POLICIES FOR A MORE SUSTAINABLE ENERGY FUTURE

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October 1999

Report Number E992

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Executive Summary

World energy use has increased ten-fold since 1900 and more than four-fold since 1950. During the past twenty years, world energy use grew on average about 1.7 percent per year. This rapid growth in energy use during the 20th century helped to propel industrialization and economic growth. It also provided expanded levels of energy services and a wide range of amenities for a large fraction (but not all) of the world's growing population.

If current energy policies and trends continue along with fairly robust economic growth, it is estimated that global energy use will double from its 1990 level by about 2025, triple by 2050, and further rise in the latter half of the 21st century. The majority of this growth is expected to take place in developing countries, which could pass industrialized countries in total energy use by around 2025. This level of energy use growth, around 2.5 percent per year in the near term falling to 1.0 –1.4 percent later in the century, could present a variety of problems and challenges for mankind including

- High capital investment requirements
- Local environmental degradation
- Increased greenhouse gas emissions and global warming
- Increased oil import dependency in many nations
- Ignoring needs of the poor

For these reasons, a business-as-usual energy future is not desirable. Nor is it inevitable. By emphasizing energy efficiency improvements, renewable energy options, greater utilization of natural gas, and the needs of the poor, all of the problems listed above can be mitigated. However, energy efficiency, renewable energy (excluding large-scale hydropower), and clean, innovative fossil fuel technologies face a host of barriers limiting their introduction and deployment throughout the world (see Table ES-1). Some of the barriers will shrink as these technologies gain acceptance and market share; others are likely to persist unless directly confronted and reduced or removed through policy interventions.

Energy Policy Options

There is no "silver bullet" for overcoming the barriers listed above, for moving away from business-as-usual energy trends and moving towards a more sustainable energy future. Many policy instruments are available and are needed for overcoming the multiple barriers that exist.

Table ES-1: Barriers to the Adoption of Energy Efficiency and Renewable Energy Technologies

Energy Efficiency	Renewable Energy
• limited product availability	• limited infrastructure
• lack of information and training	• lack of adequate production scale
• uncertainties	• information barriers
• high transaction costs	• risk
• split incentives	• lack of attractive financing
• purchasing procedures & habits	• pricing barriers
• bounded rationality	• technical barriers
• lack of money or financing	• regulatory & fiscal barriers
• pricing barriers	
• policy & regulatory barriers	

RD&D. Research, development, and demonstration (RD&D) is critical for maintaining the pipeline of innovative energy supply and end-use technologies. Government-funded RD&D has helped to advance a number of energy efficiency and renewable technologies during the past twenty years, e.g., wind turbine innovations, electronic lighting ballasts, high-efficiency appliances, and new window technologies (to name just a few). In performing energy RD&D, partnerships between universities and other research institutions and the private sector have been especially productive. Greater international cooperation in energy technology RD&D could have a wide range of benefits including cost and risk sharing, faster learning, increased access to global markets, and better prospects for rapid deployment of innovative technologies worldwide.

Financing. Financing at attractive interest rates is critical for the successful diffusion and market sustainability of end-use energy efficiency and renewable energy technologies. Traditional lenders such as national development banks or private banks have been reluctant to provide loans for these technologies because of small project size, unfamiliarity with the technologies, and other considerations. Innovative credit schemes are facilitating the adoption of off-grid household solar photovoltaic (PV) systems in a number of countries. Third-party financing, usually without subsidies, has been a key part of the energy service company (ESCO) industry now well-established in North America. The adoption of a small charge on all electricity sales (known as a public benefits or systems benefit charge) is one way to help finance investments in energy efficiency and renewable energy sources, as well as provide incentives and support RD&D. The charge is usually a few percent or less of the total electricity price.

Financial Incentives. Financial incentives can help to get new technologies established in the marketplace, encourage early adopters, scale up production levels, improve performance, and reduce costs. This process is often termed "driving costs down the learning curve." There are many examples of incentive programs for energy efficiency and renewable energy technologies. In designing financial incentives, experience shows that is important to: (1) select technologies that have good prospects for competitiveness and viability in the marketplace once they are well-established; (2) use incentives strategically to move particular technologies down the learning curve; (3) leverage available incentive funds and set incentives to match incremental costs on a life-cycle basis; (4) phase out incentives as technologies gain market share and drop in cost; and (5) reward performance in order to minimize "free riders" and maximize energy supplied or saved, not dollars expended.

Pricing Policies. Low energy prices diminish incentives for using energy more efficiently or substituting cleaner, low carbon or renewable energy supplies. It is desirable to price conventional energy resources to reflect not only direct costs but also indirect costs due to environmental and social "externalities." Many (but not all) nations recognize the broad costs associated with personal vehicle use and consequently heavily tax gasoline. This has contributed to much lower dependence on automobile use in Europe compared to North America. Five countries—Denmark, Finland, the Netherlands, Norway, and Sweden—have enacted taxes on carbon emissions or fossil fuels as part of a revenue-neutral tax shift strategy. Taxes on carbon emissions or fuel use are offset by reductions in other unpopular taxes such as personal income or employment taxes. In some cases, a portion of the tax revenue is targeted for funding energy efficiency and renewable energy programs. Net metering is another pricing policy that can be used to encourage renewable electricity generation. Customers who produce more electricity than they can use feed the electricity into the grid and run their meter backwards, thereby selling power to the utility at the retail price rather than wholesale price.

Testing, Labeling, and Voluntary Agreements. Setting up appliance and equipment testing laboratories, test procedures, and testing and labeling programs can be useful for informing consumers about the relative energy efficiency of different products. This strategy enables labeling and promotion of the top products available at any particular time, e.g., as is being done through the ENERGY STAR® labeling program in the United States. Voluntary agreements between governments and the private sector establishing energy efficiency improvement targets for manufactured goods or industries have been adopted in a number of countries. The Netherlands, for example, has implemented a relatively successful program involving agreements with industries for reducing the average energy intensity of manufacturing (see case study). In Thailand, a voluntary agreement among the government, a utility, and manufacturers succeeded in phasing out less efficient fluorescent lamps. Voluntary agreements of this type can be easier to adopt than mandatory regulations. On the other hand, voluntary agreements are not legally binding and consequently the targets may not be achieved.

Codes and Standards. Minimum efficiency standards either remove the least efficient products from the marketplace, leaving consumers to choose from an array of more efficient products with other desired options and features, or require that all new products meet a certain efficiency level on average. By making more efficient products the norm, economies of scale occur and the cost per unit of energy savings is reduced. In addition, efficiency standards can provide market pull for new technology. Minimum efficiency standards have been successfully adopted in a number of countries for mass-produced goods such as cars, domestic appliances, heating and cooling equipment, motors, and lighting products. Most industrialized countries and some developing nations have adopted building energy codes that specify minimum energy efficiency requirements in new residential and commercial buildings. Experience has shown that training, monitoring, and enforcement are important for maximizing the impacts of building energy codes.

Information, Education, and Training. Many governmental and utility energy efficiency programs include information dissemination through energy audits and dissemination of printed materials. Evaluations of these efforts often show that information dissemination, by itself, results in limited energy savings. Information programs are more effective when combined with other initiatives such as financing, incentives, direct installation services (e.g., through ESCOs), or standards. Information and training also can be important for promoting renewable energy. Informing consumers about the sources of power they are purchasing and the levels of pollution being emitted can lead to greater consumer demand for cleaner power sources. And training is critical for successfully disseminating small-scale solar water heating, photovoltaic power, and other renewable energy devices.

Procurement Policy. Large-scale purchases by government authorities and/or the private sector can help establish a market for new clean energy technologies, as well as save the government money on a life-cycle basis. Governments—federal, state, and municipal—buy large numbers of lamps and other lighting products, air conditioning equipment, motors, vehicles, appliances, etc. Governments own large numbers of buildings that can serve as users of building-integrated renewable technologies, fuel cells, etc. And governments can purchase "green power" with a high renewable energy content. In the United States, for example, if federal facilities obtained just 1 percent of their electricity from photovoltaic cells, they would utilize 334 megawatts (MW) of PV capacity—more than six times the capacity produced by the U.S. PV industry in 1997.

Market Obligations and Reserves. Utilities can be required to supply or purchase a specified amount of renewable-generated electricity, expressed as either a fixed amount of capacity or a percentage of total electricity sales. In the United Kingdom, the government mandated that utilities acquire 1,500 MW of renewable capacity by 2000 through a series of auctions—a policy known as the Non-Fossil Fuel Obligation (NFFO). The auctions, starting in 1990, have led to increasing amounts of capacity proposed and steadily declining prices for the winning bids. Providing long-term concessions to renewable energy developers in off-grid rural areas is another type of market reserve that could boost renewable energy use. Argentina, for example, is using this approach to promote renewable energy use and electrification in rural areas. Market obligations and reserves also can be used to stimulate commercialization of advanced vehicle technologies, as California is doing with electric, fuel cell, and other very low emissions vehicles.

Planning Techniques. Energy planning can be used to develop focused or comprehensive energy efficiency and/or renewable energy strategies. To be successful, energy plans should contain achievable goals, and measures and actions adequate for achieving the goals, as well as monitoring and evaluation procedures. Integrated resource planning (IRP) is a process whereby a planning authority identifies the mix of supply and demand-side resources that meet energy service needs at the lowest cost. IRP uncovers the largest and most cost-effective energy savings opportunities, often prompting policymakers to increase support for energy efficiency efforts. Better urban and transport planning also is needed to reduce urban congestion, improve air quality, reduce transport energy use, and reduce the cost of mobility. Integrated land use and transport planning can lead to more efficient land use patterns and greater reliance on public transit systems, as exemplified by Curitiba, Brazil.

Case Studies of Market Transformation

The individual policies described above were successful in some instances but were more likely to have a significant impact when implemented in combination. It is often necessary to reduce or remove a number of these barriers using a "policy-assisted, market-oriented approach" in order to achieve large-scale results and ultimately transform energy markets. This integrated approach often consists of both "technology push" through RD&D and "demand pull" through consumer incentives, procurement initiatives, market reserves, etc.

A market transformation approach attempts to make the energy efficiency or renewable energy technology or practice the norm through a set of coordinated market interventions. This type of approach has led to deployment of energy efficiency or renewable energy technologies in a number of countries, as illustrated by the following case studies.

Brazil: Ethanol Fuel. Brazil has one of the largest renewable energy programs in the world—production of ethanol fuel from sugar cane. As of 1997, ethanol provided about one-third of the fuel consumed by cars and light trucks in Brazil. Production of ethanol was stimulated through: (1) low-interest loans for the construction of ethanol distilleries; (2) guaranteed purchase of ethanol by the state-owned oil company at a price considered adequate to provide a reasonable profit to ethanol producers; (3) pricing of neat ethanol so it is competitive if not slightly favorable to the gasoline-ethanol blend; and (4) tax incentives provided during the 1980s to stimulate the purchase of neat ethanol vehicles. Guaranteed purchase and price regulation were ended recently, with relatively positive results. In addition to these other policies, ethanol producers in the state of Sao Paulo established a research and technology transfer center that has been very effective in improving sugar cane and ethanol yields.

Brazil: More Efficient Electricity Use. Brazil's national electricity conservation program (PROCEL) promotes end-use electricity conservation through projects in the areas of RD&D; education and training; testing, labeling and standards; marketing and promotion; private sector support; and implementation in partnership with utilities, states, municipalities, and businesses. PROCEL has saved about 5.3 terawatt-hours (TWh) per year as of 1998, equivalent to approximately 1.8 percent of total electricity consumption in Brazil. This level of electricity savings has enabled utilities in Brazil to avoid around $3.1 billion of investment in new power plants and transmission and distribution (T&D) facilities. In contrast, PROCEL and its utility partners spent about $260 million on energy efficiency and power supply improvement projects during 1986–98. The primary areas of electricity savings include: efficiency improvements in new refrigerators and motors; growing markets for energy-efficient lighting technologies; reducing electricity waste in industries; and installing meter in previously unmetered households.

China: National Energy Efficiency Program. In the early 1980s, China began a national energy efficiency program focused mainly on industrial energy use. The program included regulations, mandated reductions, and a monitoring system for industrial facilities; an energy efficiency financing scheme; and support for RD&D. By 1983, over 10 percent of China's energy investments were in energy efficiency. Energy demand growth during 1981–86 fell to half that of economic growth. Additional policies implemented in the late 1980s included: creation of energy conservation service centers; energy intensity standards for boilers and kilns; more favorable terms for energy efficiency loans; and allowing firms to retain the financial benefits of energy savings projects. This comprehensive energy efficiency program was extremely successful—China's overall energy intensity fell by more than 50 percent between 1980 and 1997. Part of this reduction was due to structural shifts, but most was attributed to technical efficiency improvements.

China: Improved Cookstoves Deployment. China has implemented the most sweeping and successful improved cookstoves program in the world. Around 130 million improved biomass-based stoves were installed in rural areas during 1982–92, meaning that over half of rural households in China obtained an improved stove. The Chinese National Improved Stove Program used the following strategies to disseminate improved stoves on this massive scale: (1) research and development (R&D) through a network of research institutions along with independent testing and monitoring of potential stove designs; (2) decentralized training, promotion, and monitoring through Rural Energy Offices (REOs), starting in the counties with the greatest need and interest; and (3) promotion of rural companies manufacturing, installing, and servicing improved stoves, including low-interest loans to help such companies get started, tax incentives, and continued support from the REOs. Improved stoves are sold by these companies for around $9 per stove on average, without direct government subsidy except for free stove parts provided to very poor households in some regions.

Denmark: Wind Power Deployment. The Danish government has aggressively supported wind power development and deployment through RD&D programs, capital subsidies, and tax incentives. Furthermore, electric utilities have been required to purchase output from wind turbines for about 9 cents per kilowatt-hour (kWh), while receiving about 1.5 cents per kWh from a subsidy pool created by fossil fuel taxes. These policies made wind power cost-effective for both private owners and utilities in Denmark. Installed wind power capacity reached over 1,400 MW at the end of 1998, with wind power providing nearly 10 percent of electricity in Denmark. Moreover, about 60 percent of new wind turbines installed worldwide in 1998 were made in Denmark, with the Danish wind turbine industry realizing revenues of nearly $1 billion that year.

Eastern Europe: Energy Efficiency Improvement. The formerly centrally planned economies of Eastern Europe and the Soviet Union wasted vast quantities of energy. Consequently, Bulgaria, the Czech Republic, Poland, Russia, and Ukraine created national energy efficiency centers during the 1990s. The centers provide policy analysis for reform and greater efficiency, business development through market conditioning and assistance to private firms, demonstrations of new technologies, training, information dissemination, and outreach. Among their accomplishments, CENEf in Russia developed energy efficiency standards for new apartment buildings; Arena-Eco in the Ukraine helped develop energy efficiency standards and an energy efficiency loan fund; FEWE in Poland created an ESCO that has retrofit major apartment complexes; SEVEn in the Czech Republic drafted portions of a national energy efficiency law and prepared energy efficiency plans for a number of Czech cities; and EnEffect in Bulgaria conducted analyses that helped Bulgaria to participate in the Framework Convention on Climate Change.

India: Renewable Energy Implementation. The Indian Renewable Energy Development Agency (IREDA) was established by the government of India in 1987 to finance and promote the manufacturing and adoption of renewable energy technologies. IREDA provides low-interest loans with a 5–10 year repayment period, training in technical and business skills, publicity campaigns, resource assessments, case studies and manuals, and business development and export assistance. Concurrently, the Indian government has supported RD&D of renewable energy technologies. And the government offers one-year depreciation and elimination of import duties and taxes to further improve the economics of renewable energy adoption. This comprehensive market-oriented approach has achieved impressive results. For example, over 450,000 solar PV systems aggregating to 40 MW were installed as of 1998, making India the largest user of solar PV systems in the world. Wind power also expanded rapidly for a number of years although the wind power deployment slowed in 1997 and 1998.

Netherlands: Energy Efficiency Improvement Targets and Agreements. The Dutch government has adopted formal agreements containing negotiated energy intensity targets with 31 industrial and 6 service sectors. In order to contribute to the industry target, participating companies agree to develop and implement an energy efficiency improvement plan, and improve energy efficiency wherever technically and economically feasible. Companies also agree to report on progress annually. In return, the government provides detailed energy audits of industrial facilities, tax incentives for investments in energy-efficient technologies and other subsidies, and protection from mandatory energy efficiency regulations. The average energy efficiency improvement as of the end of 1996 was 12.5 percent, meaning the participating companies were on track for achieving a 20 percent improvement on average by 2000.

