remains a constraint.

To increase Philippine geothermal capacity, provide a demonstration for private investors, and induce additional private geothermal development, the World Bank, GEF, Japanese Export–Import Bank, and the Swedish Agency for International Technical and Economic Cooperation are jointly financing a large-scale geothermal power project on the Philippine island of Leyte. Based on previous exploration, a 440-MW project was approved.[20] At this capacity, the project cost an estimated $90 million more than a comparably-sized coal-fired plant proposed for the island of Luzon. (The cost difference stemmed from the need to build a 480-km EHV transmission line from the project site to the load center on Luzon.) The GEF grant and bilateral cofinancing reduce the cost difference between geothermal and coal-fired power development, thus leveraging much greater amounts of multilateral and private investment for plant construction. *(See Table III-2).* By providing a national interconnection, the project should overcome the high cost of transmitting power from remote geothermal fields to load centers. If ultimate project capacity is at least 880 MW, geothermal development would become the "least cost" alternative—even without concessionary funding. (Estimated geothermal resources in the region would support generating capacity of 800 MW to 1200 MW.)

Private capital for the power plant itself was engaged through a "Build-Operate-Transfer" (BOT) arrangement. To attract private sector financing, the high geothermal resource royalties otherwise paid to the government were reduced by statute. Procurement was facilitated by establishing a project director within the government and selecting a turnkey contractor based on international competitive bidding. No local vendors were deemed capable of implementing the project.

**Table III-2. Leyte-Luzon Geothermal Cost and Financing Sources (US$ million)**

| | |
|---|---|
| **Project Costs** | |
| Generation | 620 |
| Transmission | 331 |
| Resource Development | 315 |
| Interest During Construction | 68 |
| **Financing** | |
| Global Environment Facility grant | 30 |
| Swedish grant | 39 |
| World Bank loan | 240 |
| Japanese loan | 170 |
| Foreign private loan guaranteed by World Bank | 100 |
| BOT financing | 620 |
| Internal cash generation[a] | 134 |

a. Philippine National Oil Company and National Power Corporation.

*Sources:* Harris, 1994.

Despite this project's likely technical success and the inclusion of a resource assessment for future geothermal development (GEF, 1991), future development of nearby geothermal resources is not assured. The lead government agency (the Philippine National Oil Company) has not been able to change the perception (based partly on the previous Mt. Apo geothermal project) that geothermal development carries local ecological risks. Moreover, people on Leyte recognize that they will bear the brunt of whatever ecological and cultural costs are incurred while most of the power will be shipped elsewhere. Leyte's dispersed population might be better served by off-grid power sources, but providing such services was not part of the project package.

### *China*

The United Nations Department of Economic and Social Development (UN-DESD) has recently completed a Tibetan geothermal demonstration plant begun in early 1991. This United Nations Development Programme (UNDP)-supported initiative also included technical and managerial training, information gathering, and energy planning. To address institutional capacity and capital barriers, the project was intended to strengthen Chinese technical and managerial expertise related to exploiting geothermal reserves; provide the hard currency needed to obtain advanced geothermal utilization technologies and equipment; and provide resource availability information. The Chinese government is seeking additional electricity generation in Tibet due to large expected demand increases, reduced hydropower generation during the winter, limited traditional fuel resources, and irregular supplies of imported oil (UNDP, 1988).

The principal project output is the 1-MW demonstration plant. Before it was built, the only power in the area (Nagchu) came from a diesel generator that operated at only about half its rated 1.6 MW capacity and for only about 5 hours a day—due to high fuel costs and maintenance problems. Output from the demonstration plant alone is expected to meet about 40 percent of the area's current annual power needs. Industrial development planned by the Chinese government would, however, boost annual power requirements by about 50 percent. Most people in this area are Tibetan; data were not available on the extent to which they were involved in planning and implementing the project relative to immigrant ethnic Chinese.

The plant employs a binary-cycle technology that can exploit geothermal resources at lower temperatures than conventional technologies can. While cost-effectively used in several industrial countries, this technology had not been used before in China which lacked the hard currency needed for equipment and technical training (Cuellar, 1993).[21] Project staff also assessed the viability of using the binary-cycle generation technology to exploit other local low-temperature reserves. (UNDP provided local institutions with the exploration and monitoring equipment needed to collect resource information.)

Chinese staff were extensively trained through cooperative work with foreign geothermal experts during both the resource assessment and construction stages, as well as through extensive international training. This instruction for planning and managerial officials, engineers, and technicians helped local institutions plan, manage, operate, and maintain geothermal resources and associated generation equipment.

UNDP has provided roughly $5.3 million in hard currency, including $100,000 for expatriate consultants and advisors, $875,000 for a geoscientific services subcontract, $200,000 for international training of the Chinese staff, and $4.2 million for equipment (including $2.5 million for the binary-cycle plant and $1.7 million for equipment for drilling six exploration wells). The Chinese Government provided RMB Yuan 66 million (at that time, $1.00 = RMB Yuan 5.21) to finance a core staff of about 40 persons (mainly geological scientists and engineers) and an additional unspecified number of support personnel, an on-site training program at the Beijing and Tianjin Universities, and support services and equipment.

### *Kenya*

Of the several East African countries with significant geothermal resources, only Kenya has capacity on line—40 MW or 6 percent of the country's generating capacity. External assistance has been used to build institutional capacity and hurdle capital barriers. As in China, initial assistance was provided by a UNDP grant for exploration; Kenya's government contributed only local currency. Interest in the project was first expressed by a private British company that was providing electric power in Kenya. The company was nationalized about the time the project was implemented.

The first exploratory holes were drilled at Olkaria in 1958, but because the nationalized utility didn't explore as diligently as its predecessor, significant resources were not discovered until 1972. Different ministries then vied for control of the project, delaying implementation another five years. The World Bank (which rarely lends for resource exploration) financed project construction, though only after the Kenyan government transferred to a two-party political system. The plant finally went on line in 1982. By current estimates, the Olkaria field contains 500 MW

of capacity, and the Kenyan government is now soliciting private equity investment to exploit it.

This project has stimulated local scientific and engineering training in geothermal development. Indeed, Kenyans now serve as geothermal consultants to other African countries. However, because the utility has largely relinquished control of project activities to foreign contractors and because procurement contracts are linked to conditional finance agreements, the use of this expertise in progressive stages of the project has actually declined (Khalil, 1992).[22]

## WIND

Long-term familiarity with wind pumps and mills in many countries has undoubtedly helped pave the way for modern wind turbines. For example, Argentina has had a thriving windpump manufacturing industry for almost a hundred years, and as of 1992, well over 20 windpump manufacturers operated in Asia, Latin America, and Africa (Stockholm Environment Institute, 1993; Hurst, 1990).