United Kingdom: Shift from Coal to Natural Gas-Based Power Plants. Starting in 1990, the U.K. power industry was largely privatized and restructured. Competition was steadily increased, subsidies for coal production were cut, natural gas production was privatized and deregulated, and regulations to cut emissions of acid rain precursors were implemented. These policies led to natural gas achieving a 30 percent market share for power production as of 1998 compared to virtually no natural gas use for power production prior to 1990. The fraction of power production from coal fell from 65 percent in 1990 to around 38 percent by 1998. The shift from coal to natural gas for power production reduced carbon emissions by about 14 million metric tonnes, equivalent to an 8 percent reduction in total U.K. carbon emissions.

United States: Appliance and Vehicle Efficiency Improvements. The energy efficiency of domestic appliances and other types of mass-produced equipment dramatically improved in the United States during the past 25 years. This was a result of enacting mandatory efficiency standards—first at the state level and later at the national level—along with utility incentive payments, government-funded RD&D, and labeling of efficient products. These complementary policies are expected to reduce U.S. electricity use by 88 TWh (2.7 percent) in 2000 and 193 TWh (5 percent) in 2010, leading to net savings of over $160 billion for consumers and about 60 million metric tons less carbon emissions in 2010.

Efficiency standards on cars and light trucks (known as Corporate Average Fuel Economy (CAFE) standards) are largely responsible for the near doubling in the average fuel economy of new cars and the more than 50 percent increase in light truck fuel economy from 1975 to 1985. A tax on inefficient "gas guzzlers" also contributed to the overall increase in fleet fuel economy during the 1980s. Had these improvements not occurred, the U.S. car and light truck fleet would have consumed an additional 3 million barrels of gasoline per day as of 1995.

United States: More Efficient Electricity Use in California. Utilities in the state of California have implemented large-scale demand-side management (DSM) programs for about 15 years. The programs included rebates for consumers that purchase efficient appliances, air conditioners, and lighting products; free retrofits for low-income households; support for implementation of building energy codes; and technical assistance to businesses and industries. During 1990–94, these programs in aggregate saved over 5,000 gigawatt-hours (GWh) per year at a cost of saved energy of around $0.025 per kWh, providing consumers in California net benefits of $2.2 billion. The California Public Utilities Commission encouraged these efforts by allowing utilities to recover lost sales revenues and keep a portion of the net societal benefits resulting from their DSM programs. As part of electric utility restructuring legislation adopted in 1996, the California legislature mandated a "wires charge" to maintain funding for energy efficiency and other "public goods" programs. Greater emphasis is now devoted to creating a robust energy efficiency services industry as well as supporting a range of market transformation programs.

Special Considerations in Developing Countries

Developing countries present some special needs and opportunities when considering policies for advancing energy efficiency, renewable energy, and clean fossil fuel technologies. First, developing countries often lack institutions and capacity for promoting and implementing these technologies on a large scale and in a sustained manner. Second, energy policies should take into account social and economic conditions and priorities such as job creation and poverty alleviation. Third, developing countries present opportunities for technology innovation and leadership since they still putting into place their industrial, transport, buildings, and power infrastructures.

Capacity Building. Capacity and institution building is essential if energy efficiency, renewable energy, and clean fossil fuel technologies are going to make a major contribution to future energy resource and service needs in developing countries. These countries require multi-disciplinary expertise in

- technology development, adaptation, and testing
- manufacturing and marketing
- deployment and behavioral issues
- monitoring and evaluation
- training energy managers and end-users
- policy development and implementation

Capacity and institution building are needed to form and staff public sector agencies, research institutes, and the private companies that will produce, market, and install energy efficiency, renewable energy, and clean fossil fuel technologies. The Global Environmental Facility (GEF) could devote more resources to capacity and institution building (and less to discrete projects).

Energy and Social Links. There are strong links between energy production and use on the one hand and social conditions on the other. Lack of modern energy sources (especially in rural areas) contributes to poverty, poor health and education, unemployment, and high population growth. Conversely, provision of clean, efficient, and modern energy sources reduces burdensome manual labor requirements, enhances education opportunities, lowers population growth, strengthens public health, and creates job opportunities. Providing renewable-based fuels and electricity, improved cookstoves, mechanical water pumping, and mechanized farming equipment should be given high priority in national and regional economic and social planning, not just energy planning. Likewise, energy policies and programs should pay special attention to serving the needs of low-income households in both urban and rural areas.

Fostering Technological Innovation and Leadership. Developing countries have some features that could enable them to be leaders in worldwide sustainable energy innovation. These features include plentiful renewable energy resources and energy efficiency opportunities; large, untapped markets; nascent industrial, transport, buildings, and power infrastructures; and rapid growth rates. As developing countries progress economically and socially, they have the opportunity to "leapfrog" over the inefficient, fossil fuel-based, and polluting energy production and consumption patterns commonly found in industrialized nations. The policies that can foster energy technology innovation and leadership in developing countries include: (1) supporting RD&D that emphasizes clean energy supply and energy end-use technology innovation; (2) encouraging development of new industries and introduction of new technologies through international joint ventures and other mechanisms; (3) adopting and enforcing strong energy efficiency and environmental standards so that new infrastructure is state-of-the-art rather than outdated; and (4) providing attractive financing, market development assistance, and government procurement to clean energy technology entrepreneurs.

International Policies

Cooperation among countries can be useful in achieving market transformation, especially for mass-produced products that are manufactured and sold on an international scale. Cooperative efforts are underway to increase the energy efficiency of automobiles in Europe and office equipment in the United States, Japan, and the European Union. International policy cooperation faces a number of challenges including establishing key technical parameters, program coordination, and program administration.

Technology transfer between industrialized and developing countries is one element of sustainable energy development worldwide. Encouraging joint ventures, licensing, and technology acquisition can be effective strategies for transferring clean energy technologies to developing countries. Joint ventures and licensing can help developing countries obtain state-of-the-art technologies at attractive prices. Governments can encourage joint ventures and licensing of sustainable energy technologies and services by providing financing, tax incentives, and/or market development support. Furthermore, strengthening intellectual property rights protection can facilitate the flow of advanced technology to developing countries.

A number of industrialized countries have increased their bilateral support for sustainable energy development and deployment in Third World countries in recent years. But bilateral assistance tends to be project-focused, controlled and carried out by industrial nation representatives, and driven by political considerations. Greater emphasis should be given to longer-term and multi-pronged efforts aimed at barrier removal, capacity and institution building, and market development in developing nations.

The World Bank and other multilateral development banks (MDBs) are important lenders for energy development in the Third World. Historically, the vast majority of their energy sector loans went to large-scale hydropower, fossil fuel, and energy infrastructure projects. Very little lending was devoted to energy efficiency or smaller-scale renewable energy technologies. This is starting to change. But the World Bank and other MDBs should devote a greater portion of their energy lending to sustainable energy technologies. As the markets for and capability in sustainable energy technologies grows, the MDBs should phase out their funding for conventional energy projects and focus entirely on sustainable energy technologies. To facilitate this transition in priorities, the MDBs should increase their own capacity and expertise in energy efficiency and renewable energy technologies.

The Kyoto Protocol to the Framework Convention on Climate Change allows joint implementation (JI) between industrialized and transition nations. The Kyoto Protocol also provides for a Clean Development Mechanism (CDM) that could foster additional investment in renewable energy, energy efficiency, and natural gas projects in developing countries. The CDM allows parties in industrialized nations to receive emissions credits for investing in projects that reduce greenhouse gas emissions in developing countries. However, the fate of the Kyoto Protocol is unclear. If the Protocol is ratified by enough countries so that it enters into effect, the detailed structure and functioning of the JI and CDM provisions need to be worked out. The definition of baselines, procedures for certification, monitoring and verification of emission reductions, and whether or not there will be a limit on the use of credits are some of the issues that still need to be resolved.

Conclusion

The case studies presented show that policies can have a significant impact on energy supply and consumption patterns. But much more needs to be done. Many of the successful policies and programs outlined above need to be expanded. Moreover, comprehensive energy efficiency and renewable energy policies and programs like China's energy efficiency programs, the Danish wind power program, Dutch industry agreements, U.S. appliance efficiency standards, PROCEL, and IREDA are needed in every nation, rich and poor.

While national policies and programs are the foundation for successful market transformation, the participation of state and local authorities and action at the regional and local level can be critical to the success of national policies and programs. Likewise, international agencies such as the MDBs and Global Environmental Facility can play a key role in financing national efforts, as well as in supporting capacity and institution building. And international cooperation should be expanded where appropriate, such as in promoting efficiency improvements in mass-produced products that are manufactured and sold worldwide.

The private sector should be involved in policy development since it plays a key role in implementation. Private sector cooperation can determine whether not a policy (or set of policies) succeed(s). While some companies have a vested interest in maintaining an inefficient and carbon-intensive energy future, other companies are actively developing, producing, or investing in high-efficiency, renewable energy, and advanced fossil fuel technologies. Policymakers can work with these innovative companies to develop and implement progressive policies and programs that will lead to a more sustainable energy future.

ACKNOWLEDGMENTS

This report was prepared at the request of the United Nations Development Programme. The author would like to thank Jose Goldemberg and Thomas Johansson for providing guidance and helpful comments on earlier drafts, and Renee Nida for assisting with editing and production.

INTRODUCTION

World energy use has increased ten-fold since 1900 and more than four-fold since 1950. During the past twenty years, world energy use grew on average about 1.7 percent per year. This rapid growth in energy use during the 20th century helped to propel industrialization and economic growth. It also provided expanded levels of energy services and a wide range of amenities for a large fraction (but not all) of the world's growing population.

If current energy policies and trends continue along with fairly robust economic growth, it is estimated that global energy use will double from its 1990 level by about 2025, triple by 2050, and further rise in the latter half of the 21st century, as characterized by the IIASA-WEC high growth scenarios (Nakicenovic, Grubler, and McDonald 1998). The majority of this growth is expected to take place in developing countries, which could pass industrialized countries in total energy use by around 2025. This level of energy use growth, around 2.5 percent per year in the near term falling to 1.0–1.4 percent later in the century, could present a variety of problems and challenges for mankind including:

1. *High Capital Requirements.* Vast amounts of capital for finding, extracting, and converting energy resources would be required if worldwide energy use continues at the current rate. High-growth scenarios require energy supply investments of $14–17 trillion (1997 $) during 1990–2020 and $23–31 trillion during 2020–2050 (Nakicenovic, Grubler, and McDonald 1998). This level of investment in energy supply means less capital would be available for other priorities such as health care, education, telecommunications, manufacturing, etc.

2. *Local Environmental Degradation.* Acid rain, urban smog, fine particulates, and other air pollutants due to burning fossil fuels are already significantly harming public health and ecosystems worldwide. It is estimated that fossil fuel power plant emissions caused about $70 billion of harm to human health, buildings, and crops in the European Union as of 1990, equivalent to about one percent of the E.U.'s GDP (Krewitt et al. 1999). Outdoor air is especially dirty in some urban areas of developing countries due to poor combustion efficiencies and lack of pollution controls. And indoor air pollution from burning solid fuels in traditional stoves is causing about two million premature deaths in women and children annually. Fossil fuel-intensive, high energy growth over the next century would greatly exacerbate these air quality problems, adversely affecting economic output as well as public health.

3. *Global Warming.* Growing carbon dioxide emissions (which is the main gas causing global warming) is another characteristic of business-as-usual energy supply policies and trends. Worldwide emissions would increase by a factor of 2–2.5 by 2050 and 3.5– 4 by 2100 in high-growth, high fossil fuel use scenarios, leading to atmospheric carbon dioxide concentrations of 650–750 parts per million by volume (ppmv) by 2100 (2.3–2.7 times the pre-industrial level). According to the consensus of scientific opinion as spelled out by the

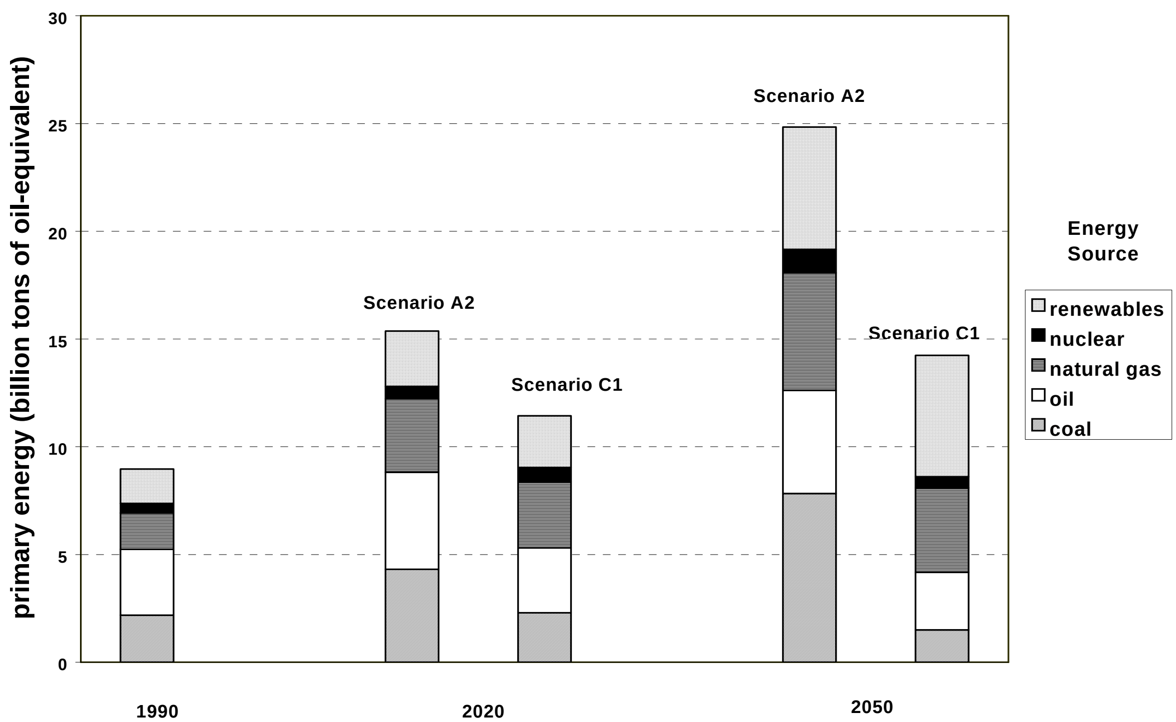
Intergovernmental Panel on Climate Change, this degree of greenhouse gas build-up would raise the mean surface temperature by 3–4 degrees centigrade during the next century, leading to a significant sea level rise, increase in severe weather occurrences, adverse effects on human health, and negative impacts on ecosystems worldwide.

4. *Oil Import Dependency.* Oil imports already account for a large fraction of total energy use in most industrialized and developing nations, adversely affecting trade balances and posing risks of supply interruptions, price shocks, and military conflict. High energy growth will increase import dependence. For example, under current policies and trends, Organization for Economic Development (OECD) nations are expected to increase their oil import dependence from 56 percent in 1996 to 72 percent in 2010 and 76 percent in 2020 (IEA 1998).

5. *Ignoring Needs of the Poor.* Business-as-usual energy policies emphasize increasing energy use among the wealthier citizens of the world (both in industrialized and developing nations) rather than emphasizing providing modern energy sources and services to poorer citizens. Nearly half the world's population lives in rural areas of developing countries, and most of these people do not use electricity or modern cooking fuels. In India, for example, less than 30 percent of rural households use electricity, over 90 percent use traditional biomass cooking fuels, and more than 55 percent of farm land is cultivated by animal power (Pachauri and Sharma 1999). Business-as-usual scenarios do not envision this pattern changing significantly in the next few decades (IEA 1998).

For these reasons, a business-as-usual energy future is not desirable. Nor is it inevitable. By emphasizing energy efficiency improvements, renewable energy options, greater utilization of natural gas, and the needs of the poor, all of the problems listed above can be mitigated. This type of energy future is illustrated by the "low growth, low carbon scenario" developed in the IIASA-WEC study (see Figure 1). In the C1 scenario, global energy intensity declines 1.0–1.5 percent during the next century and modern biomass, solar, and other renewable sources start to contribute a significant fraction of global energy supply starting around 2020. This scenario leads to nearly 65 percent less carbon emissions by 2050 and over 90 percent less carbon by 2100 compared to the high growth, high coal use A2 scenario developed by IIASA-WEC. The low growth, low carbon scenario would stabilize atmospheric carbon dioxide at about 450 ppmv, sufficient to greatly reduce the risks associated with climate change. Reducing total energy use and increasing the share provided by renewable sources also will mitigate other environmental impacts. And an emphasis on efficiency and renewable energy sources reduces capital investment needs and could provide much improved energy services to poorer citizens of developing nations.

Figure 1: Comparison of Global Energy Consumption in the IIASA-WEC High Growth, High Coal Scenario (A2) and the Low Growth, Low Carbon Scenario (C1)



Source: Nackicenovic, Grubler, and McDonald (1998).

A wide range of policy innovations including policies at the international, national, regional, and local levels are needed to move away from the business-as-usual path and towards the higher efficiency, higher renewable energy path embodied in the IIASA-WEC low carbon scenarios. But before reviewing these policy options, it is useful to consider the broader context in which these policies will operate in the 21st century.

BROADER ECONOMIC AND SOCIAL CONTEXT

Increasing globalization, energy sector restructuring and the growing importance of the private sector, rapid technological innovation, and urbanization will influence energy strategies and systems in the next century (Reddy, Williams, and Johansson 1997). These trends need to be taken into account as policies for a more sustainable energy future are crafted and implemented. Each of these major trends is briefly discussed below.

1. *Increasing Globalization.* Trade barriers are falling and world trade is growing. The global economy is becoming more integrated through mergers, acquisitions, joint ventures, and the

expansion of multinational companies. Multinational companies are playing an increasing role in fossil fuel production and distribution, gas and electric utilities, and manufacturing of energy end-use technologies. As companies and markets become increasingly international, so too should policy interventions through coordinated action and policy harmonization.

2. *Restructuring and Privatization.* Many nations are privatizing formerly government-owned utilities, petroleum and natural gas companies, and other institutions. This is being done in large part to reduce inefficiency and attract private capital to the energy sector. At the same time, efforts are being made to increase the transparency of policymaking, reduce government subsidies, and open up markets to greater competition. Successful policies, whether financing, incentives, regulations, etc., must engage the private sector and catalyze private investment in the desired technologies on a large scale.

3. *Rapid Technological Innovation.* The microelectronics revolution and its various ramifications are well-known. One is increasing worldwide access to information through dissemination of personal computers, the growth of the Internet, and telecommunications advances. Rapid technological innovation is also occurring across a wide range of energy supply and end-use industries including electric generation, oil production, fuel conversion, vehicles, appliances, and some manufacturing processes (e.g., electric mini-mill steelmaking). However, the scope of these innovations is not equally shared, with a growing "technology gap" between rich and poor nations as well as between richer and poorer segments of some nations. Policies should be adopted to maximize innovation in clean energy technologies and ensure that these innovations are widely diffused.

4. *Urbanization.* The fraction of the world's population living in urban areas was about 46 percent as of 1996 and is expected to rise to 61 percent by 2030. Most of the population growth projected over the coming decades will occur in the world's cities, especially those in developing countries. It is expected that there will be 36 metropolitan areas with a population of at least eight million by 2015 (UN 1996). The proliferation of "megacities" like Tokyo, Mexico City, Sao Paulo, Bombay, Shanghai, etc. presents special challenges related to transport, air quality, services, and employment. Urbanization also offer opportunities for distributing new energy technologies and designing more efficient and sustainable habitats and industrial systems. Energy policies should be designed in ways that are sensitive to growing urbanization and address the multiple challenges this trend presents, while not ignoring the needs of rural areas.

TECHNICAL, FINANCIAL, AND MARKET BARRIERS

Energy efficiency, renewable energy (excluding large-scale hydropower), and clean, innovative fossil fuel technologies face a host of barriers limiting their introduction and deployment throughout the world (see Table 1). Some of the barriers will shrink as these technologies gain acceptance and market share; others are likely to persist unless directly confronted and reduced or removed through policy interventions. The principal barriers to increased energy efficiency and use of renewable energy sources are summarized below.

Table 1: Barriers to the Adoption of Energy Efficiency and Renewable Energy Technologies

Energy Efficiency	Renewable Energy
• limited product availability	• limited infrastructure
• lack of information and training	• lack of adequate production scale
• uncertainties	• information barriers
• high transaction costs	• risk
• split incentives	• lack of attractive financing
• purchasing procedures & habits	• pricing barriers
• bounded rationality	• technical barriers
• lack of money or financing	• regulatory & fiscal barriers
• pricing barriers	
• policy & regulatory barriers	

Barriers to Greater Energy Efficiency (Eto, Goldman and Nadel 1998; Reddy 1991)

1. *Limited Product Availability.* Energy-efficient products may be produced on a limited scale and may not be readily available in stores or through suppliers to builders, contractors, or industries. This creates a "vicious circle" where demand is low, suppliers do not make products available as long as demand is low, and demand remains low due to limited availability.

2. *Lack of Information and Training.* Consumers, businesses, contractors, etc. may not be aware of energy efficiency options or may lack information on how much energy certain efficiency measures are likely to save, the extent of other benefits such as productivity improvements or environmental benefits, or how fast the measures will pay back their first cost.

3. *Uncertainties.* Consumers and businesses may be skeptical of energy savings claims made by vendors or contractors, or may have doubts whether an energy savings device will work properly in their home, commercial building, or factory. Future energy prices also are uncertain.

4. *High Transaction Costs.* Acquiring energy efficiency measures, or even adequate information for making an informed purchase decision, can take time and/or money; for example, to contract for a specific product or service.

5. *Split Incentives.* The financial interests of those responsible for purchasing energy efficiency measures may not be aligned with those who would benefit from the purchase. In rental property, for example, the owner is responsible for capital purchases while tenants pay the energy bills. And in new construction, the builder has an incentive to cut corners and minimize first cost once a project begins.

6. *Purchasing Procedures and Habits.* Many buildings are constructed, products purchased, facilities renovated, etc. on the basis of least first cost, not least life-cycle cost. Many governments, for example, are required to purchase goods and services based on lowest bid. Furthermore, some purchases are made in a hurry—replacing a failed appliance, motor, or heating system, for example—with little time available to shop for an efficient model.

7. *Bounded Rationality*. Consumers and businesses are only able to process a finite amount of information and often pay more attention to other factors like price, features, and non-energy performance when buying a home, purchasing appliances, building or renovating a commercial building, or installing a new production line. Energy costs may represent only a few percent or less of the total cost of owning and operating a factory, business, or home, often leading to little or no attention paid to energy efficiency at the time of purchase.

8. *Lack of Money or Financing.* Consumers or businesses may lack the capital needed for an energy efficiency project or the extra cost for a more efficient device. And third-party financing on reasonable terms may not be available or may not be convenient, unlike large-scale energy supply projects where attractive financing is often readily available.

9. *Pricing Barriers.* Energy prices may be subsidized or structured so that they are based on average rather than marginal costs. Even if energy prices are not subsidized, they rarely reflect the full direct and indirect costs to society associated with energy production and use (i.e., they do not include social and environmental externalities). And utilities often overprice backup capacity and underpay for excess electricity supplied to the grid in order to discourage on-site cogeneration.

10. *Policy and Regulatory Barriers.* Government policies, such as regulation of utilities, often reward increased energy sales and penalize improvements in the efficiency of energy supply and end-use. Likewise, energy planning often fails to take into account the potential to increase the availability and reduce the cost of energy services through energy efficiency improvements.

These barriers, taken as a whole, lead to what is sometimes termed the "payback gap" where customers implicitly require a rate of return of 30 percent or greater (i.e., a payback of three years or less) before investing in energy efficiency measures. This rate of return is much higher than the social or market cost of capital. It should be remembered that this rate of return is inferred from actual purchasing decisions—decisions that reflect the host of barriers listed above. It does not necessarily reflect a conscious choice on the part of consumers.

Barriers to Renewable Energy Use (IEA 1997b; Nogee et al. 1999)

1. *Limited Infrastructure*. Small-scale renewable energy technologies such as solar heating and electricity systems may not be readily available, especially in rural areas where they are most cost-effective. Likewise, windpower and biomass technologies may not be available in some countries or regions. The demand for renewable energy technologies may be too low or too diffuse to justify local production, import, or marketing. And knowledge concerning proper installation, operation and maintenance may be lacking.

2. *Lack of Adequate Production Scale.* Although production of many renewable energy technologies is increasing, it is still not large enough to achieve economies of scale and drive down production costs. And as long as prices are high, demand will remain limited.

3. *Information Barriers.* As is the case for energy efficiency measures, consumers may be unaware of renewable energy options, local suppliers, financing opportunities, etc. Obtaining this information can take time and/or money. Lack of information can be especially problematic for newer technologies.

4. *Risk.* Renewable energy technologies generally have a long payback period. Potential users may be unwilling to accept the risk associated with this long payback—that performance may not be adequate, lifetime may be shortened, operating costs may be higher, etc. such that the actual rate of return is negative. Again, the perceived risk tends to be high with new, unproven technologies, whether or not the perceived risk is justified.

5. *Lack of Attractive Financing.* With the relatively long payback, it is critical to finance renewable energy measures at low interest rates and long loan terms. Consumers and businesses generally do not have access to attractive financing for small-scale renewable energy projects.

6. *Pricing Barriers.* As is the case for energy efficiency measures, market energy prices may be subsidized or structured so that they are not based on actual or marginal costs—for example, not reflecting the full cost of grid extension in rural areas of developing countries. Energy prices rarely reflect the full direct and indirect costs to society associated with conventional energy production and use (i.e., they do not include social and environmental externalities). And buyback rates may not reflect all the benefits of renewables—for example, the value of supply diversification, increased system reliability, peak demand reduction, etc.

7. *Technical Barriers.* Renewable energy technologies can confront a variety of technical barriers, either intentional or unintentional, that make installation difficult and/or more costly than necessary. Utilities can use excessive interconnection requirements, certification processes, or time-consuming procedures to impede renewable energy development. Moreover, building codes can make it difficult to install renewable energy measures in building applications.

8. *Regulatory and Fiscal Barriers.* Siting and approval of centralized renewable energy projects can be time-consuming and costly. Also, regulations and tax policies can favor lower capital cost energy resources over higher capital cost options such as most renewable technologies (e.g., allowing businesses to deduct fuel purchases from income for tax purposes). Imported renewable energy technologies or components such as PV cells can be subject to onerous import duties. And renewables can be discouraged by the tax breaks such as “depletion allowances” provided to conventional fossil energy resources.

These barriers can be especially problematic for renewable energy technologies that have a difficult time competing with conventional energy sources in the marketplace today. Some of the barriers listed above inhibit off-grid applications, others apply more to grid-connected renewables. But without targeted policy initiatives to overcome these barriers, renewables will remain a set of niche technologies contributing relatively little to worldwide energy supplies in the next few decades.

ENERGY POLICY OPTIONS

There is no "silver bullet" for overcoming the barriers listed above and moving towards a more sustainable energy future. Many policy instruments are available and are needed for overcoming the multiple barriers that exist. These policies can be grouped into the following categories:

- RD&D
- financing
- financial incentives
- pricing policies
- testing, labeling, and voluntary agreements
- codes and standards
- information, education, and training
- procurement policy
- market obligations and reserves
- planning techniques

Each type of policy is reviewed below. Then the concept of integrating policies into a market transformation strategy is presented along with specific examples of successful implementation of market transformation strategies in different countries.

RD&D

Research, development, and demonstration is critical for maintaining the pipeline of innovative energy supply and end-use technologies. Government-funded RD&D has helped to advance a number of energy efficiency and renewable technologies during the past twenty years, e.g., wind turbine innovations, electronic lighting ballasts, high-efficiency appliances, and new window technologies in the United States (Geller and McGaraghan 1998; Loiter and Norberg-Bohm 1999). RD&D (along with market development, learning effects, and economies of scale) caused dramatic reductions in the cost of renewable energy technologies. The cost of wind power fell by a factor of ten, the cost of solar photovoltaic power fell by more than a factor of ten, and the cost of solar thermal power fell by more than a factor of five during the past twenty years, meeting or exceeding cost reduction projections (McVeigh et al. 1999).

Unfortunately, energy RD&D has declined significantly in a number of countries including the United States over the past twenty years (Dooley 1998; Reddy, Williams, and Johansson 1997). This decline is noticeable in both public and privately funded energy RD&D. In addition, nuclear energy and fossil fuels have received the majority of energy RD&D funds, with relatively small shares for energy efficiency and renewable energy technologies in the United States, Japan, and Western Europe over the past twenty years (Dooley 1998). However, RD&D priorities have shifted recently in a number of countries due to the decline in interest in nuclear power and growing concerns about global warming. The fraction of government-sponsored energy RD&D devoted to efficiency and renewables has risen significantly in the United States, Japan, Germany, and a few other countries (Dooley and Runci 1999). Japan, for example, had increased its government support for RD&D of renewable energy, energy efficiency, and advanced coal technologies to about $400 million per year as of 1998 (Katsumata 1999).

Greater international cooperation in energy technology RD&D could have a wide range of benefits including cost and risk sharing, faster learning, increased access to global markets, and better prospects for rapid deployment of innovative technologies worldwide (PCAST 1999). Partnering between industrialized and developing nations in energy RD&D could be particularly valuable for accessing large markets; driving down the costs of new technologies such as fuel cells, bioenergy conversion techniques, or photovoltaic cells; and deploying state-of-the art technologies in the developing world. But new mechanisms for funding clean energy technology RD&D are needed given recent declines in funding, government budget cuts, and declining incentives for privately funded RD&D (Reddy, Williams, and Johansson 1997).

In performing energy RD&D, partnerships between universities and other research institutions and the private sector have been especially productive. The universities and research institutes have new ideas and strong technical capabilities, while private companies understand the needs and limitations of the marketplace. If private companies are involved in the RD&D, it is much more likely that an innovative technology will be successfully commercialized and marketed. One RD&D strategy that has proven particularly effective in the United States is partnering between national laboratories and smaller entrepreneurial companies. Once an innovative technology is technically and commercially proven, larger companies become interested, enter the market, make refinements, and scale up production (Geller and McGaraghan 1998).

Financing

Financing at attractive interest rates is critical for the successful diffusion and market sustainability of end-use energy efficiency and renewable energy technologies. Traditional lenders such as national development banks or private banks have been reluctant to provide loans for these technologies because of small project size, unfamiliarity with the technologies, and other considerations. Innovative credit schemes are needed to make relatively small loans—$500,000 or less for businesses, $1000 or less for households—readily available with limited transaction costs.

Innovative credit schemes are facilitating the adoption of off-grid household solar PV systems in a number of countries. In India, ten-year loans at attractive interest rates are offered as part of India's comprehensive renewable energy development program (see case study below). About 10,000 rural households in the Dominican Republic and Honduras are served by solar PV systems financed by and obtained from local solar energy entrepreneurs who have access to a revolving loan fund (Verani, Nielsen, and Covell 1999). Micro-credit and revolving loan programs also are supporting the adoption of solar home energy systems in Bangladesh, China, Indonesia, Mexico, and Vietnam.

Third-party financing, usually without subsidies, has been a key part of the energy service company industry now well-established in North America. ESCOs provide technology, installation, financing, and performance guarantees—providing a "one-stop" service for consumers and businesses unable or unwilling to implement cost-effective efficiency measures on their own. However, ESCOs providing third-party financing and performance contracting are nonexistent or just starting to operate in most developing and transition countries. The European Bank for Reconstruction and Development (EBRD) is providing both debt and equity financing to help develop a network of private ESCOs in some Eastern European countries (Meyers 1996). Also, the World Bank and the Global Environmental Facility are funding a project to help establish ESCOs in a few Chinese provinces. Additional initiatives could be taken along these lines.

The adoption of a small charge on all electricity sales (known as a public benefits or systems benefit charge) is one way to help finance investments in energy efficiency and renewable energy sources, as well as provide incentives and support RD&D. The charge is usually a few percent or less of the total electricity price. In the United States, regulators in a number of states (including California, New York, Massachusetts, and Connecticut) have adopted public benefits charges to maintain energy efficiency and other public-purpose programs (Kushler 1998). In Brazil, the federal regulatory agency is requiring distribution utilities (many recently privatized) to invest at least 1 percent of their revenues in distribution system and end-use energy efficiency improvements (Geller et al. 1999).

Other policies that could be instituted to stimulate financing of clean energy technologies include expansion of the "Project Finance" strategy to efficiency and renewable energy businesses and projects, development of credit guarantee funds, and development of secondary credit markets. Project financing could allow equipment vendors and/or users to obtain credit on basis of expected future project revenue. For example, project financing could enable vendors of small-scale PV or bioenergy systems to obtain capital for expansion or credit for customers, secured on the basis of expected revenues from sales contracts. Loan guarantee funds, using national resources, bilateral assistance, or funds from multilateral agencies like the GEF, could lower capital costs and collateral requirements for borrowers, as well as leverage substantial lending for energy efficiency and renewable energy projects. Creation of a secondary market involves financial institutions that would buy up loans from "primary lenders" such as local banks, cooperatives, utilities, ESCOs, renewable technology vendors, and others, thereby reducing risk and increasing the amount of financing available for projects.