### *India*

To address Indian utilities' lack of capacity to integrate wind power projects into their grids, the Danish International Development Assistance Agency (DANIDA) helped the Indian Department of Non-Conventional Energy Sources (DNES, now a ministry), the Tamil Nadu Electricity Board (TNEB), and the Gujarat Energy Development Agency (GEDA) develop three demonstration wind farms with a total of 20 MW capacity.[23] Assistance also supported technical cooperation to develop indigenous wind-farm planning, implementation, and operating and maintenance (O&M) capabilities (T. Bak-Jensen/PA Consulting Group, 1992). The project was initiated by DNES, which requested a DANIDA appraisal mission that was conducted in December 1986. A year later, DANIDA retained an experienced Danish wind energy consulting firm to plan, design, and oversee implementation of the project, and the agency contracted two well-established Danish manufacturers to supply and install equipment.

The project emphasized local participation and shared responsibility. All three Danish firms were required to work closely with local partners to develop indigenous technical capacity. In addition, the state-level implementing agencies, the TNEB and GEDA, were responsible for preparing their respective sites and constructing access roads, foundations, transmission lines, and substations. Danish contractors manufactured and delivered the turbines and 90 percent of the towers, which were then installed at the prepared sites. (Ten percent of the towers were manufactured locally.) On-site training in planning, implementation, and O&M was supplemented by off-site training in these topics, as well as in constructing and replacing wind-turbines and central monitoring systems.

During the first year of operation, the two Tamil Nadu wind farms produced 23,548 MWh (92 percent of estimated production). The wind farm in Gujarat produced only 8,810 MWh (47 percent of estimated production) due to initial operational difficulties. Experience was gained in wind farm planning, implementation, and management by DNES and the state electricity board staff members. Local staff are now trained enough to operate and maintain the farms.

After its wind farms proved themselves, the TNEB asked the local consulting firm that participated in the project to prepare a wind-power development Master Plan for the state, announced plans to install 100 MW of wind capacity, and identified the sites of future substations for connection to private wind farms to encourage private investment. Although the GEDA has understandably been less enthusiastic, it has nonetheless established an internal wind farm unit, conducted a DANIDA-funded study for future wind development for its grid, and said it would finance two substations to be connected to private wind farms. Private investors have financed the installation of 1.5 MW of wind capacity near one of the Tamil Nadu wind farms and private orders have been placed for an additional 4.25 MW of capacity.

Assistance has also afforded local contractors experience in civil and electrical works. Indian firms that constructed some of the towers subsequently obtained approval to manufacture 100 KW to 300 KW grid-connected turbines. Their phased production plans call for a gradual increase of indigenous content from 40 percent (towers only) the first year to "full" production (towers, generators, controllers, and blades—about 90 percent of the equipment) the

fourth year. DNES hopes to create enough demand under the Eighth Plan to sustain local production by at least five public and private manufacturers.

At the national level, DNES has established a 500-MW construction target (300 MW publicly financed and 200 MW privately financed) within its Eighth Plan (1991–95) and offered tax incentives for private wind projects. Up to 70 MW of the private capacity may be financed through the Indian Renewable Energy Development Agency, sponsored by the IBRD, International Development Association, and GEF. An apparent outgrowth of the earlier experience, much of the new wind capacity is being sited in Tamil Nadu (100 MW by 1994's end), and DANIDA, along with other donors, will likely provide mixed credit financing. The 500-MW national target will be exceeded if several states complete approved projects totaling 500 MW, along with another 180 MW under consideration (D'Monte, 1994a). Still, costs may have to drop before wind power can compete, without substantial subsidies, with conventional capacity (ESMAP, 1992).[24]

The experience of seeing small applications prove themselves appears to have caused wind technology in India to move from initial demonstration to a stream of equipment orders by Indian utilities as well as to private investment in windfarms. Two other keys to success were project size (large enough to interest both public and private stakeholders) and the decision to use progressively more locally manufactured equipment in each year of the project. This experience offers success factors that apply to other grid-connected renewable projects. *(See Box III-1).*

**Box III-1. Wind Project Success Factors**

Additional factors have contributed to DANIDA's success with wind projects in India and elsewhere: 1) commitment and active involvement by national policy planners and utility officials who have the ability to implement large projects; 2) clear definition of project objectives (for example, separation of R&D from demonstrations); 3) allocation of sufficient resources for planning and appraisal; 4) separation of implementation from appraisal activities by using different contractors; 5) integration of projects with national power sector planning; 6) provision of technical assistance for planning, implementation, training, and service; 7) use of multiple local contractors for infrastructure construction, financed where possible by recipient; 8) focus on a single technology and application, and 9) focus on larger countries to maximize economies of scale in developing physical infrastructure and returns to institutional investments (T. Bak-Jensen, 1991).

### *Morocco*

The Centre de Développement des Energies Renouvelables (CDER) is a USAID-sponsored agency responsible for helping to commercialize renewable energy in Morocco. In 1988, CDER contracted Bergey Windpower Co. (BWC) to implement a water-pumping project in a small Moroccan village (Bergey, 1991). The proposed wind-electric pumping system was expected to be more efficient and less expensive to operate and maintain than conventional diesel or mechanical wind pumps. Major project objectives were to provide technical and economic performance data, finance a first-of-a-kind field demonstration, and provide a visible application to stimulate demand and encourage political support for the technology. In other words, the principal barrier addressed was insufficient national capacity to commercialize a new technology.

A USAID grant of $120,000 financed the project. The funds came as part of a larger grant for improving the technical capability of the CDER that also covered U.S. consultants and local staff. Research and testing were funded by the U.S. Solar Energy Research Institute.

Implementation involved several steps. In mid-1988, before the wind turbines and pumping systems were installed, they were laboratory and field tested and a CDER technician was trained—both in the United States. Next, BWC surveyed the project site, which was located in the home province of the Moroccan Minister of Energy and Mines (a bid for political support that proved ineffective). The Délégation Provinciale d'Agriculture (DPA) then constructed the turbine tower's foundations and water tank according to BWC's specifications. BWC subsequently installed

the pumping equipment and turbines and conducted five hours of operational and service training for local operators.

The project has had to overcome several challenges. The systems can supply 220 percent more water than previous diesel pumps, but just after the project was completed in 1989, they operated only intermittently. Operation has since improved after a local entrepreneur began servicing them. Early problems were attributed to the immaturity of the technology, CDER's weak technical support staff and lack of commitment to the project, and inadequate local project management. CDER's lack of support in turn was due to previous negative experience with a "costly and unsuccessful" wind project, unexpectedly high project costs, "different interpretations...[of] the nature and level of support" expected from CDER, the project's distance from CDER headquarters, timing problems (the project was installed during the month-long Ramadan holiday), and low staff morale (Bergey, 1991). Local commercialization was also inhibited because the two-machine project was too small to stimulate interest in Morocco (in contrast to windpower development in India), local technical personnel were insufficiently trained to maintain an unfamiliar technology, and a mechanism for overcoming high upfront costs was lacking.

In assessing the effectiveness of the bilateral assistance, neither private entrepreneurs in Morocco nor the Moroccan government have shown much interest in disseminating the technology since the initial demonstration, despite recent improvements in CDER's overall capability. On the other hand, the USAID grant gave BWC an incentive to design a new wind-electric pumping system that is more reliable and has lower lifecycle cost than diesel pumps for medium-scale pumping needs. Similar BWC systems have now been demonstrated or marketed elsewhere, including Indonesia.

## SMALL HYDROPOWER

Traditional use of running water in developing countries for mechanical work has provided a basis for more recent technology transfer. Small-hydro turbine technology is now well established in several countries, including Brazil, China, India, and Nepal.

### *Nepal*

A private nonprofit agency called United Mission to Nepal (UMN) has worked since 1963 in Butwal and other parts of Nepal to develop local small and micro-hydropower using indigenous industrial capacity. UMN's objectives are to make daily life easier for the Nepalese people, serve local needs for water resources, develop alternative energy sources to prevent forest degradation and dependence on imported fossil fuels, create rural employment to stem migration and poverty, reduce the cost and difficulty of rural lighting and heating, and encourage other end uses of electricity (Upadhayaya, 1992; Upadhayaya, 1991). To meet these objectives, UMN has dismantled some of the capital, energy-pricing, and institutional barriers to renewable energy deployment.

UMN formed the Butwal Technical Institute (BTI) in 1963 to train young people to work in hydropower and other industries. The four-year program includes six months of workshop instruction followed by an apprenticeship in both affiliated industries created by UMN and unaffiliated workshops (Leane, 1994; Durston, 1988). The first of these industries, the Butwal Power Company (BPC), was created to design, construct, and operate the 1-MW Tinau hydropower project to supply power to UMN's industrial and training center in Butwal. The plant—a demonstration project and a training exercise—was completed in 1978. BPC turned it over to His Majesty's Government of Nepal (HMGN) in 1980 (Durston, 1988). Meanwhile, in 1978 Himal Hydro and General Construction Pvt. Ltd. (HH)[25] was formed from the workforce that built the Tinau plant. The aim was to institutionalize the design and construction expertise developed during the project. In 1982, HH commenced work on the civil construction components of the 5-MW Andhikhola hydropower project. Like the Tinau plant, this Norwegian-financed run-of-river project was built using labor-intensive construction methods and local materials. Experience with this project encouraged the Norwegian government to finance construction of a 12-MW project, which commenced in late 1990. HH and BPC have also implemented projects for HMGN, UMN, and other NGOs (Himal Hydro, undated). From 1980 to 1990, staff size and project activity grew rapidly.

Butwal Engineering Works Pvt. Ltd. (BEW), an outgrowth of the BTI mechanical training unit, was also formed in 1978 to produce 10-KW to 40-KW micro turbines and other hydro- and irrigation-related steel products. Other firms were created on this model. While developing firms to implement projects and supply equipment for them, UMN also promoted development and dissemination of micro-hydro technologies. In recent years, UMN has shifted its focus to the 50-500 KW range as industrial capacity has become established in smaller plants. By the end of 1993, the Nepalese hydro industry that UMN and other donors had nurtured had produced over 680 (mostly 8 KW to 12 KW but up to 60 MW) turbines (McConkey, 1993).

UMN's electrification efforts have been aided by the government. In 1984, HMGN sanctioned "private" micro-hydro projects under 100 KW, eliminated licensing requirements for such schemes, and granted approval for charging unrestricted tariffs. In 1985, announcement of a 50-percent subsidy of the cost of electrical equipment for private rural electrification produced a rush of orders, but subsidies were discontinued the following year when the government experienced difficulties in dispersing them. Since then, the subsidy has been available only erratically (Mackay, 1992; Jantzen and Koirala, 1989). Government deregulation of micro-hydro projects of up to 1 MW in 1993 has stimulated private proposals for such projects (Leane, 1994).

Resources for small hydro development have come from diverse sources. UMN's major contribution has been the time commitment by expatriate engineers and other professionals for research and development, training, and technical assistance. HMGN, the Norwegian government, other donors, and the private sector provided capital to finance individual projects. HMGN and UMN provided NRs. 8 million for the Tinau project, for example; and the Norwegian government provided NRs. 60 million for the Tinau project and NRs. 250 million for later projects.[26]

Early successes and diverse funding notwithstanding, several factors still constrain small hydropower expansion by rural Nepalese. Knowledge about and access to existing markets is lacking, as are transportation and communication facilities for remote rural systems. More income-generating applications to finance systems are needed along with entrepreneurs to fully use such applications (Jantzen and Koirala, 1989). The GEF is currently considering a grant to establish a revolving fund for continued market expansion (Lovejoy, 1994). Otherwise, large schemes continue to dominate MDB-financed hydro development in Nepal—notably, a 402-MW project that is much too large to allow local industry participation any time soon and that may crowd out future private hydropower development (Pandey, 1994).

***Philippines***

To improve access to capital and create local capacity, Germany's GTZ helped the Philippines National Electrification Administration (NEA) and the local Cebu I Electric Co-operative (CEBECO I) implement the 720-KW Matutinao Mini-Hydropower Project, which was completed in mid-1990. GTZ gave a grant to finance design and construction and establish a revolving fund to finance similar mini-hydro projects. It also provided technical assistance to transfer mini-hydro design technologies and train local engineers in project design and construction.

The project was designed to maximize the use of local labor and materials so as to increase local economic benefits and minimize adverse environmental impacts. Ten Philippine engineers were trained through work on individual project components under the supervision of an expatriate GTZ hydropower specialist. To offer training opportunities for the engineers in project planning and site management, CEBECO I did all the construction work itself, instead of soliciting bids and negotiating and administering contracts with private firms and then mobilizing labor—a move that also saved time and money. Granted, the use of an inexperienced local labor force lengthened construction time but it developed human resources and provided local income. In addition, direct control over project implementation permitted engineers to substitute local labor and materials for mechanical and imported inputs in building the earthworks and other civil works. Similarly, local haulers were used instead of motor vehicles when the weir was constructed, obviating the need to build an expensive and environmentally intrusive access road. Indeed, overall design and operation support local tourism initiatives (PGSEP, 1992).

The project has resulted in a mini-hydro plant capable of generating 34.8 percent of the peak load and 43.8 percent of the annual energy requirements of the local electric cooperative, with apparently minimal negative environmental impacts. The plant produces electricity at a cost of 1.75 cents per KWh, and GTZ has calculated the project's internal rate of return at 21.9 percent. NEA has replicated this design and construction method in another mini-hydro project, and CEBECO I has independently decided to allocate a portion of plant revenues to finance local watershed protection (Scholz and Nation, 1992). However, NEA has not, as GTZ proposed, recycled plant revenues up to the amount of the GTZ contribution into a revolving fund to finance similar projects; the extent to which this project will be replicated is still unclear.