Financial Incentives

Financial incentives can help to get new technologies established in the marketplace, encourage early adopters, scale up production levels, improve performance, and reduce costs. This process is often termed "driving costs down the learning curve." There are many examples of incentive programs for energy efficiency and renewable energy technologies, a few of which are mentioned here. Others are covered in more detail in the case studies presented later of Brazil’s ethanol fuel program, India's national renewable energy program, and promotion of more efficient electricity use in California. In designing financial incentives, experience shows that is important to: (1) select technologies that have good prospects for competitiveness and viability in the marketplace once they are well-established; (2) use incentives strategically to move particular technologies down the learning curve; (3) leverage available incentive funds and set incentives to match incremental costs on a life-cycle basis; (4) phase out incentives as technologies gain market share and drop in cost; and (5) reward performance in order to minimize "free riders" and maximize energy supplied or saved, not dollars expended (Piscitello and Bogach 1997).

The United States provides numerous examples of financial incentives programs for energy efficiency and renewable energy sources, some successful and others less so. Many U.S. electric utilities have provided rebates that helped to build markets for energy-efficient appliances, lighting products, motors systems, etc., with a cost per kWh saved well below incremental electricity supply costs (Nadel and Geller 1996). Some utilities also provided incentives that stimulated the development and commercialization of some new technologies including "superefficient" refrigerators and clothes washers (Lee and Conger 1996). On the other hand, tax credits were offered for energy efficiency improvements in households and businesses in the late 1970s and early 1980s. Studies of these tax credits found that most participants would have installed the measures in the absence of the incentives (i.e., were "free riders") due to the small size of the tax credit and focus on conventional efficiency measures (Geller 1999).

Financial incentives have been used successfully in a number of countries to stimulate commercialization and/or establish initial markets for specific energy efficiency technologies. In Mexico, incentives were used to introduce compact fluorescent lamps (CFLs) into the housing market in two cities (Friedmann 1998). In Poland, incentives were used to build the market for CFLs using financing from the International Finance Corp. (IFC) and a grant from the GEF. In this case, incentives were paid to manufacturers to “buy down” the wholesale price and increase the impact of the limited funds that were available (Granda 1997). In both examples, incentives were offered for a limited period in order to increase awareness, prove technical and economic viability, increase product availability, and lower costs (Martinot and Borg 1998).

Renewable energy technologies, while rapidly declining in cost, are still not competitive with conventional fossil fuel technologies in most grid-connected applications. Therefore, it is necessary to maintain incentives in order to build markets and move the renewable technologies "down the learning curve." But incentives should be adjusted as technologies mature and approach competitiveness, as is the case for wind power (Neij 1997).

Most industrialized countries and some developing nations provide financial incentives to stimulate the development and introduction of renewable energy sources. Incentives are provided either through tax credits, low-interest loans, capital or output subsidies, buyback rates above normal wholesale electric generation prices, or a combination of these options (Goldstein, Mortensen, and Trickett 1999). The financial incentives offered in successful renewable energy programs in Denmark and India are described in the case studies below.

In Germany, the Electricity Feed Law (EFL) pays renewable electricity generators up to 90 percent of the average price paid for electricity by end-users, leading to payments of around 10 cents per kWh (US$). As a result, Germany led the world with about 2,900 MW of installed wind power capacity by the end of 1998. Attractive feed-in rates are stimulating large-scale introduction of renewables in other European countries including Denmark, Italy, Switzerland, and Spain.

In Japan, the federal government provides substantial capital subsidies for rooftop PV systems. The Japanese government spent about $85 million on PV subsidies and about $10 million on field tests as of 1997 (Shoda 1999). Also, utilities are required to pay 15–19 cents per kWh for PV power fed into the utility grid as well as about 10 cents per kWh for wind power. As a result of these policies, Japan led the world with about 25,000 grid-connected solar-powered homes in operation as of 1998 (O'Meara 1999).

The Global Environmental Facility was created to help pay the incremental costs for technologies that offer significant global environmental benefits in developing countries. However, the GEF has operated largely on an ad hoc "project-by-project" basis so far. But the GEF is starting to work systematically on some advanced energy technologies, e.g., through its Photovoltaics Market Transformation Initiative (PCAST 1999).

Pricing Policies

Low energy prices diminish incentives for using energy more efficiently or substituting cleaner, low carbon, or renewable energy supplies. It is desirable to price conventional energy resources to reflect not only direct costs but also indirect costs due to environmental and social "externalities." Many (but not all) nations recognize the broad costs associated with personal vehicle use and consequently heavily tax gasoline. This has contributed to much lower dependence on automobile use in Europe compared to North America. In another example, Sweden adopted new energy and carbon taxes in the early 1990s that contributed to large increases in bioenergy use for district heating purposes.

Energy prices were heavily subsidized in many countries in order to stimulate economic development and benefit the public at large. But subsidization is costly for governments, leads to inefficiencies, and discourages innovation. Consequently, energy price subsidies have been heavily cut in many countries recently (Reid and Goldemberg 1998). Russia, for example, reduced fossil fuel subsidies by about two-thirds between 1991 and 1996. Likewise, China cut its fossil fuel subsidies by over 50 percent. Other countries cut subsidies and increased electricity prices in conjunction with utility privatization. While subsidies overall have been reduced, a number of countries (both rich and poor) maintain energy price subsidies for the purpose of assisting low-income households. However, energy price subsidies are often not an effective or efficient way of helping impoverished households (Reddy, Williams, and Johansson 1997).

Differential fuels taxes have been adopted in a number of countries to reduce oil import dependence and improve urban air quality. Differential taxes are used to promote ethanol fuel use in the United States and Brazil, as described in a case study below. A number of countries have eliminated or reduced taxes on compressed natural gas (CNG) in order to encourage natural gas vehicles. For example, starting in 1984, Argentina eliminated taxes on CNG and constructed a network of CNG filling stations. As a result, around 425,000 natural gas vehicles are operating in Argentina, almost 10 percent of cars there and the largest CNG fleet in the world (Suarez 1999).

Further energy tax reform has been introduced or is under discussion in a number of OECD countries in the context of efforts to cut carbon dioxide emissions and meet United Nations' Framework Convention on Climate Change and Kyoto Protocol goals. Five countries—Denmark, Finland, the Netherlands, Norway, and Sweden—have enacted taxes on carbon emissions or fossil fuels as part of a revenue-neutral tax shift strategy (Roodman 1998). Taxes on carbon emissions or fuel use are offset by reductions in other unpopular taxes such as personal income or employment taxes. In some cases, a portion of the tax revenue is targeted for funding energy efficiency and renewable energy R&D or incentive programs. A policy along these lines was announced in the United Kingdom in early 1999, for example. The revenue-neutral tax shift approach can reduce the political opposition that prevents raising taxes by itself.

Net metering is another pricing policy that can be used to encourage renewable electricity generation. Customers who produce more electricity than they can use feed the electricity into the grid and run their meter backwards, thereby selling power to the utility at the retail price rather than wholesale price. In the United States, about 18 states have adopted net metering although usually with capacity limits (Nogee et al. 1999).

Testing, Labeling, and Voluntary Agreements

Setting up appliance and equipment testing laboratories, test procedures, and testing and labeling programs can be useful for informing consumers about the relative energy efficiency of different products. This strategy enables labeling and promotion of the top products available at any particular time. Testing and labeling can be very cost-effective for governments since all of the investment in more efficient products is made by the private sector and paid for by consumers. Standardized testing also provides the foundation for incentive programs (by identifying high-efficiency products) and minimum efficiency standards.

In the United States, the ENERGY STAR® rating and labeling program is informing consumers of high-efficiency appliances, office equipment, lighting products, and other devices. The program also works with manufacturers to increase the availability of efficient products. It has had a positive impact on production and sales of a number of efficient technologies (Suozzo and Thorne 1999). Brazil has adopted labeling and promotion of top-rated appliances, lighting products, and motors, as well as voluntary agreements with manufacturers for increasing the overall efficiency of these products (Geller et al. 1999). These efforts are a key part of Brazil's national electricity conservation program (see case study below). And in Europe, a voluntary labeling and information program is being established to promote the production and purchase of consumer electronic devices with low standby power consumption (Meier and Lebot 1999).

Voluntary agreements between governments and the private sector establishing energy efficiency improvement targets for manufactured goods or industries have been adopted in a number of countries. Japan has used this approach at various times for improving the efficiency of vehicles and residential appliances with mixed success (IEA 1997b). The Netherlands has implemented a relatively successful program involving agreements with industries for reducing the average energy intensity of manufacturing (see case study below). In Thailand, a voluntary agreement among the government, a utility, and manufacturers succeeded in phasing out less efficient fluorescent lamps (Yang and Rumsey 1997). In Europe, auto manufacturers and the European Commission completed a voluntary agreement in 1998 whereby the manufacturers pledge to achieve a fuel economy target of 140 grams of carbon dioxide emission per kilometer by 2008, a 25 percent reduction from the 1995 average of 185 grams per kilometer for new cars sold in Europe (ACEA 1998). Voluntary agreements of this type have the advantage that they can be easier to adopt than mandatory regulations. On the other hand, voluntary agreements are not legally binding and consequently the targets may not be achieved.

Codes and Standards

Minimum efficiency standards either remove the least efficient products from the marketplace, leaving consumers to choose from an array of more efficient products with other desired options and features, or require that all new products meet a certain efficiency level on average. By making more efficient products the norm, economies of scale occur and the cost per unit of energy savings is reduced. In addition, efficiency standards can provide market pull for new technology. Minimum efficiency standards have been adopted in a number of countries for mass-produced goods such as cars, domestic appliances, heating and cooling equipment, motors, and lighting products (see U.S. case study below).

Some developing countries have realized that codes and standards can be a very effective energy efficiency strategy and have taken steps to implement these policies. South Korea launched a standards and labeling program for appliances and lamps in 1992; standards have been strengthened over time and equipment efficiency has significantly improved (Egan and du Pont 1998). Mexico enacted mandatory efficiency standards on refrigerators, air conditioners, and motors, initially at modest levels of efficiency but later equivalent to U.S. standards (Friedmann 1998). The Philippines adopted minimum efficiency standards for room air conditioners and refrigerators and is considering standards for motors (Wiel et al. 1998).

Most industrialized countries and some developing nations have adopted building energy codes that specify minimum energy efficiency requirements in new residential and commercial buildings. This can be an important energy savings strategy over the long run in industrialized nations where the building stock turns over slowly. In developing countries where the building stock is expanding rapidly, building energy codes in theory can have a dramatic impact on energy use within ten to twenty years. But it can be difficult to enact and implement mandatory building energy codes in developing countries due to opposition from the construction industry and/or weak follow-up (Flanigan and Rumsey 1996). Experience has shown that thorough training of architects and builders is critical to the success of building energy codes, as is concerted monitoring and enforcement (Wiel et al. 1998).

Information, Education, and Training

Many governmental and utility energy efficiency programs include information dissemination through energy audits and dissemination of printed materials. Evaluations of these efforts often show that information dissemination, by itself, results in limited energy savings (Levine et al. 1995; Nadel and Geller 1996). During the 1980s, for example, utilities in the United States were required to provide free energy audits to their residential consumers. After six years, about 7 percent of households participated in the program and energy savings averaged 3–5 percent per participant (Nadel and Geller 1996).

Information programs are more effective when combined with other initiatives such as financing, incentives, direct installation services (e.g., through ESCOs), or standards. In China, energy efficiency service centers at the provincial and local levels have been successful, in conjunction with RD&D, financing, incentives, and regulations (Sinton, Levine, and Qingyi 1998). In Thailand, a public awareness campaign for energy-efficient fluorescent lamps was successful, carried out in conjunction with a voluntary agreement with lamp manufacturers (Yang and Rumsey 1997). In the United States, education and training of builders and building code officials have been very effective, carried out in conjunction with adoption of more stringent building codes (Geller and Thorne 1999).

The U.S. Green Lights and ENERGY STAR® commercial buildings programs provide training, information, analytical tools, and recognition once companies have agreed to audit their facilities and install more efficient lighting and other efficiency measures wherever cost-effective. As of 1998, participants had upgraded approximately 350 million square meters of floor space, cutting electricity use by nearly 12 billion kWh per year and reducing energy bills by about $800 million annually (EPA 1999). The success of this effort is directly attributed to the commitment required of companies before they are eligible to receive assistance and recognition.

Information and training also can be important for promoting renewable energy. In particular, customers can be informed about the sources of power they are purchasing and the levels of pollution being emitted by these sources. This type of disclosure, coupled with a competitive retail electricity marketplace, can lead to greater consumer demand for cleaner power sources or "mixes." Another approach is to certify as "green power" electricity production with some minimum renewables content (e.g., 50 percent), as is starting to be done in the United States (Nogee et al. 1999). And training is critical for successfully disseminating small-scale solar water heating, photovoltaic power, and other renewable energy devices in developing countries (Kammen 1999).

Procurement Policy

Large-scale purchases by government authorities and/or the private sector can help establish a market for new clean energy technologies, as well as save the government money on a life-cycle basis. Governments—federal, state, and municipal—buy large numbers of lamps and other lighting products, air conditioning equipment, motors, vehicles, appliances, etc. Also, governments own large numbers of buildings that can serve as users of building-integrated renewable technologies, fuel cells, etc. Governments can purchase "green power" with a high renewable energy content for use in their facilities, and demand by individual consumers for “green power” can be aggregated as well.

In Sweden, the National Board for Industrial and Technical Development (NUTEK) organized bulk procurement of a variety of high-efficiency appliance, lighting, and building technologies as well as advanced vehicles. Purchase commitments were made by both public agencies and private firms, with manufacturers competing for the procurement. These efforts led to the introduction of and growing markets for a number of new products such as high-efficiency refrigerators, clothes washers and dryers, windows, and electronic lighting ballasts (Nilsson 1996). The cost to the Swedish government was relatively low since it only played a facilitating role.

Starting in 1993, U.S. federal agencies were required to buy ENERGY STAR® personal computers and other types of ENERGY STAR® office equipment. This was one of the key factors that led to widespread production of ENERGY STAR® personal computers by manufacturers worldwide (Thigpen et al. 1998). A new Executive Order issued in June 1999 requires federal agencies to purchase ENERGY STAR® products when purchasing lighting products, air conditioners, and appliances.

The federal government and many cities in the United States are purchasing natural gas and other alternative fuel vehicles for their vehicle fleets and procurement of advanced hybrid and fuel cell vehicles by government and private fleet owners has been proposed (DeCicco 1997). Likewise, eight municipalities in Europe are participating in a "Green Fleets" procurement initiative (DeCicco 1999).

Government procurement could greatly expand the market for photovoltaic cells. In the United States, for example, if federal facilities obtained just 1 percent of their electricity from PV cells, they would utilize 334 MW of PV capacity—more than six times the capacity produced by the U.S. PV industry in 1997 (Stronberg and Singh 1998).

Market Obligations and Reserves

Utilities can be required to supply or purchase a specified amount of renewable-generated electricity, expressed as either a fixed amount of capacity or a percentage of total electricity sales. In the United States, eight states (as of the end of 1998) were requiring utilities to obtain some fraction of their capacity from renewables through what is known as a Renewable Portfolio Standard (RPS) (Nogee et al. 1999). Also, the Clinton Administration has proposed a national RPS of 7.5 percent (excluding hydropower) for 2010, with utilities allowed to achieve the goal through installation of renewables facilities and/or purchase of tradable renewable energy credits. The tradable credit scheme is designed to minimize the overall cost of compliance.

In the United Kingdom, the government mandated that utilities acquire 1,500 MW of baseload equivalent renewable capacity by 2000 through a series of auctions—a policy known as the Non-Fossil Fuel Obligation. The price premium paid for this clean power is reimbursed to utilities through a tax on fossil fuels. These auctions, starting in 1990, have led to increasing amounts of capacity proposed and steadily declining prices for the winning bids. But there have been difficulties in bringing winning projects on-line due to complex contracting procedures, environmental and social concerns related to proposed wind power projects, and high transaction costs (Flavin 1999).

Providing long-term concessions to renewable energy developers in off-grid rural areas is another type of market reserve that could boost renewable energy use. Argentina, for example, is using this approach to promote renewable energy use and electrification of 1.4 million unserved rural households as well as schools and health clinics in Northwestern Argentina. About half the cost of renewable energy systems will be recovered from users and about half provided through state and federal government subsidies (Reddy, Williams, and Johansson 1997).