## BIOMASS

Agricultural or forestry residues, already used for cogeneration in several developing countries, are also the largest renewable power source produced privately. Use of residues could be expanded in most countries. For example, simply upgrading cogeneration equipment in the Indian sugar industry could add 2,000 MW to national capacity (*Biologue*, 1993).

Growing dedicated biomass feedstocks and generating power with them poses more complex technical, economic, and institutional issues. Such systems might, for example, involve feedstock producers who sell their output directly or through an intermediary to an independent power generator, who then sells the power to the grid.

### *Brazil*

CHESF, a federally owned utility in northeast Brazil, is interested in pursuing alternatives to hydroelectricity because its low-cost hydro resources will be fully exploited by the end of the century. A GEF grant is being used to mobilize local institutions to push biomass integrated gasification-gas turbine (BIG-GT) technology along a learning curve to cost competitiveness. Once the technology is successfully demonstrated, fuelwood plantations might be established to supply dedicated feedstocks, and bagasse and other agricultural residues used more efficiently (Elliot and Booth, 1993).[27] Potential annual generation from sugarcane processing facilities ranges from 6.1 TWh to 41 TWh, depending on assumptions, compared to the region's total 1990 electricity supply of about 31 TWh. Estimated costs range from 4.4 to 8.1 cents per KWh. The potential from stand-alone power plants fed by biomass plantations ranges from 735 TWh a year to 1,400 TWh a year. CHESF's parent company, ELECTROBRAS, has approved the sale of electricity from the demonstration plant (Carpentieri et al., 1992). While much of the initial equipment will be imported, the project addresses institutional capacity barriers at the early stages of technology development.

GEF grant support consists of $7.7 million already approved for UNDP-administered project preparation and $23 million to leverage private investment for a pilot plant. The initial project proposal was funded by Winrock International, Rockefeller Foundation, USEPA, and USAID.

Because the project's developers do not know the optimal configuration of BIG-GT technology, two distinct (high-and-low pressure) options are being kept open: two independent project teams are developing technology packages. After demonstrations are completed, a technology choice will be made based on gasification test results, thermal efficiency, simplicity of design, ease of operation, and potential for further cost and efficiency improvements.

The goal of halving the cost of a "first-of-a-kind" 25-MW to 30-MW plant requires optimizing capital and operating costs and reliability, replicating standard designs five to ten times, and arranging for preassembly with little on-site fabrication. To achieve these cost reductions will require surmounting both endogenous (technological and commercial) and exogenous (political and environmental) risks. Even if cost goals can be met in subsequent demonstrations, private equity will be needed for market diffusion. Equity participants might include utilities, portfolio investors, biomass producers, equipment manufacturers, or $CO_2$ producers in industrialized countries. Private investors are likely to require that industrial cogenerators be allowed to sell their excess power to utilities at the marginal cost of new generation[28] and that utilities and feedstock suppliers form partnerships. Potential damage to water quality, biodiversity,



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and soil quality must also be addressed before large land areas are converted to feedstock production. While already degraded lands are currently targeted, monoculture eucalyptus plantations developed elsewhere could damage biodiversity and other ecological functions (Bowles and Prickett, 1994).

***Mauritius***

As in Brazil, utilities in Africa have little experience acquiring power from agricultural processing industries. Mauritius has many such industries and it depends heavily on diesel generation, so average electricity tariffs were 11.4 cents per KWh in 1988. Against this backdrop, the World Bank and the GEF are financing a multi-faceted strategy to increase bagasse-generated electricity production in the island nation.[29] A World Bank loan is financing market diffusion of bagasse cogeneration equipment to improve sugar mill efficiency. A GEF-administered grant funds research on bagasse transport and cane residue cogeneration techniques, training Mauritian staff to operate this equipment and do R&D, and establishing international R&D collaborative arrangements. The project grant also supports development of a management committee for the Mauritian Bagasse Energy Development Program (BEDP), to be responsible in part for intra-governmental and government-industry market coordination. The project objectives are to expand bagasse-generated electricity production, encourage use of waste bagasse and mill improvements to increase bagasse availability for power production, promote biomass fuels through research and testing, and strengthen BEDP through technical and institutional support (World Bank, 1992c).

The demonstration component involves constructing a bagasse-cum-coal power plant at the Union St. Aubin Sugar Factory (USASF), connecting the plant to the Central Electricity Board (CEB) grid, and improving the steam generating units and processing equipment at approximately 12 other mills in order to free additional bagasse for power production at the USASF plant. The resulting 30-MW USASF plant is expected to produce 180 GWh per year, 170 GWh of which would be available to the national grid—thus eliminating the need to construct a new diesel plant. Annually, the USASF plant would burn 103,000 tons of bagasse (nearly half of it imported from other mills) and 81,000 tons of coal. Even with coal combustion during the sugar cane off-season, annual $SO_2$, $NO_x$ and particulate emissions are projected to be substantially lower than those from a comparable diesel plant (Trapman, 1994).

Technical training consists of 32 person-months of technical skills-building for the Mauritian USASF power plant operators, as well as training for the Mauritian Bagasse Energy Technology Study Team in how to evaluate the supply of cane residue available for additional power generation. An international workshop planned at the end of the study is intended to facilitate international coordination and collaboration in bagasse energy R&D and commercial applications. A parallel study of bagasse compacting and transport operations is designed to minimize both capital costs and the use of rural roads during peak periods. In addition, the project is designed to support development of a BEDP Coordination Unit by providing consultant and administrative services, training, and logistical support (for example, vehicles and office equipment). The Coordination Unit is to serve under the BEDP Management Committee (composed of representatives from relevant government ministries, parastatal agencies, and the private sector), which will integrate government policies affecting the sugar and energy sectors, and "ensure that the Government's policy directives related to BEDP are followed" (World Bank, 1992c).

Foreign investors are financing $23.1 million of the USASF power plant construction costs; the World Bank is providing $15 million for mill improvements; and local financing institutions, industry, and government are financing the remaining $13.7 million of power plant and mill-efficiency costs. The GEF grant is providing $1.6 million for the two technology studies, $0.6 million for the USASF and CEB staff-development programs, and $1.1 million for institutional support of the BEDP Coordination Unit and the environmental monitoring program.

This project could encourage diffusion of biomass cogeneration by providing industry with experience in sugar-mill cogeneration and a visible example of a privately owned plant, conducting broadly useful research on using biomass feedstocks, and establishing an institutional and policy framework in which cogenerated power can be profitably sold. To

displace diesel capacity, the project must interest private financiers in the power plant, train operational staff, and develop government-industry agreements for selling the power produced. Lengthy negotiations were required between the CEB and the private partner to agree on power purchase rates (averaging 7 cents a KWh) that would allow private investors an acceptable return, as well as on financial incentives for using bagasse in season and coal out of season. Now that the terms of the first joint venture contract have been settled (in late 1993), other sugar companies are more likely to plan their own cogeneration plants.



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# IV. LESSONS AND RECOMMENDATIONS

What does the assessment of overall trends in development assistance for renewables and of experience from individual projects teach? Some of the lessons summarized below are new; others were learned years ago by field practitioners but have yet to pervade development-assistance bureaucracies. All feed into the recommendations presented here on how assistance funds should be spent to best promote replication. Where it makes sense, the roles that various types of agencies should play are differentiated according to their comparative advantages while the importance of cooperation is stressed.

## LESSONS LEARNED

**1. Development assistance that is part of a comprehensive strategy for commercial development is more likely to result in technology diffusion than "one-off" projects.** Most early projects fell prey to one or more of these mistakes: a focus on immature or otherwise inappropriate technologies, insufficient duration and scope, or lack of a plan to develop commercial markets. Assistance agencies have more recently recognized that simply demonstrating a technology isn't enough to spur its widespread adoption. But though project design has improved, the other barriers inhibiting development of markets for specific renewable power applications have not been adequately addressed by donors.

Any technology's commercial development is a complex process, one that invariably involves investment in R&D, demonstrations, and market diffusion. Several technologies have been shown to generate power reliably from renewable resources in full-scale field tests, but they won't be widely diffused without improved marketing infrastructures (such as financing, service, parts), or cost reductions, or both. Markets are more likely to emerge and last when public programs focus on dismantling the barriers that prevent a technology from moving to the next stage of commercial development. Public or private efforts that ultimately result in sustained markets for renewables have been based on A-to-Z models of commercial development. In hydropower development in Nepal, for example, an incremental approach to manufacturing capability, access to credit, stakeholder partnerships, and attention to institutional capacity were an essential combination.

Forging linkages between electricity producers and consumers makes it more likely that products and services are designed, priced, and financed to meet local demands. Most rural initiatives in photovoltaics (PVs), for example, require some initial influx of capital to finance up-front equipment costs. Under the Enersol full-cost recovery model being implemented in the Dominican Republic and elsewhere, the number of systems installed continues to increase as the initial capital is recovered through loan or lease payments from end users. The U.S. Department of Energy (USDOE) PV project in Brazil relies instead on external capital inputs for additional installations. And while the GTZ hydropower project in the Philippines is similar in some respects to Nepal's hydro development, the lack of an ongoing financing mechanism makes large-scale replication less certain.

A related success factor is a donor commitment that is sustained long enough in a given location to catalyze commercial development and market diffusion. Implementing a commercialization strategy may require institution-building, training, or market-development activities, all of which take longer than traditional assistance projects that are limited to physical construction. PV programs in the Dominican Republic and elsewhere have now been operating for at least 10 years and their market penetration is still increasing. The private hydro program in Nepal has been operating for several decades. India has logged over a decade of experience in wind development. Only over several years can programs be built up incrementally and respond to feedback from stakeholders.

Finally, experience with wind and other renewable power projects suggests that economies of scale can be important in institution building. A single

small project may not justify investments in training and technical assistance. Because some minimum investment in institution-building is needed regardless of a project's power capacity, (especially given likely personnel turnover), projects that are replicated can better amortize this investment (T. Bak Jensen/PA Consulting Group, 1991).

Finally, even if individual projects are designed and implemented to incorporate the above success factors, the targeted technology's competitiveness may not improve much. At current costs, the market demand for declining cost technologies (like PV) in a single host country is often too small to overcome their "chicken-egg" problem.

**2. Growing private participation in power sector finance and management, though beneficial in several respects, is unlikely to boost the market share of renewable electric generation.** Even if renewables enter the mainstream of multilateral lending, concessional capital can influence only a minority of power sector investments. To make significant inroads in market share, renewable power options will need to attract a big part of the swelling private capital now flowing into developing-country power sectors.

Unless development assistance agencies more actively promote oversight mechanisms as part of power sector privatization, decisions over generation technologies will be biased toward fossil fuels. When donors encourage private over public financing, fossil fuel generation technologies, with their relatively low capital costs, are favored. In addition, the technical assistance offered to guide the development of national private power laws and regulations typically does not consider how these laws—and resulting power markets—can affect a country's choice of generating technology. For example, power-purchase policies are biased if they do not fully credit the value of renewably produced power when periods of high utility costs coincide with periods of peak output from a wind farm, solar plant, or sugar cogeneration facility. Decisions based simply on lowest per kilowatt hour cost can similarly be misguided if, for instance, environmental costs and fuel price and construction risks are ignored. Contract terms between utilities and private power developers (i.e., payment schedule, dispatchability requirements, and terms of transmission access) may also affect generation choices.

**3. Improving local capacity for commercializing renewable technologies is critical for stimulating sustainable markets.** The most successful of the diverse projects reviewed in Chapter III directly involve key in-country stakeholders in project implementation. In many cases, equipment is marketed and serviced by local entrepreneurs, while imported system components must be used because their technical complexity or market entry cost prohibits local manufacture. In fewer cases, in-country producers have also adapted the technology to perform better under local resource conditions, meet local energy service needs, or reduce system costs. For example, hydro turbines are fabricated in Nepal and wind turbine towers manufactured in India. In contrast, the Moroccan wind project was characterized by little local stakeholder training, involvement, and accountability.

The extent of local involvement (and, correspondingly, the amount of a project's total value that is created locally) varies considerably among countries. PV modules are imported to the Dominican Republic and Kenya, for example, while in Zimbabwe and Sri Lanka, modules are manufactured in-country using imported cells (Hankins, 1993). Local value-added may increase as a country's scientific, engineering, manufacturing, and marketing capabilities grow, or as market size increases. For example, national PV markets must grow beyond about 5 MW per year before it makes sense to establish indigenous cell-manufacturing facilities, though smaller markets may justify module assembly or component manufacturing (Maycock, 1993). Nonetheless, when assistance projects maximize the potential for using local inputs for design, construction or manufacturing, marketing, and maintenance, the employment and income gains are likely to prompt stakeholders to organize. Such constituencies in India, Costa Rica, and elsewhere have lobbied successfully for national policy reforms that improve the market for renewables (D'Monte, 1993; ACOPE, 1992). By the same token, local communities are more apt to accept adverse land-use impacts from a utility-scale renewable project if they also reap some of its economic benefits.

In this era of shrinking development assistance budgets and increased global competition, political pressure to promote donor country exports is growing. Not surprisingly, though markets for PVs are expanding most rapidly in developing countries, PV manufacturers in these nations have been losing ground in world market share since 1987 (Maycock, 1994). When project aid is tied, goods or services in which the donor country has a comparative advantage are likely to be used. However cost effective at first blush, their use may not serve the recipient country's development priorities optimally. For example, in Tanzania's donor-driven PV "market," post-project maintenance of equipment is complicated by competing bilateral programs.

> Scandinavian development workers buy equipment from Scandinavian countries, Italian missionaries buy from Italian companies, American Peace Corps buy from American companies and the British buy from the British...Getting a contract is more important than developing the local industry. There are so many different types of controls, lamps, modules, wiring systems, pumps, and inverters that the local technician has little chance of making sense of the situation (Hankins, 1994).