Requiring utilities to purchase power from renewable energy suppliers and/or cogenerators at avoided costs is another type of market obligation. In the United States, the Public Utility Regulatory Act of 1978 (PURPA) included this policy as well as requirements that utilities provide standby and backup power to cogenerators at reasonable rates. As a result, cogeneration capacity in the United States increased from about 10,000 MW in 1980 to 46,000 MW in 1996, with cogenerators accounting for about 9 percent of total power generation in 1996 (Bluestein and Lihn 1999). But with the advent of competitive wholesale markets in the mid-1990s, PURPA became much less effective and the growth in cogeneration leveled off.

Market obligations and reserves also can be used to stimulate commercialization of advanced vehicle technologies. California, for example, is requiring that a small fraction of new vehicle sales consist of electric, fuel cell, and other very low emissions or "zero emissions" vehicles (ZEVs). The ZEV requirement increases to a 10 percent market share by 2003. This state policy has stimulated the development and market entry of electric and hybrid vehicles in the United States.

Planning Techniques

Energy planning can be used to develop focused or comprehensive energy efficiency and/or renewable energy strategies. To be successful, energy plans should contain achievable goals, and measures and actions adequate for achieving the goals, as well as monitoring and evaluation procedures.

One example of successful planning is the Energy Plan adopted and implemented in Upper Austria, a highly industrialized region with 1.4 million inhabitants. It developed an Energy Plan in 1991 that promoted greater energy efficiency and renewable energy use through information and education efforts, grants and loans, financing, R&D, and some regulatory measures. Specific targets to be met by 2000 were established in each sector. The Plan appears to have been well-implemented and most of the goals are expected to be achieved. By 1996, Upper Austria achieved nearly a 12 percent reduction in carbon dioxide emissions (Egger and Dell 1999).

Integrated resource planning is a process whereby a planning authority identifies the mix of supply and demand-side resources that meet energy service needs at the lowest cost (NARUC 1988). The objective is to provide services such as heat, light, refrigeration, and motive power—not energy per se—as cost-effectively as possible. IRP has been successfully applied in many portions of the United States. For example, IRP led to over $1 billion in energy efficiency investments by utilities in the Pacific Northwest during 1980–95, resulting in 8 TWh per year of electricity savings by 1995 at an average cost of 2–2.5 cents per kWh saved (Ogden 1996).

For capital-short developing countries where energy services are undersupplied, an IRP perspective can be valuable. IRP studies have helped to guide policymakers to increase support for end-use energy efficiency efforts in Brazil (Geller 1991), India, and Sri Lanka (Padmanabhan 1999). In developing and transition countries pursuing utility privatization and increasing competition in electricity generation, IRP is useful for providing a rationale for public benefits "fees" supporting energy efficiency improvements and renewable energy investments. IRP can direct planners, regulators, and utilities to the largest and most cost-effective energy savings opportunities. Besides considering direct costs, environmental and social costs associated with different energy resource options can be included in IRP studies.

Better urban and transport planning also is needed to reduce urban congestion, improve air quality, reduce transport energy use, and reduce the cost of mobility (Zegras et al. 1995). Integrated land use and transport planning can lead to more efficient land use patterns and greater reliance on public transit systems, as exemplified by Curitiba, Brazil. Starting in the 1970s, Curitiba, with a population of about 2.3 million, implemented careful urban planning and a sophisticated public transportation infrastructure aimed at reducing automobile use and urban sprawl. As a result, about 75 percent of commuters use buses, fuel use is well below that of comparable Brazilian cities even though Curitiba is relatively wealthy, and ambient air pollution is relatively low due to less automobile dependence (Rabinovitch and Leitman 1996).

Freiburg, Germany offers another example of integrated land use and transport planning, combined with other policies to promote more sustainable personal transportation. Freiburg has maintained a compact land development pattern, limited urban sprawl, closed its downtown to private cars, increased parking fees, introduced an inexpensive public transit pass, and improved its public transportation network. As a result, ridership on public transport more than doubled between 1983 and 1995 and close to 60 percent of trips were by public transport, bicycle, or foot as of 1992 (FitzRoy and Smith 1998).

CASE STUDIES OF MARKET TRANSFORMATION

The individual policies described above were successful in some instances but were more likely to have a significant impact when implemented in combination. As noted above, energy efficiency, renewable energy, and cleaner fossil fuel technologies can face a wide range of technical, financial, and market barriers. It is often necessary to reduce or remove a number of these barriers using a "policy-assisted, market-oriented approach" in order to achieve large-scale results and ultimately transform energy markets (Reddy 1991). This integrated approach often consists of both "technology push" through RD&D and "demand pull" through consumer incentives, procurement initiatives, market reserves, etc. (Loiter and Norberg-Bohm 1999).

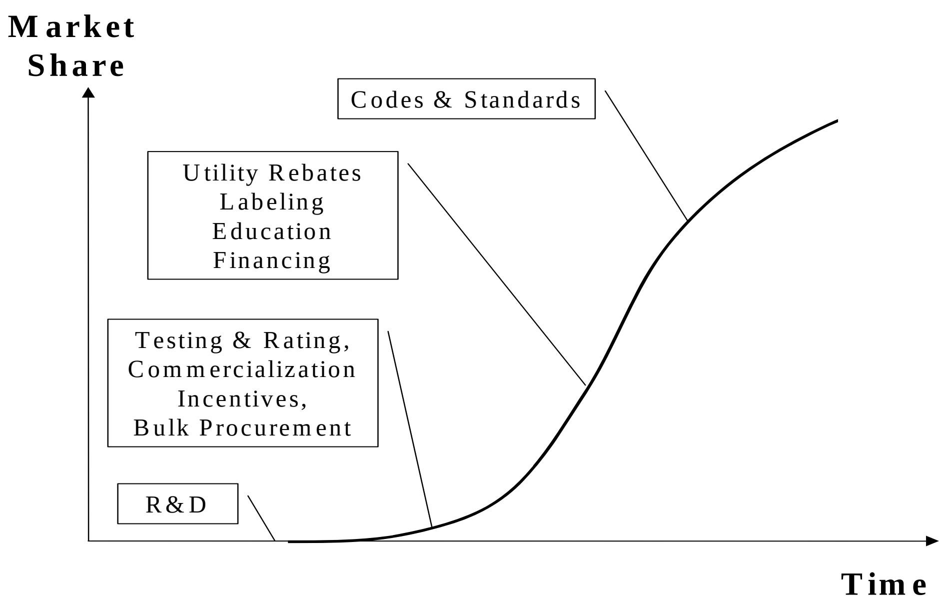
The market transformation approach has been developed, tested, and evaluated over the past 5–10 years in the energy efficiency and to a lesser degree the renewable energy field. A market transformation strategy removes barriers in order to achieve a set of market effects that persist after the policy interventions have been withdrawn, reduced, or changed (Eto, Prahl and Schlegel 1996). The market effects can be defined as sales levels or market shares for energy-efficient products, practices, and renewable energy technologies. Intermediate effects such as commercialization and increased availability of advanced technologies are important as well. The ultimate objective is to make the energy efficiency or renewable energy technology or practice the norm through a set of coordinated market interventions.

Figure 2 illustrates the application and possible integration of market interventions in order to transform markets. The types of policy interventions discussed above are shown in relation to their role in the classic "S curve" diffusion process. Certain interventions are appropriate for stimulating introduction and commercialization of new technologies, others for accelerating adoption once a technology is well-established in the marketplace, and still others for completing the process at the maximum market share.

Figure 2: Policy Options to Facilitate Market Transformation

Source: Nadel and Latham (1998).

The appropriate combination of policies and programs in any particular situation depends on the characteristics of the technology and market and the barriers that exist. Some energy efficiency measures, such as improving the efficiency of personal computers and other types of office equipment through adding power management features, are relatively low cost and



provide multiple benefits, making them attractive to consumers and relatively easy to introduce, promote, and achieve high market share. Other measures are more costly, provide narrower benefits, and face other barriers, necessitating more complex strategies involving a number of the policies outlined above (Geller and Nadel 1994).

Both government agencies and utilities are undertaking market transformation energy efficiency programs in the United States (Eto, Goldman, and Nadel 1998). Considerable progress is being made promoting the commercialization and deployment of high-efficiency appliances, office equipment, and lighting technologies (Suozzo and Thorne 1999). The market transformation approach has led to the deployment of energy efficiency and renewable energy technologies in other countries, as illustrated in the case studies below. All of the case studies demonstrate deployment of energy efficiency or renewable energy technologies on a large scale. Some have resulted in market transformation and self-sustaining adoption of efficiency improvements or renewable technologies. Other efforts are still in mid-stream although they have already achieved large-scale impacts.

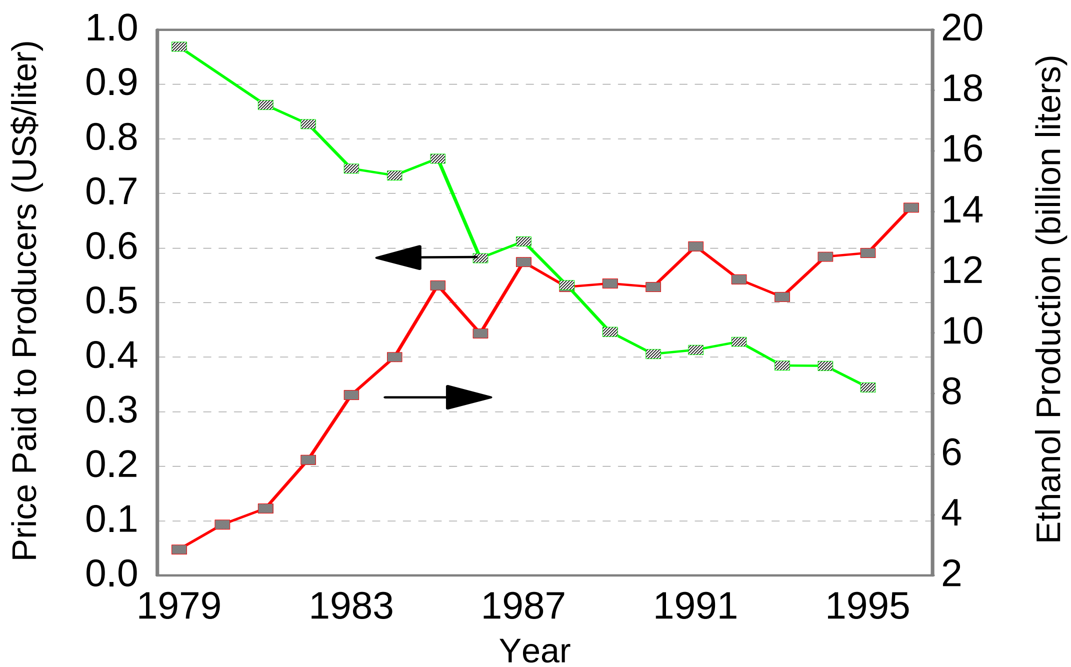
Brazil: Ethanol Fuel

Brazil has one of the largest renewable energy programs in the world—production of ethanol fuel from sugar cane. Ethanol fuel production was begun in 1975 to reduce oil imports and support Brazilian sugar producers. It grew rapidly during 1975–85 and then leveled off (see Figure 3), reaching nearly 14 billion liters per year as of 1996 (Machado 1997). Sugar cane for ethanol is grown on about 2.7 million hectares of land and processed in around 350 distilleries (Moreira and Goldemberg 1999). Ethanol is blended with gasoline with approximately 22 percent ethanol in the fuel blend and also sold to a fleet of approximately 4 million cars that run on neat ethanol. As of 1997, ethanol provided about one-third of the fuel consumed by cars and light trucks in Brazil.

Production of ethanol was stimulated through a combination of policies including: (1) low-interest loans for the construction of ethanol distilleries, (2) guaranteed purchase of ethanol by the state-owned oil company at a price considered adequate to provide a reasonable profit to ethanol producers; (3) pricing of neat ethanol so it is competitive if not slightly favorable to the gasoline-ethanol blend; and (4) tax incentives provided during the 1980s to stimulate the purchase of neat ethanol vehicles. Guaranteed purchase and price regulation were ended recently, with relatively positive results. In addition to these other policies, ethanol producers in the state of Sao Paulo established a research and technology transfer center that has been very effective in improving sugar cane and ethanol yields.

Production of ethanol from sugar cane improves Brazil's balance of payments, reduces unemployment and urbanization pressure, and provides both local and global environmental benefits. Concerning balance of payments, production of ethanol during 1976–96 saved Brazil about $33 billion in oil imports (1996 $) or around $50 billion considering that imports would have been partially debt-financed (Moreira and Goldemberg 1999). This is approximately equal to Brazil's hard currency reserves as of 1998/99. Concerning employment, ethanol production supports around 700,000 jobs in rural areas at a very low investment cost per worker (Moreira and Goldemberg 1999.) Concerning air pollution, introduction of ethanol reduced lead, sulphur, and carbon monoxide emissions in Brazil. Also, Brazil avoided about 9 million metric tonnes of carbon emissions due to ethanol substitution for gasoline in 1996/97, equivalent to nearly 20 percent of its actual carbon emissions from burning fossil fuels (Machado 1997).

Figure 3: Ethanol Production and Price Trends in Brazil



Source: Moreira and Goldemberg (1997).

Regarding economic viability, the price paid to ethanol producers as of 1996/97 was about twice the price of gasoline, in spite of nearly a factor of three reduction in the cost of ethanol production during the past 15 years (see Figure 3) (Goldemberg 1996). Ethanol production was subsidized, based on its positive balance of payments, social, and environmental impacts, using tax revenue collected on gasoline. In 1998/99, the supply of ethanol was deregulated with the price determined by the market, leading to a further decline in the retail price of ethanol, which reached 38 cents (US) per liter (46 cents per liter of gasoline equivalent) as of mid-1999.

Brazil: More Efficient Electricity Use

Brazil's national electricity conservation program (PROCEL) promotes end-use electricity conservation as well as T&D loss reduction. PROCEL supports a wide range of projects in the areas of:

- RD&D
- education and training
- testing, labeling and standards

- marketing and promotion
- private sector support
- implementation in partnership with utilities, states, municipalities, and businesses

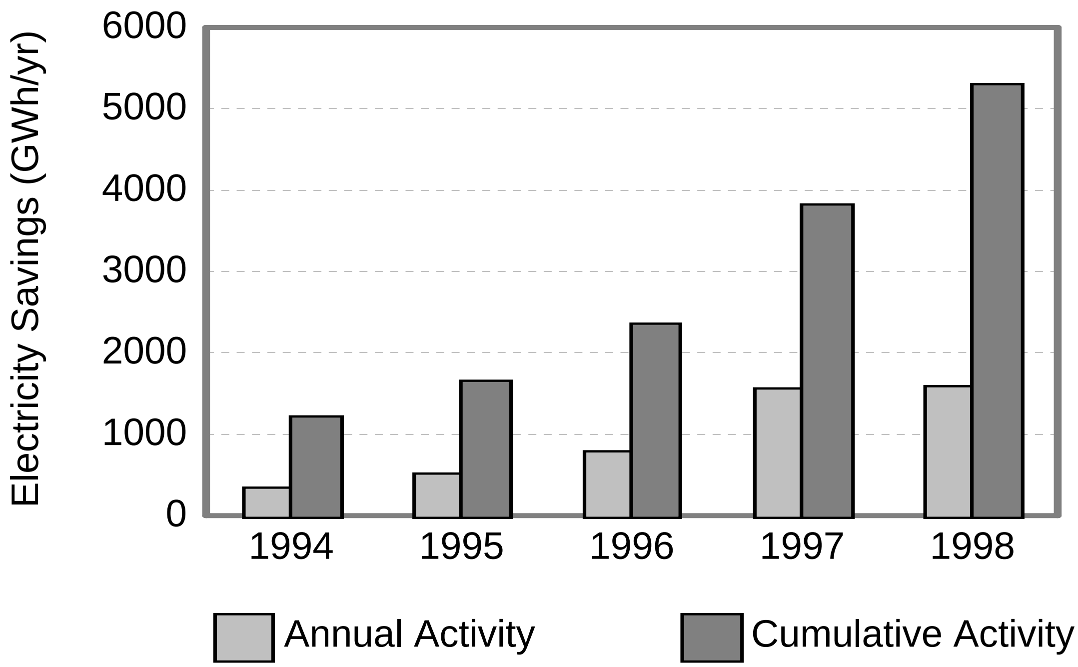
PROCEL began in 1986. By 1996, PROCEL spent about $10 million on "core projects" and facilitated about $40 million in low-interest loans for energy efficiency projects through an energy efficiency financing program. Funding for core projects reached nearly $20 million on low-interest loans totaling nearly $140 million by 1998. However, expenditures lagged due to delays in starting and implementing some projects.