If mostly imported equipment is used, technical capacity-building can go by the way too (as in the Brazilian PV and the Philippine and Kenyan geothermal projects). In addition, the potential foreign exchange savings of renewables (particularly important whenever fossil fuels would have to be imported) become increasingly diluted as post-project component imports increase. For example, an import-intensive wind project whose returns are less than international lending rates may not reduce a country's foreign exchange requirements (T. Bak-Jensen/PA Consulting Group, 1991). Moreover, local importers may not be able to mobilize enough foreign currency to make bulk purchases to keep unit prices and duties down. If importing components is inhibited by foreign currency shortages, devaluation of local currency, or, for that matter, customs bottlenecks, local prices increase and diffusion is hampered.

**4. Local conditions determine what institution is most appropriate to deliver renewably-generated electricity services.** Experiences with various technologies defy easy generalizations about whether local utilities, communities, cooperatives, government agencies, nongovernmental organizations (NGOs), or private developers would be best suited as the primary local partner for transferring a given technology in a given country. In several projects reviewed in Chapter III, utilities have been partners in renewable power generation (Brazil, India, Kenya, Philippine geothermal development, and Mauritius), whereas in Nepal and the Dominican Republic alternative institutions were deemed more appropriate. The Philippine hydro project was implemented largely by a local electric cooperative, while the Nepal hydro industry has developed privately. In contrast to the success of Nepal's private hydro development, small hydro schemes implemented by the Nepalese government have not been based on commercial viability, did not adapt imported technology sufficiently, and relied on centralized management—all of which led to revenue shortfall, operational problems, overstaffing, and lack of local accountability (Cromwell, 1992).

What about off-grid electricity services? Conventional wisdom—borne out by Enersol's experience—is that local nonutility organizations are most appropriate. In the Enersol model, which has been adopted in some form by NGOs working in China, Sri Lanka, and other countries, either new institutions for financing and marketing are created, or local NGOs and small businesses are helped to take on the financing and marketing of PV systems. The Dominican utility, the Corporación Dominicana de Electricidad (CDE)—a natural partner for Enersol—was almost completely inactive in rural electrification during the late 1980s and early 1990s due to its bias toward other activities as well as to the large-scale deterioration of generation and management capacity (Doernberg, 1993). Collaboration was also hampered by heavy mid-level administrative turnover within CDE.[30]

Utility participation, or at least coordination with other organizations, should not be overlooked either. DOE has found Brazilian utilities stable, independent, and technically expert enough to implement the PV project and, building on technical success, to expand project activity. Out of six institutional models for providing power to the Pacific Islands (characterized by low population density and skill level), a utility-of-

fered fee-for-service model is thought most likely to succeed (Liebenthal et al., 1994). An off-grid PV project in Indonesia also depends on utility involvement. The advantages of utility participation include their access to comparatively cheap capital (which reduces the cost of financing off-grid projects), and an in-house pool of engineering expertise. Participation in off-grid electricity services also confers an advantage to utilities. Because utilities that subsidize rural power tariffs are increasingly hard-pressed to make up revenue shortfalls, they stand to gain financially when extending rural service with an off-grid renewable power system costs less than extending the grid. Recovering the costs of off-grid systems may also be easier for the utility than collecting tariffs for power from the grid since electricity theft and the need for metering may be obviated. Moreover, because many nominally grid-connected villages receive only intermittent power and many homes in such villages remain unconnected, developing even a nondispatchable renewable power system may be more cost effective than investing in grid extension. Finally, renewable projects may offer a unique niche for public utilities left with under-used human resources as conventional power development shifts to the private sector.

**5. Even if renewable energy assistance projects are well-designed to address other barriers, project funds may be squandered in countries with severe power-sector distortions.** Fuel and electricity subsidies can adversely affect the competitiveness of renewables. Rate structures that do not make customers pay more for power during peak demands or at remote locations may also bias end-user decisions against off-grid renewables. Similarly, renewable power options are unlikely to figure easily into capacity expansion plans when commonly used power sector planning models and analytic tools do not take account of characteristics that distinguish renewables from conventional power options.

Multilateral development banks (MDBs) have historically set the standard for capacity-expansion planning. Local power sector policy-makers, therefore, can hardly be expected to adopt improved approaches until lenders get their own house in order. For example, a continuing focus on isolated generation, transmission, or distribution projects will be at the expense of opportunities for renewables (such as grid-connected distributed applications) that require more comprehensive analyses of entire power systems and demand patterns. In addition, planning methodologies that do not quantify the financial risks (such as construction time and cost overruns) associated with various generating technologies shortshrift the flexibility that renewables afford in system expansion. It has taken a Latin American energy research group (OLADE) to modify the World Bank's planning tool to better account for uncertainty, irreversibility, and small-scale power supply options.

## RECOMMENDATIONS FOR FUTURE ASSISTANCE

As in other areas of international assistance, renewable energy projects should be designed to be more consistent with clearly stated objectives, project evaluation must be accorded higher priority, and various assistance organizations should make better use of their respective comparative advantages. Beyond these truisms, the lessons underscore the importance of more specific changes in how international assistance for renewables is provided.

**1. International donors and lenders need to "mainstream" applications of renewable technologies that are already often cost competitive.** While making some progress (by, for instance, lowering financing threshholds), multilateral development banks, as well as agencies that lend to the private sector, have not yet "mainstreamed" renewables in their lending portfolios. Averaging only a few percent of MDBs' power-sector lending portfolios, renewables do not yet command attention commensurate with their potential market shares in—and benefits to—developing countries. Such initiatives as the World Bank's Asia Alternative Energy Unit, the FINESSE (Financing Energy Services for Small-Scale Energy Users) program, and the International Fund for Renewable Energy and Efficiency were designed to help, but they need more resources and support at all levels within the institutions they seek to influence. For example, senior MDB managers should supplement positive policy statements on renewables with explicit operational directives requiring project managers to use state-of-the-art planning processes

and investment criteria that fully account for renewables' potential benefits in project prefeasibility studies. In the face of top-down pressure to minimize loan preparation costs, project managers must be given positive incentives to fully evaluate small-scale or unfamiliar technologies. At the same time, technical assistance should strengthen capacity within developing countries for both preparing their own project proposals and evaluating those from private developers. Furthermore, to help private developers get over the hurdle of renewables' high capital-intensity, agencies such as the IFC and bilateral export-import banks might extend favorable financing terms to renewable power generation projects.

Creating a level playing field within which financing institutions consider proposed generation projects is not enough, however. The need for development assistance to shift from supply-push to demand-pull approaches for renewables will grow as the private sector role in electric generation financing and management increases. If development assistance for renewables continues to focus on individual projects, private developers will constantly be constrained by a country's power sector policies. Assistance agencies should better coordinate their privatization and renewable energy activities. Technical assistance should be used to help ensure that national private power policies are crafted to treat all sources of generation fairly.

**2. Multilateral and bilateral agencies and developing countries should implement cooperative strategies for technology commercialization.** Aside from the globally-shared risk of climate change, why should commercialization strategies be internationally coordinated? First, OECD countries as a group have greater financial and technical resources, while developing countries generally have greater potential for renewables to gain market share: resource quality is high, power demand is growing rapidly, power from conventional sources is costly, and high value niche (such as off-grid) applications are numerous. Second, the investments necessary to fully commercialize a single technology (as much as $12 billion for PVs) appear beyond the reach of individual OECD governments or firms.[31] If, however, many countries pooled and jointly administered their resources, specific cost and scale-up targets would be easier to achieve. Third, an internationally coordinated program could more effectively exploit the potential synergism between technology-push (i.e. subsidized R&D and demonstrations) and market-pull (i.e. market entry subsidies, guaranteed markets) activities than individual efforts could.

In its own efforts to create a market-pull, the United States has accumulated experience with technology-specific models of cooperation between utilities and equipment suppliers. (Depending on technology, costs can be reduced by expanding market volume, standardizing design, or gaining experience in manufacturing and installation.) One such model is a utility consortium that issues requests for competitive bids for an aggregate quantity of a particular technology with certain specifications. By pooling individual utility needs, the consortium could generate threshhold annual sales to interest manufacturers in investing in new production capacity. In one version, early utility participants would get rewarded for taking risks: if commercialization is successful, they get royalty payments on future sales of equipment (Kozloff and Dower, 1993).

Expanding such models of utility-supplier cooperation internationally offers scale advantages since similar renewable resource and electricity demand characteristics are found in many (not necessarily contiguous) regions. Technologies that exhibit steeply declining costs with increased output and experience are excellent candidates for a coordinated multilateral program that could:

- match the technology with renewable energy resource characteristics in both OECD and non-OECD countries;
- help utilities and other would-be developers identify appropriate applications for the technology;
- structure individual countries' needs into an aggregate stream of orders;
- issue a competitive notice for bids from potential suppliers in any country; and
- award contracts based on a maximum allowable price that would decline over time.

For close-to-competitive technologies, program costs would be limited largely to the transactions costs associated with market aggregation. For less mature technologies, the program would also bridge

the temporary gap between a low bid and the maximum price per KWh that purchasers are willing to pay. Since U.S. initiatives have been helped by the "herd instinct" among domestic utilities, an international program would need to address the relative heterogeneity and **lack** of communication among utilities in different countries. Another challenge, which the GEF already faces, is to avoid creating incentives for utilities to exaggerate incremental costs.

No existing multilateral institution is ready to play such a catalytic role in commercial development: While the UN Commission on Sustainable Development was created in part to coordinate UN programs, it has yet to do so and non-UN players also need to be involved. Despite its recent solar initiative, the World Bank remains unsure of its role in technology commercialization. The FINESSE program, which bundles many small projects into a single package for MDB funding, is still too small to achieve major economies of scale in equipment production. The GEF's activities come the closest to the mark, but its current resources and mandate (limited to projects in developing countries) are not, by themselves, up to it. Instead of a new agency, a program with earmarked capital should be added to the GEF, the International Energy Agency, or the United Nations. According to some proposals for coordinating commercialization of renewable energy technologies, the Consultative Group for International Agricultural Research (CGIAR) should be considered as an institutional model.

**3. Donors should give higher priority to long-term strategies for building markets for renewables than to competing for exports.** As long as demand for renewable power from utilities and other electricity service providers in developing countries remains weak, export markets will be constrained. In bilateral assistance programs, the emphasis on near-term market share should give way to the promotion of long-term demand for renewables. To determine which exports are most compatible with sustainable development, donors should first assess the capacity of in-country institutions and stakeholders in delivering renewable energy services. Depending on the stage of market development, software or hardware exports may be needed for resource assessment, siting, economic and environmental analysis, grid integration, or organizational development.

Multilateral agencies (such as the Energy Sector Management Assistance Program) and bilateral agencies already help developing-country utilities improve their financial performance, operations, and management by giving technical assistance and by facilitating collaborative linkages with OECD utility experts. But little attention has been paid to how the choice of generating technology affects environmental or financial performance. Technical cooperation efforts should adapt state-of-the-art planning and evaluative tools developed in the United States and elsewhere to help developing-country utilities compare distributed vs. central station, grid vs. off-grid, capital vs. fuel intensive, and intermittent vs. dispatchable generation options. Utilities, independent power producers, and state utility regulators in the United States have accumulated substantial experience in designing and implementing renewable power pilot programs, analytic tools, and economic incentives.[32] Several such utilities have independent power subsidiaries operating in developing countries that could share expertise accumulated with renewable technologies.

In countries with enough market demand to support indigenous production, assistance should "move upstream" to promote the development of production capability, perhaps by exporting production licenses. One model for technology cooperation is the joint venture, with its long-term commitment to business development, training, and continued technological adaptation and improvement (Khatib, 1993). As early as 1982 workshops on renewable energy in developing countries, participants recommended that "international development assistance agencies establish programs to encourage joint ventures between Northern firms offering energy management, [and] renewable technology integration with conventional energy systems, and...developing-country engineering and consulting firms" (Bartlem, 1984).

Joint ventures may be initiated by firms in the North or South. One U.S. firm, Integrated Power Systems, solicited a local partner for a joint venture to develop village power systems among Indonesia's eastern islands. The Brazilian PV producer Heliodinamica has also sought such a partner. Northern firms can greatly benefit from such ventures, espe-

cially when the technology must be adapted to local conditions and close coordination with local stakeholders is needed.

Help for exporting firms that want to enter foreign markets may be appropriate if their products already have a clear comparative advantage, but bilateral donors should recognize that close integration of development assistance with export-promotion functions can threaten the adaptation and diffusion of technology. Donor incentives to implement short-term projects must be countered at the policy level by senior management.[33] Donors should shift the focus of project evaluation from short-term outcomes to indicators of local capacity for market diffusion. For example, instead of equipment performance and number of households served, better indicators of success would be the number of firms involved in producing or marketing goods and services and the presence of local financing. Such reforms are unlikely in the absence of international coordination to prevent a donor country from taking unfair advantage of another's policy.

**4. Multilateral and bilateral assistance agencies should target programs for renewable energy preferentially to countries whose policies allow renewables to compete fairly with other technologies.** No country should receive assistance for renewable energy development unless electricity rate structures and fossil fuel prices reflect marginal costs of production or, at least, national commitments to completing such reforms appear irreversible. (Instituting countervailing subsidies for renewables is no substitute for energy price reform.) Similarly, assistance programs for renewables should target countries that have implemented sectoral reforms that promote fair competition, including requirements to purchase electricity from nonutility sources (industry cogenerators, private power producers, cooperatives, and individuals) at true avoided costs. Required reforms should also include an analysis of how off-grid options can be integrated with conventional rural electrification. Finally, utilities or other implementing organizations should be required to involve local people in project planning and mitigating site impacts.