PROCEL has had its biggest impacts in the following areas: (1) increasing the energy efficiency of refrigerators and freezers through testing, labeling, and voluntary agreements with manufacturers; (2) increasing the efficiency of motors through testing, labeling, and R&D projects; (3) increasing the market for energy-efficient lighting technologies such as CFLs; (4) increasing the energy efficiency of street lighting and of fluorescent lamp ballasts; (5) reducing electricity waste in industry through audits, workshops, and information dissemination; and (6) installation of meters in previously unmetered households (Geller et al. 1998).

PROCEL's cumulative efforts reduced electricity consumption and supply-side losses by about 5.3 TWh per year as of 1998, equivalent to about 1.8 percent of total electricity consumption in Brazil (Geller et al. 1999). The electricity savings realized in 1998 were about three times that in 1995 (see Figure 4). Electricity savings as of 1998 enabled utilities in Brazil to avoid constructing about 1,570 MW of new capacity, meaning around $3.1 billion of avoided investments in new power plants and T&D facilities. In contrast, PROCEL and its utility partners spent about $260 million on energy efficiency and power supply improvement projects during 1986–98. Thus, from the utility sector perspective, PROCEL has achieved an overall benefit-cost ratio of around 12:1.

PROCEL has co-funded many projects together with utility, state, and private sector partners. One example was a program in the Jequitinhonha valley, a poor, rural region in the state of Minas Gerais. As of the early 1990s, the region was served by an overloaded transmission line, leading the state utility (CEMIG) to promote greater energy efficiency in order to improve service quality and avoid or delay a costly T&D upgrade. The goal, cutting peak load in the region by 9 MW, was achieved by distributing CFLs to households, stimulating the use of peak demand limiters in houses with electric resistance shower water heaters, upgrading the efficiency of street lighting, and encouraging peak demand management by industries and farms in the region. The program cost CEMIG and PROCEL about $3 million but enabled CEMIG to postpone a $25 million T&D investment while improving energy services to low-income households and small farms.

Figure 4: Electricity Conservation Trends in Brazil



Source: Geller et al. (1999).

China: National Energy Efficiency Program

In the early 1980s, China began a national energy efficiency program focused mainly on industrial energy use in order to reduce investment requirements for energy supply expansion and prevent energy from becoming a brake on economic growth. The program included regulations, mandated reductions, and a monitoring system for industrial facilities; an energy efficiency financing scheme; and support for RD&D. By 1983, over 10 percent of China's energy investments were in energy efficiency. Energy demand growth during 1981–86 fell to half that of economic growth (Sinton, Levine, and Qingyi 1998). Additional policies implemented in the late 1980s included: creation of energy conservation service centers; energy intensity standards for boilers and kilns; more favorable terms for energy efficiency loans; and allowing firms to retain the financial benefits of energy savings projects. Also, steps were taken to increase the average efficiency of power production, e.g., building larger, more efficient power plants.

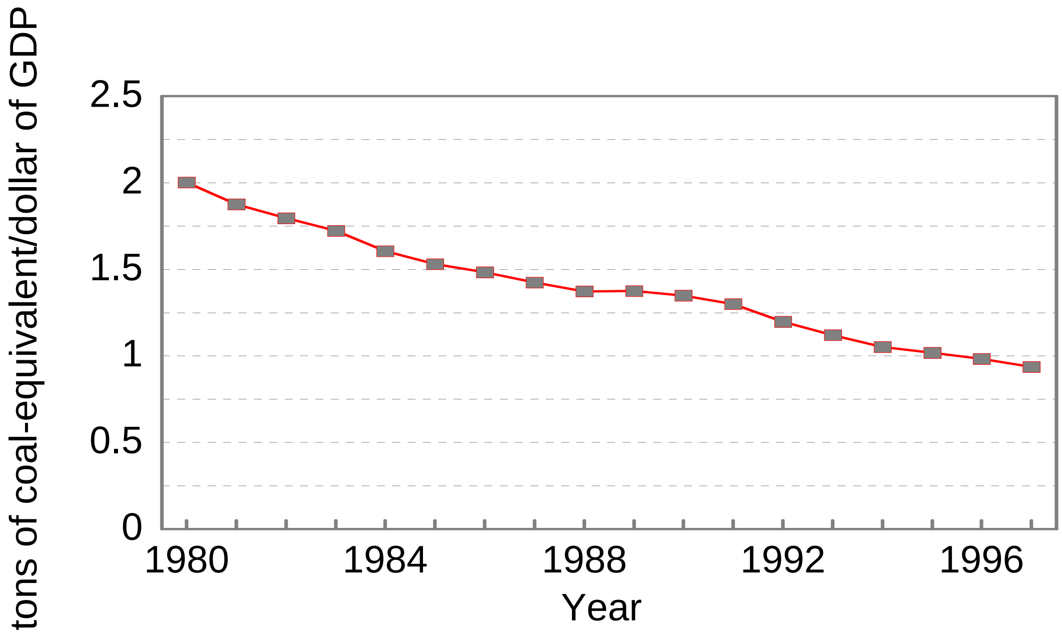
This comprehensive energy efficiency program was extremely successful. As shown in Figure 5, China's energy intensity fell by more than 50 percent between 1980 and 1997 (Zhang 1999). Total energy use and carbon emissions more than doubled during this period due to population growth, very high economic growth, and increasing amenities and standards of living, but energy consumption and emissions would have grown at least twice as fast had these energy efficiency gains not occurred. Part of this reduction in total energy intensity was due to structural shifts, but most was attributed to technical efficiency improvements (Sinton, Levine, and Qingyi 1998). For example, the use of inefficient open hearth furnaces for steelmaking was cut from about 50 percent of capacity in 1970 to less than 15 percent in 1995, with the average energy intensity in steel production falling by 20 percent during 1980–90 alone (Phylipsen et al. 1999). Likewise, the use of the inefficient wet process for cement production was phased out by 1990 with the average energy intensity in cement production falling about 18 percent during 1980–94 (Phylipsen et al. 1999).

China is continuing to enact policies for stimulating energy efficiency improvements. Reductions in energy price subsidies enacted during the 1990s were mentioned previously (see the **Pricing Policies** section). In 1997, an Energy Conservation Law was enacted that calls for stronger energy management efforts in industries, labeling and efficiency standards for mass-produced products, building energy codes, and further financial incentives (Sinton, Levine, and Qingyi 1998). But implementing regulations for the law still need to be developed. Also, with support from the World Bank and the GEF, authorities are attempting to establish private energy service providers and delivery mechanisms (i.e., ESCOs) in China.

China: Improved Cookstoves Deployment

Traditional cooking methods with their high levels of fuel use and smoke cause severe environmental, public health, and social problems for vast numbers of households (and women in particular) in rural areas of developing countries. China has implemented the most sweeping and successful improved cookstoves program in the world. Around 130 million improved stoves, mostly biomass (wood and crop residue) stoves, were installed in rural areas during 1982–92, meaning that over half of rural households in China obtained an improved stove. Although there were problems with quality control and durability in the beginning, these problems were overcome and most stoves have saved fuel, improved indoor air quality, and remained in use (Smith et al. 1993).

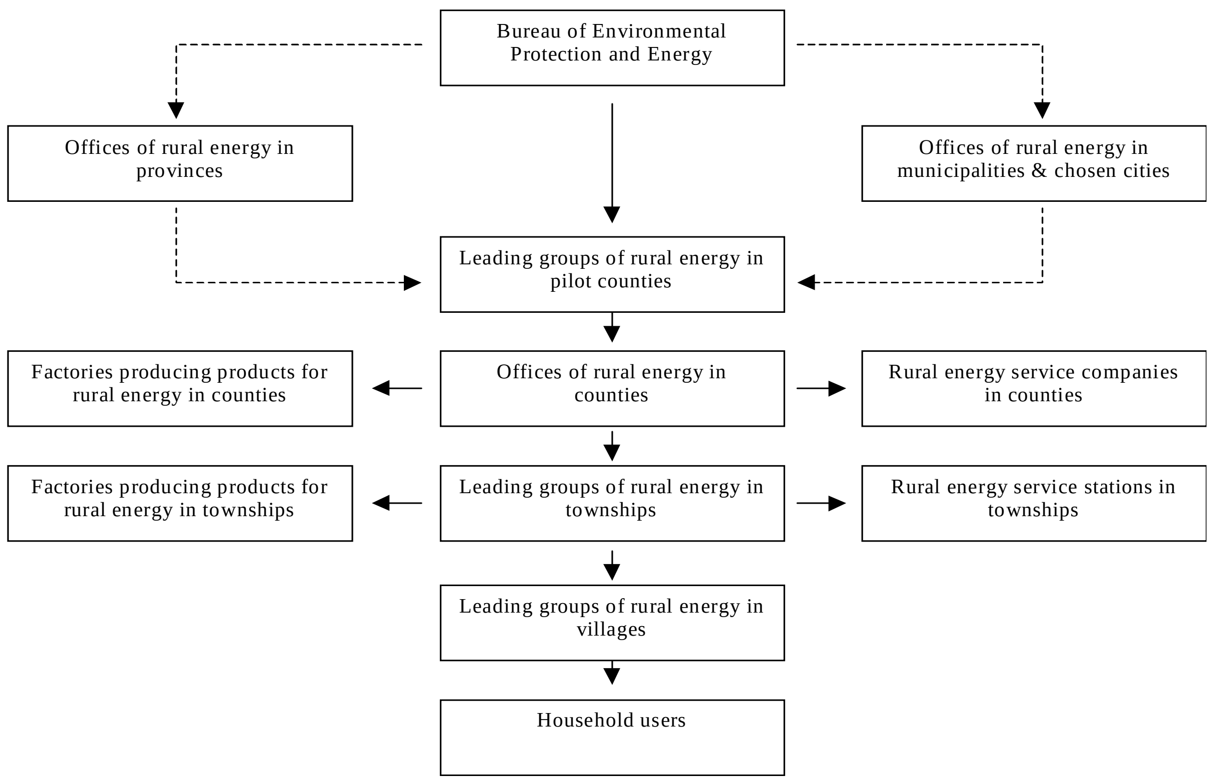
Figure 5: Overall Energy Intensity Trends in China



Source: Zhang (1996)

The Chinese National Improved Stove Program used the following policies and strategies to disseminate improved stoves on this massive scale: (1) R&D through a network of research institutions along with independent testing and monitoring of potential stove designs; (2) decentralized training, promotion, and monitoring through Rural Energy Offices, starting in the counties with the greatest need and interest; and (3) promotion of rural companies manufacturing, installing, and servicing improved stoves, including low-interest loans to help such companies get started, tax incentives, and continued support from the REOs (Smith et al. 1993). Improved stoves are sold by these companies for around $9 per stove on average, without direct government subsidy except for free stove parts provided to very poor households in some regions. The entire effort is overseen by the national Bureau of Environmental Protection and Energy (see Figure 6).

Figure 6: Structure of China's Improved Cookstove Program



Source: Smith et al. (1993).

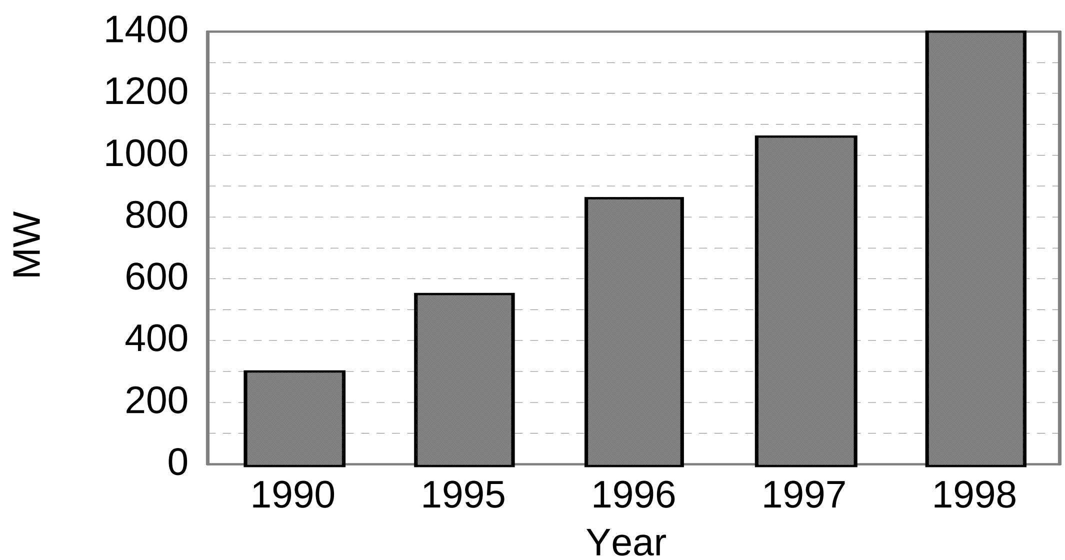
During 1983–89, the Chinese government (national, province, and local) spent about US$158 million supporting the construction of over 110 million stoves. Most of these funds were for local training, promotion, and evaluation activities; subsidies for low-income households; and program staff. For comparison, the total cost for building and purchasing these stoves was about $1 billion. Rural households found that fuel savings, improved air quality, convenience, and other benefits justified the roughly $9 average cost for an improved stove.

Denmark: Wind Power Deployment

Starting in the late 1970s, the Danish government began RD&D programs and introduced capital subsidies to stimulate wind power development. About $75 million was spent on RD&D during 1976–96 (EIA 1999a). Later taxes were placed on fossil fuels, with part of the tax refunded through output subsidies for wind power production. And electric utilities were required to purchase output from wind turbines for about 9 cents per kWh, while receiving about 1.5 cents per kWh from a subsidy pool created by the fossil fuel tax (EIA 1999a). The financial incentives were reduced over time in order to lower government subsidies as the cost of wind power declined.

These policies made wind power cost-effective for both private owners and utilities in Denmark (IEA 1997b). Installed wind power capacity grew from about 300 MW in 1990 to 550 MW in 1995 and then to over 1,400 MW at the end of 1998 (see Figure 7). Denmark is close to meeting its goal of supplying 10 percent of electricity generation from wind power, well in advance of the original 2005 target date.

Figure 7: Installed Wind Power Capacity in Denmark



Source: IEA (1997a).

Denmark has the third largest installed wind power capacity in the world—well ahead of wind power implementation in much larger countries such as France, the U.K., Russia, and Canada. Denmark developed an indigenous wind industry that is contributing significantly to the Danish economy. About 60 percent of new wind turbines installed worldwide in 1998 were made in Denmark, with the Danish wind turbine industry realizing revenues of nearly $1 billion that year (Flavin 1999). Danish wind turbines predominate in Germany and other European countries, and Danish manufacturers have established joint ventures in India and Spain. About 9,000 people were employed directly and indirectly in the wind power industry as of 1995 (IEA undated). One Danish firm recently opened a wind turbine assembly plant and another a wind turbine blade manufacturing facility in the United States—the first new wind turbine facilities built in the United States in many years.

In May 1999, the Danish Parliament modified the policies for promoting wind power, cutting subsidies and shifting to an RPS-type market obligation policy in the future. The overall target is for renewables to provide 20 percent of electricity by the end of 2003 (Madsen and Krogsgaard 1999). Only time will tell if these new policies will be successful.

Eastern Europe: Energy Efficiency Improvement

The formerly centrally planned economies of Eastern Europe and the Soviet Union wasted vast quantities of energy. Consequently, Bulgaria, the Czech Republic, Poland, Russia, and Ukraine created national energy efficiency centers during the 1990s (Chandler et al. 1996). The centers stimulate energy efficiency investments by the private sector and thereby help to lower energy bills and reduce local pollutants and greenhouse gas emissions.

The centers initially received core funding from AID agencies, charitable foundations, and environmental organizations but were required to obtain self-financing after three years. This transition occurred through a combination of contracts and grants from host governments and international organizations, and sales of services to the private sector.

The energy efficiency centers provide policy analysis for reform and greater efficiency, business development through market conditioning and assistance to private firms, demonstrations of new technologies, training, information dissemination, and outreach (Chandler et al. 1996). Among their accomplishments:

- New apartment buildings in six Russian cities, including Moscow, are now built according to standards written by CENEf, the Russian Center for Energy Efficiency.

- Ukraine has invested $6 million in Kyiv government buildings and in private factories at Gostomel and Avdeevka to cut staggering energy costs, thanks to the help of Arena-Eco, the Ukrainian efficiency center. Arena-Eco has helped develop a comprehensive national energy efficiency program including energy efficiency standards and an energy efficiency loan fund.

- Poland has implemented a utility reform law that ensures independent power producers access to the national grid and utility investment in energy efficiency, thanks to legislation drafted by FEWE, the Polish Foundation for Energy Efficiency. FEWE also created an ESCO that has retrofit major apartment complexes.

- SEVEn, the Czech Energy Efficiency Center, has facilitated business partnering, drafted portions of a national energy efficiency law, and prepared energy efficiency plans for a number of Czech cities.

- Bulgaria is participating in the Framework Convention on Climate Change, in part due to the analyses performed by EnEffect, the Bulgarian Center for Energy Efficiency.

India: Renewable Energy Implementation

The Indian Renewable Energy Development Agency was established by the government of India in 1987 to finance and promote the manufacturing and adoption of renewable energy technologies. IREDA provides low-interest loans with a 5–10 year repayment period, training in technical and business skills, publicity campaigns, resource assessments, case studies and manuals, and business development and export assistance (Lal 1998). Concurrently, the Indian Ministry of Non-Conventional Energy Sources works with universities, research institutes, and the private sector to encourage development, demonstration, and deployment of renewable energy technologies. And the Indian government offers one-year depreciation and elimination of import duties and taxes to further improve the economics of renewable energy adoption (Pachauri and Sharma 1999). Market development is a major focus of this strategy, which has received co-funding from the World Bank and the GEF.

This comprehensive market-oriented approach has achieved impressive results (see Table 2) although it remains to be seen if the adoption of renewable technologies will continue to grow in India if/when government subsidies are cut. About 15 companies are engaged in production and assembly of wind turbines, often through licensing or joint ventures, and nearly 1,000 MW of wind capacity was installed as of 1998 mostly by private companies (Kamalanathan 1998). This makes India the world's fourth largest wind power generator behind Germany, the USA, and Denmark. However, installation of wind turbines fell significantly in 1997 and 1998 compared to 1996 due to a reduction in tax credit benefits caused by changes in overall tax policy, reduced marketing in some states, and other indirect factors (TERI 1998).

Furthermore, around 75 companies are involved in PV cell and panel production in India. Over 450,000 solar PV systems have been installed aggregating to 40 MW, making India the largest user of solar PV systems in the world (Boparai 1998). In the area of bioenergy, about 250 MW of biomass-based power systems are operating or under construction along with over 2.5 million biogas plants. The total renewable energy market in India is over $500 million per year (Boparai 1998).

Table 2: Promoting Renewable Energy in India

Policies	Results (as of March, 1998)
• revolving load funds & low-interest loans	• 970 MW of wind power
• accelerated depreciation (tax incentives)	• 800 MW of bagasse cogeneration
• R&D & demonstrations	• 155 MW of mini & micro hyrdopower
• development of manufacturing, marketing, and service infrastructure	• 40 MW of photovoltaic power systems
• training	• 2.7 million biogas plants
• information dissemination	• 430,000 solar cookers
	• 400,000 square meters of solar water heaters

Source: Lal (1998); TERI (1998).

Netherlands: Energy Efficiency Improvement Targets and Agreements

The Dutch government adopted a comprehensive set of policies to stimulate industrial energy efficiency improvements starting in 1990. The policies are based around formal agreements between the government and specific industrial sectors. The agreements, which are based on independent assessments of cost-effective savings potential, contain negotiated targets that are legally binding and typically call for a 20 percent average increase in energy efficiency by 2000 relative to 1989 levels (Nuijen 1998).[1] Participating companies agree to develop and implement an energy efficiency improvement plan, and improve energy efficiency wherever technically and economically feasible, in order to contribute to the industry target. Companies also agree to report on progress annually. In return, the government provides detailed energy audits of industrial facilities, tax incentives for investments in energy-efficient technologies and other subsidies, and protection from mandatory energy efficiency regulations.

By the end of 1996, the Dutch government had signed agreements with 31 industrial sectors and 6 service sectors. About 1,000 industrial companies accounting for over 90 percent of industrial energy use in the Netherlands were participating. Furthermore, the average energy efficiency improvement as of the end of 1996 was 12.5 percent, meaning the companies were on track for achieving a 20 percent improvement on average by 2000 (Nuijen 1998). Some examples are illustrated in Table 3. So far no sectors have abandoned their agreement.

[1] Energy efficiency is based on primary energy use per unit of output; 23 sectors adopted a 20 percent efficiency improvement target, five sectors adopted a target of less than 20 percent, and nine adopted a target greater than 20 percent.

Table 3: Energy Intensity Reduction Targets and Achievements in Key Industrial Sectors in the Netherlands

Sector	Target for 2000 (a)	Achievement in 1995 (b)
chemicals	20	9.3
iron & steel	20	10.8
paper	20	13.2
textiles	20	9.9
glass	20	12.0

(a) target relative to energy intensity in 1989, in percentage reduction
(b) achievement during 1989–1995, in percentage reduction

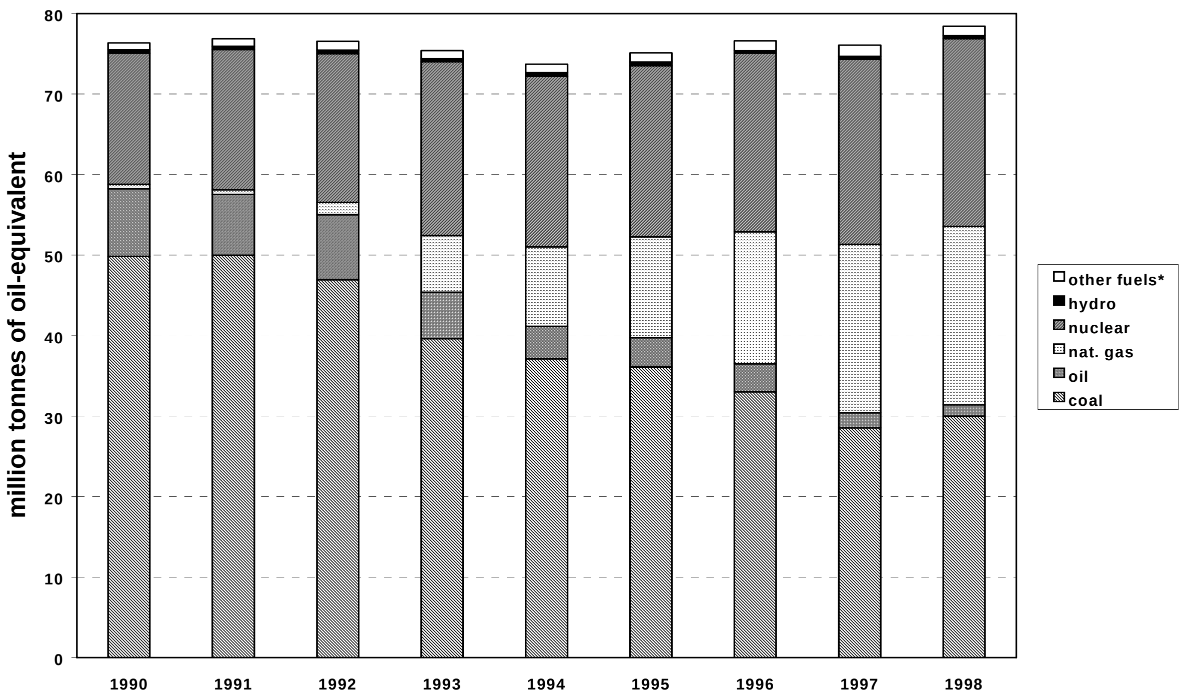
Source: Nuijen (1998); Rietbergen, Farla, and Blok (1998).

An evaluation of the Dutch industry agreements program found that participating companies devoted more attention to energy management and opportunities for efficiency improvement, and that companies were generally satisfied with the program (Nuijen 1998). Assessments indicated that 25–45 percent of the energy efficiency improvement achieved during 1990–95 can be attributed to the agreements (Rietbergen, Farla, and Blok 1998). The effort is projected to cost the Dutch government $690 million during 1990–2000 including tax incentives and other subsidies, with industries saving this amount on their energy bills annually by 2000 (Nuijen 1998). Given the success so far, a new round of agreements for 2000–2010 is expected to be developed and approved by the end of 1999.

United Kingdom: Shift from Coal to Natural Gas-Based Power Plants

The restructuring that has occurred in the electric sector in the United Kingdom during the 1990s has produced substantial environmental benefits including a significant reduction in sectoral CO_2 emissions. Starting in 1990, the U.K. power industry was largely privatized and restructured. During the 1990s, competition was steadily increased, subsidies for coal production were cut, natural gas production was privatized and deregulated, and regulations to cut emissions of acid rain precursors were implemented (Eikeland 1998). These policies led to substantial growth in natural gas-fired combined cycle generation by privatized utilities as well as independent power producers (IPPs). Natural gas achieved a 30 percent market share for power production as of 1998 compared to virtually no natural gas use for power production prior to 1990 (Eyre 1999). The fraction of power production from coal fell from 65 percent in 1990 to around 38 percent by 1998 (see Figure 8).

Figure 8: Fuel Input for Power Production in the United Kingdom



Source: Eyre (1999).

The shift from coal to natural gas for power production reduced carbon emissions by about 14 million metric tonnes between 1990 and 1997, equivalent to an 8 percent reduction in total U.K. carbon emissions (Eyre 1999). This significant reduction was due to both the lower carbon content of natural gas compared to coal and the efficiency improvement provided by state-of-the-art combined cycle power generation. Other policies that contributed to a "decarbonization" of power generation in the U.K. include greater competition in the gas industry leading to falling natural gas prices, improvements in nuclear power plant performance, and promotion of combined heat and power (CHP) systems. Also, the Non-Fossil Fuel Obligation (described above under **Market Obligations and Reserves**) led to about 2.5 percent of capacity supplied by renewables and waste materials (Eyre 1999).

With the election of the new Labour government, additional steps are being taken to reduce carbon and other pollutant emissions by the power sector. The government proposed a target of 10 percent of total electricity from renewable sources and doubling installed CHP capacity by 2010 as well as a climate change tax on fuel and electricity. However, a moratorium on approval of new gas-fired combined cycle power plants was adopted due to concerns that further deep and rapid reductions in coal use could occur (Eyre 1999). Ironically, this policy gave a boost to CHP since gas-fired CHP plants are exempt from the moratorium. A 500 MW state-of-the-art gas-fired cogeneration plant was approved in South Wales in early 1999 (Ellis 1999).

The experience in the U.K. shows that restructuring and increased competition in the power and fuels sectors can be compatible with environmental protection and declining CO_2 emissions. However, this positive result is by no means guaranteed, as evidenced by the experience in the United States where electric sector restructuring, stimulated by national legislation in 1992 that increased wholesale competition along with the introduction of retail competition in some states, has resulted in greater reliance on low-cost, dirty coal-fired generation. During 1990-98, 47 percent of the growth in power production in the United States was provided by coal-fired capacity and only 26 percent by natural gas in spite of significant growth in IPPs (EIA 1999b).

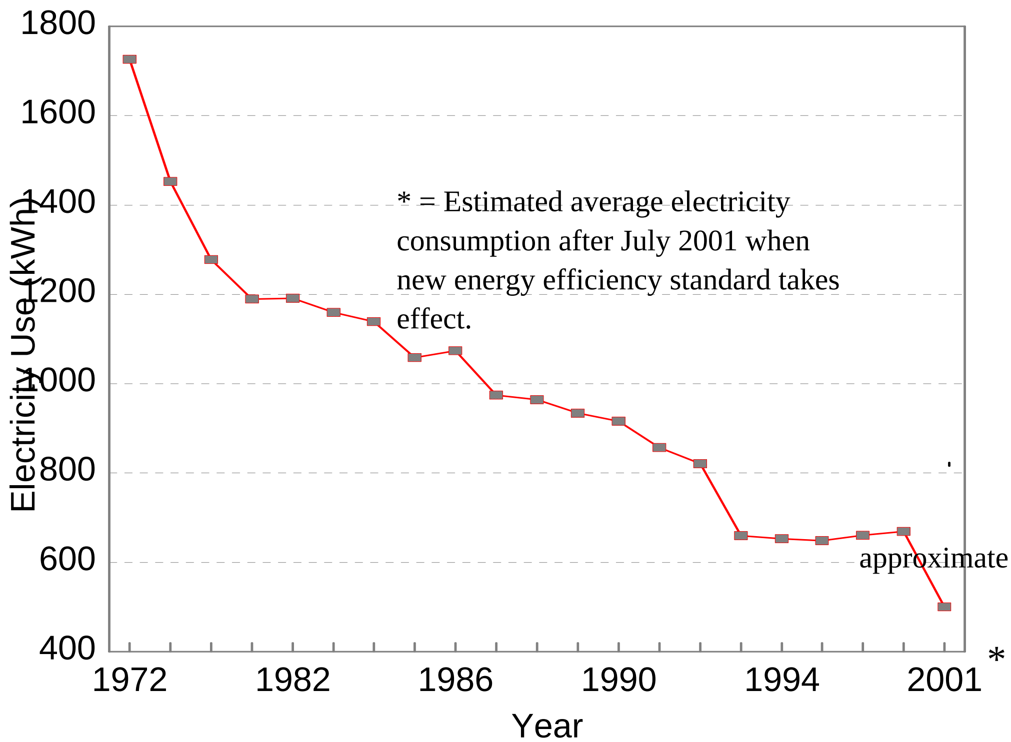
United States: Appliance and Vehicle Efficiency Improvements

The energy efficiency of domestic appliances and other types of mass-produced equipment dramatically improved in the United States during the past 25 years. For example, the average electricity use of new U.S. refrigerators declined from 1800 kWh per year in 1974 to about 600 kWh per year in 1998 (see Figure 9), while the average size and number of features increased. This was a result of enacting mandatory efficiency standards—first at the state level and later at the national level—along with utility incentive payments, government-funded RD&D, and labeling of efficient products (Geller and Nadel 1994).

These complementary policies are expected to reduce U.S. electricity use by 88 TWh (2.7 percent) in 2000 and 193 TWh (5 percent) in 2010, leading to net savings of over $160 billion for consumers and about 60 million metric tons less carbon emissions in 2010 (Geller and Goldstein 1998). New standards under consideration by the U.S. Department of Energy could save an additional 100 TWh by 2010 and at least $15 billion net for consumers.

Efficiency standards on cars and light trucks, known as Corporate Average Fuel Economy standards were adopted in the United States in 1975. They are largely responsible for the near doubling in the average fuel economy of new cars and the more than 50 percent increase in light truck fuel economy from 1975 to 1985 (Greene 1999). Had these improvements not occurred, the U.S. car and light truck fleet would have consumed an additional 3 million barrels of gasoline per day as of 1995. The standards were met largely with cost-effective technological innovations (engine improvements, weight reduction, etc.) and without significant negative side effects (Greene 1999). A tax on inefficient "gas guzzlers" also contributed to the overall increase in fleet fuel economy during the 1980s (Geller and Nadel 1994).

Figure 9: Average Electricity Consumption of New U.S. Refrigerators



Source: Assoc. of Home Appliance Manufacturers

The CAFE standards for cars reached their maximum level in 1985; small increases in the standards for light trucks were adopted since then. The average fuel economy of new cars and light trucks has actually declined slightly since the mid-1980s because of a shift from cars towards sport utility vehicles, pickup trucks, and minivans. However, the decline in fuel economy would have been greater had the CAFE standards not remained in effect. Opposition from vehicle manufacturers has prevented policymakers from strengthening the CAFE standards.

United States: More Efficient Electricity Use in California

Utilities in the state of California have implemented large-scale demand-side management programs for about 15 years. As of 1994, utilities in California were spending about $260 million per year or 1.4 percent of their revenues on these efforts (Eto, Goldman, and Nadel 1998). The programs include rebates for consumers that purchase efficient appliances, air conditioners, and lighting products; free retrofits for low-income households; support for implementation of building energy codes; and technical assistance to businesses and industries. During 1990–94, these programs in aggregate saved over 5,000 GWh per year at a cost of saved energy of around $0.025 per kWh, providing consumers in California net life-cycle benefits of $2.2 billion (Ogden 1996).