In addition to unbiased power sector policies, donors should target countries with trade policies that allow renewable technology markets to develop. Policy reforms may be needed in import licensing, foreign exchange controls, duties, and nontariff trade barriers that adversely affect imports of renewable generating equipment. Moreover, donors will be reluctant to expand exports of intellectual property to developing countries if legal protection against piracy is weak.

Targeting development assistance to certain countries requires multilateral coordination. Without it, bilateral donors might undermine other donors' reform efforts by offering similar assistance without attaching conditions (Foley, 1991). The World Bank and OECD should establish standards for sectoral reforms and encourage cooperation among bilateral and multilateral donors working in developing countries. Assistance programs that work with the private sector (such as the International Finance Corporation and bilateral export-import banks) should use the same standards as those working with public agencies.

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# NOTES

1. This report's focus on electric generation technologies is not intended to detract from the importance of nonelectric renewable and energy efficiency technologies to sustainable development.
2. This scenario is representative of other "business as usual" projections.
3. The use of geothermal resources, while not based on solar energy, would further boost the market share of "renewable" power in this scenario. On the other hand, this scenario is even more optimistic than accelerated supply scenarios by other analysts (World Energy Council, 1993b; Swisher, 1993).
4. While their severity and causes may differ, these barriers are not unique to developing countries. (*See*, for example, Kozloff and Dower, 1993.)
5. For an Indian utility, intermittent renewables could comprise 25%–30% of total system capacity without jeopardizing reliability (Hossain, 1993).
6. The Conference considered hydropower, draft animal power, solar, wind, biomass, fuelwood, geothermal, ocean energy, peat, tar sands, and oil shale.
7. In contrast to investments in fixed capital, donors are not required to report technical cooperation expenditures. These data are thus approximate.
8. ASTAE implements the Asia portion of FINESSE (Financing Energy Services for Small-Scale Energy-Users), a project initiated in 1989 by the World Bank Energy Sector Management Assistance Program (ESMAP) with funding from the U.S. Department of Energy (USDOE) and the Netherlands Ministry of Development Cooperation (DGIS). FINESSE is intended to promote affordable alternative energy services with an initial focus on Indonesia, Malaysia, the Philippines and Thailand.
9. Here, cost effectiveness is a function of a renewable generation technology's incremental cost and lifecycle carbon reductions relative to some baseline power source.
10. U.S. Treasury Department officials calculate that, for every dollar the United States contributes to MDBs, U.S. exporters win back more than $2 in procurement contracts (Chandler, 1994).
11. The United States, which has used tied-aid credits less than several other major donors, has successfully sought stricter OECD rules to lessen commercial advantage from their use (Baldwin et al., 1992).
12. Member agencies include USAID, the Export–Import Bank (Eximbank), the Office of the U.S. Trade Representative, the Overseas Private Investment Corporation, the Small Business Administration, the U.S. Information Agency (USIA), the Environmental Protection Agency, the Trade and Development Program, and the departments of Energy, Commerce, Interior, State, Treasury, and Defense.
13. Biomass, geothermal, small hydropower, photovoltaic, solar thermal, and wind energy technologies are eligible for support.
14. Diesel technology may be particularly unforgiving if proper operating procedures and maintenance are neglected.
15. Rural electrification benefits tend to be overstated and skewed toward higher-income classes. (*See*, for example, Del Bruno, 1993; Schramm, 1991; Foley, 1990; Mason, 1990; and Pearce and Webb, 1987.)
16. Although these 11 cases cannot be formally generalized, the factors contributing to their success or failure are broadly consistent with studies of other energy projects. (See, for example, Foley, 1994; and Barnett, 1990.)
17. Heliodinamica has made cells and marketed modules since 1982 and has installed over 20,000 systems, with 1993 shipments totaling 0.5 MW (Maycock, 1994; Hankins, 1993). It has begun a home lighting campaign by distributing display lighting kits to farm stores across the country and is arranging for financing and distribution through a utility. The company is seeking an infusion of private capital to expand its output and become more competitive. Brazil has reduced PV import tariffs from 40 to 20 percent.



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18. Due to initial limited capitalization, revolving fund credit has been used for only approximately 20 percent of the systems purchased from Enersol-associated installers. Most customers have been small entrepreneurs, individuals receiving remittances from relatives in the United States, or others with enough savings to pay cash.
19. Domestic car batteries are of lower quality than imported deep-discharge batteries, on which the government imposes 100 percent duties. Countrywide power shortages in mid-1988, in conjunction with political factors, prompted import-duty exemptions for electrical generators (including batteries and PV equipment). Duties were reinstated several years later, however, after the exoneration legislation expired.
20. Had its capacity rating been higher, the project's present value would have been greater, but the thermal resource would become exhausted more quickly. The 440 MW project is the second phase of geothermal development on Leyte; the first was a 200 MW project.
21. The technology is in use in Italy, Iceland, New Zealand, and the United States. Except for a small plant in Thailand and the Leyte-Philippines project, the technology had not been used in Asia.
22. This is measured by a declining ratio of locally produced value to total project value.
23. A 10-MW farm in Gujarat and 4 MW and 6 MW farms in Tamil Nadu.
24. Besides concessional financing from the Indian Renewable Energy Development Agency, wind and other renewable projects are eligible for a 100-percent depreciation allowance, tax holidays, and low import duties.
25. Owned 25 percent by HMGN and 75 percent by UMN.
26. As of September 8, 1994, 1 NR = $0.02.
27. Potential exists for 2,700 MW of capacity from sugar industry cogeneration in Brazil.
28. Even though national legislation now opens up generation to private developers, utility payments for power are the subject of continuing disagreement (Moreira, 1994.)
29. Both projects use agricultural residue feedstocks, but the gasification technology being developed in Brazil is more advanced than the cogeneration technology used in Mauritius.
30. In fact, Enersol faces a four-year business cycle since politicians promise grid extension just before national elections, dampening local interest in purchasing systems until after elections are held. A for-profit Enersol spin-off now leases PV systems mounted on poles, which reduces the sunk cost risk facing users if the grid is actually extended to their village.
31. According to one estimate (based on relationships between the cost and cumulative global output of PVs), a present worth investment of $12 billion would reduce to seven years the time for PVs to become competitive with grid power (Williams and Terzian, 1993).
32. For example, a barrier to greater use of renewable technologies is the high cost of identifying and evaluating distributed generation. Screening tools being developed for U.S. utilities are designed to seek standard information available to utilities, remain valid for several years, use standard techniques where possible, and focus evaluation at the planning level in which large investment decisions are actually made (Heffner, 1994, Shugar, Wenger, and Ball, 1993). Such screening tools are likely to require modification, given the analytic abilities and data constraints of developing-country utilities.
33. These incentives can include political pressure to promote exports of goods and services from donor country firms and the pressure on program managers to show immediate results. Resisting them may be a bigger problem for bilateral donors than for NGOs.

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