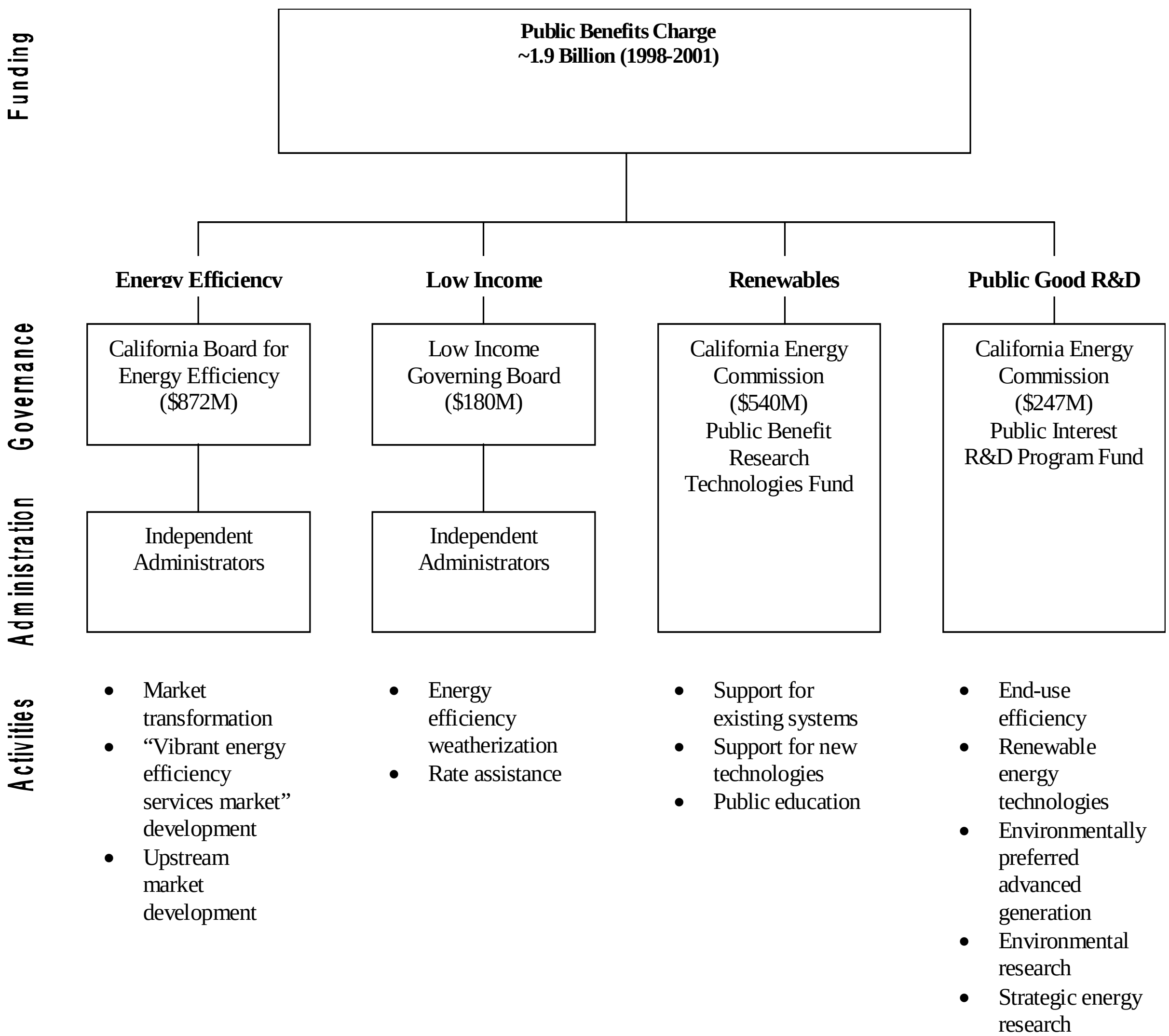
Vigorous utility DSM programs in California were stimulated in part by the regulatory policies of the California Public Utilities Commission (CPUC). The CPUC allowed utilities to recover lost sales revenues and keep a portion of the net societal benefits resulting from their DSM programs. The cost recovery and bonus payments were implemented through a small rate adjustment each year following thorough monitoring and evaluation of each utility's DSM programs. The regulations provided utilities with financial incentives to maximize energy savings and the net economic benefits of their DSM programs (Nadel, Reid, and Wolcott 1992).

Utility DSM programs, appliance efficiency standards, tough building energy codes, and other energy efficiency efforts had a significant impact on electricity use in California during the past twenty years. Electricity use per capita remained relatively constant during 1975–93, a period during which electricity use per capita increased 35 percent in the United States as a whole (CEC 1995).

With the passage of electricity restructuring legislation in California in 1996, policymakers developed a new model for ratepayer-funded energy efficiency programs—a model more appropriate for a competitive electricity marketplace. The legislature mandated a nonbypassable "wires charge" of $0.003 per kWh (equivalent to about 3 percent of the average tariff) on all kWhs entering the T&D system in order to maintain funding for a variety of "public goods" programs in California including energy efficiency programs, low-income energy assistance, support for renewable energy sources, and public goods R&D (see Figure 10).

Energy efficiency programs, funded at around $220 million per year ($0.0013 per kWh), are implemented through a competitive process overseen by a newly created advisory board (Eto, Goldman, and Nadel 1998). This ended the de facto monopoly utilities had on ratepayer-funded energy efficiency programs. In practice, distribution utilities are continuing to implement a large portion of the new energy efficiency programs. However, greater emphasis is now devoted to creating a robust energy efficiency services industry in California as well as supporting a range of market transformation programs, with considerably less money spent on traditional rebates and other financial incentives (Eto, Goldman, and Nadel 1998).

Figure 10: Structure of Public Benefit Programs in California



Source: Eto, Goldman, and Nadel (1998).

SPECIAL CONSIDERATIONS IN DEVELOPING COUNTRIES

Developing countries present some special needs and opportunities when considering policies for advancing energy efficiency, renewable energy, and clean fossil fuel technologies. First, developing countries often lack institutions and capacity for promoting and implementing these technologies on a large scale and in a sustained manner. Second, energy policies should take into account the social and economic conditions and priorities that exist in developing countries. And third, developing countries present opportunities for technology innovation and leadership since they are still putting in place their industrial, transport, buildings, and power infrastructures. Each of these issues is addressed below.

Capacity Building

Capacity and institution building is essential if energy efficiency, renewable energy, and clean fossil fuel technologies are going to make a major contribution to future energy resource and service needs in developing countries. These countries require multidisciplinary expertise in:

- technology development, adaptation, and testing
- manufacturing and marketing
- deployment and behavioral issues
- monitoring and evaluation training energy managers and end-users
- policy development and implementation

Capacity and institution building is needed to form and staff the public sector agencies and research institutes that can support sustainable energy development. Capacity building also is needed to create and staff the private companies that will produce, market, and install energy efficiency, renewable energy, and clean fossil fuel technologies. Without strong private sector actors and markets as well as sustainable energy programs and agencies, energy efficiency and renewable energy efforts in developing countries are likely to be ad hoc, limited in scope, and insufficient to overcome the full set of barriers inhibiting large-scale implementation (Kammen 1999).

There is empirical evidence showing that technological and managerial capabilities are critical for successful technology transfer and innovation in developing countries. For example, studies show that industrial firms in Thailand were more successful at implementing energy-saving process improvements if they had higher levels of technical and managerial skills (Chantramonklasri 1990).

Capacity and institution building in part means forming strong national energy efficiency and renewable energy centers and programs like those established and successfully operating in Brazil, China, India, and Eastern Europe (see case studies above). These centers and programs work with the private sector, utilities, and other entities to introduce and widely disseminate energy efficiency and renewable energy measures. The centers and national programs can:

- provide education and training
- conduct RD&D
- adopt and implement efficiency standards
- perform product testing, labeling, and certification
- conduct marketing and promotion
- encourage local manufacturing of energy efficiency and renewable energy technologies
- help establish and support energy service companies
- provide financing and/or financial incentives
- develop and analyze policy reforms

It is critical that such centers and programs support rather than compete with the private sector in market development. This means involving the private sector in program design as well as implementation. Strong government-private sector collaboration was a key characteristic of many of the case studies presented above (e.g., wind power in Denmark, improved cookstoves in China, and renewable energy in India).

Capacity and institution building could be given greater priority both by national governments in developing countries and by international assistance agencies, both bilateral and multilateral agencies. The Global Environmental Facility, for example, could provide more resources for capacity and institution building, and consequently less funding for implementation of discrete projects. Donors will need patience since capacity and institution building, while essential over the long run, may not provide immediate, tangible results in terms of renewable energy or energy efficiency devices installed.

Energy and Social Links

There are strong links between energy production and use on the one hand and social conditions on the other. Put simply, lack of modern energy sources (especially in rural areas) contributes to poverty, poor health and education, unemployment, and high population growth. Conversely, provision of clean, efficient, and modern energy sources (especially in rural areas) can:

- reduce burdensome labor requirements for collecting firewood and water, and relying on human labor for farming;
- enhance education opportunities by diminishing the need for child labor, providing better quality artificial lighting, and freeing up capital that would otherwise be spent on conventional energy supply expansion for investment in education infrastructure;
- strengthen public health by cutting the need for "backbreaking" human labor and improving indoor and outdoor air quality, and water quality and sanitation;

- create job opportunities in energy efficiency and renewable energy industries, as exemplified by the ethanol fuel program in Brazil, the wind power industry in Denmark, and the development of renewable energy manufacturing and service industries in India; and
- lower population growth by improving education levels and reducing the need for child labor.

Thus, providing renewable-based fuels and electricity, improved cookstoves, mechanical water pumping, and mechanized farming equipment should be given high priority in national and regional economic and social planning, not just energy planning and investment. Likewise, energy policies and programs should pay special attention to serving the needs of low-income households in both urban and rural areas, not just to serving (or in place of serving) the needs of businesses and wealthier households. This means ensuring that low-income households get access to solar energy devices and efficient lighting, appliances, dwellings, and vehicles, rather than getting stuck with low-quality fuels; older, second-hand appliances; incandescent lamps; poorly insulated dwellings; etc. In order to provide this access, attractive micro-credit and/or discount schemes are necessary, e.g., as demonstrated by the successful Grameen Bank in Bangladesh (Werner 1999).

Aggressively pursuing energy efficiency and renewable energy sources can help to address another major social need in developing and some industrialized countries—job creation. The example of Brazil's ethanol fuel program, which employs about 700,000 workers in rural areas, was previously outlined in a case study. Another example is the wind turbine industry in Europe. Some 30,000 jobs have been created in the wind turbine industries in Denmark, Germany, and Spain alone (Wagner 1999). Likewise, increasing energy efficiency can increase net employment since it shifts economic activity away from sectors that employ relatively few workers (i.e., coal mining, oil production, etc.) to sectors that are more labor-intensive, due to the direct impacts as well as the recycling of energy bill savings (Geller, DeCicco, and Laitner 1992).

Fostering Technological Innovation and Leadership

Developing countries have some features that could enable them to be leaders in worldwide sustainable energy innovation. These features include plentiful renewable energy resources and energy efficiency opportunities; large, untapped markets; nascent industrial, transport, buildings, and power infrastructures; and rapid growth rates in energy production and energy-intensive activities (Reddy, Williams, and Johansson 1997). As developing countries progress economically and socially, they have the opportunity to "leapfrog" over the inefficient, fossil fuel-based, and polluting energy production and consumption patterns commonly found in industrialized nations (Goldemberg 1998).

The Brazilian ethanol fuel program provides one example of "technology leapfrogging." Other examples underway or under consideration are reliance on distributed renewable power technologies for rural electrification; use of biogas plants in China and India; adoption of CNG, electric, and fuel cell-based vehicles as motorized vehicles are introduced in developing countries; and use of high-efficiency, low-polluting industrial manufacturing processes, such as electric arc furnaces, continuous casting, and smelt reduction steelmaking in the steel industry (PCAST 1999). For example, South Korea and South Africa installed the first COREX smelt reduction steel plants that are operating in the world. Also, steel manufacturers in these countries have adopted a high level of continuous casting relative to international standards (Phylipsen et al. 1999).

The policies that can foster energy technology innovation and leadership in developing countries include: (1) supporting RD&D that emphasizes clean energy supply and energy end-use technology innovation in developing countries; (2) encouraging development of new industries and introduction of new technologies through international joint ventures and other mechanisms (see next section, **International Policies**); (3) adopting and enforcing strong energy efficiency and environmental standards in developing countries so that new infrastructure is state-of-the-art rather than outdated; and (4) providing attractive financing, market development assistance, and government procurement to clean energy technology entrepreneurs, whether these companies are locally owned, international, or joint venture (Goldemberg 1998).

Bilateral and multilateral financing and assistance agencies could be more open to supporting energy technology innovation in developing countries. The World Bank and the GEF are supporting renewable energy technology market development in India and an innovative biomass gasification and combined cycle power plant demonstration project in Brazil. But projects like these are still the exception rather than the rule for the World Bank and other MDBs.

INTERNATIONAL POLICIES

Cooperative Action

Cooperation among countries can be useful in achieving market transformation especially for mass-produced products that are manufactured and sold on an international scale. Cooperative efforts to increase the energy efficiency of electronic products and automobiles in Europe was mentioned previously in **Testing, Labeling, and Voluntary Agreements**. Also, the United States, Japan, and the European Union have agreed to work together to promote energy-efficient office equipment through use of the ENERGY STAR® label (Thigpen et al. 1998). This is an especially attractive area of cooperation given that the same personal computers, printers, copiers, and fax machines are sold worldwide and that demand for these products is growing rapidly.

International policy cooperation faces a number of challenges including agreeing upon key technical parameters (e.g., minimum energy efficiency levels or incentive levels), program coordination, and program administration (Thigpen et al. 1998; Varone and Aebischer 1999).

For example, it has been very difficult to agree on harmonized appliance efficiency standards in the European Union due to different national perspectives and interests. The experience in Europe shows it is easier to agree on voluntary or labeling schemes than strict regulatory policies.

Technology Transfer Mechanisms

Technology transfer between industrialized and developing countries can be an important component of sustainable energy development worldwide. In considering technology transfer mechanisms, it is important to recognize that foreign direct investment by private companies is a growing share of total net resource flows to developing countries. Official development aid (ODA) has remained relatively steady in recent years but represents a shrinking fraction of net resource flows. ODA represented only about 15 percent of net resource flows to developing countries in 1997 compared to about 43 percent in 1990. Of the roughly $48 billion in ODA in 1997, technical cooperation represented about $13 billion. In contrast, foreign direct investment reached about $110 billion in 1997, around 43 percent of net resource flows that year (Goldemberg 1999).

Given the growing importance of foreign direct investment and the substantial technological and business expertise in energy efficiency and renewable energy technologies among industrialized countries, encouraging joint ventures, licensing, and technology acquisition can be effective strategies for disseminating clean energy technologies in developing countries. Manufacturing (or assembly) and marketing are carried out locally by joint venture partners or licensees. This key strategy is used in renewable energy development in India, for example. In another example, Shell International Renewables Ltd. and Eskom (a state-owned utility in South Africa) have established a joint venture to assemble, market, and service off-grid PV systems in South Africa. The solar panels will be manufactured by Shell but other system components are being made and assembled in South Africa. In the case of smelt reduction steel mills built in South Korea and South Africa, the technologies were purchased from specialized suppliers based in industrialized countries (de Beer, Worrell, and Blok 1998).

Joint ventures and licensing can help developing countries obtain state-of-the-art technologies at attractive prices. A substantial number of local jobs can be created through local manufacturing or assembly, helping to reduce costs. In some cases, it may be necessary to import key components and assemble technologies locally at first, with nationalization occurring as markets grow. Governments can encourage joint ventures and licensing of sustainable energy technologies and services by providing financing, tax incentives, and/or market development support. Furthermore, strengthening intellectual property rights protection can facilitate the flow of advanced technology to developing countries (PCAST 1999).

Bilateral Assistance

A number of industrialized countries have increased their bilateral support for sustainable energy development and deployment in Third World countries in recent years (PCAST 1999). There are many examples of valuable bilateral assistance. The Brazilian PROCEL program, for example, has received assistance in program design and evaluation, training, and marketing from Canadian, European, and U.S. experts. PROCEL is implementing an industrial Best Practices program with support from U.K. experts; motors incentive programs with support from Canadians experts; and ESCO training and development with help from U.S. experts. Likewise, the Danish International Development Agency (DANIDA) has provided grants and low-interest loans to help establish wind power in various developing countries, based on export or licensing of Danish wind technologies.

But bilateral assistance tends to be project-focused, controlled and carried out by industrial nation representatives, and driven by political considerations (PCAST 1999). Greater emphasis should be given to longer-term and multi-pronged efforts aimed at barrier removal, capacity and institution building, and market development. A long-term commitment from donors and lenders is needed to develop self-sustaining markets and ultimately market transformation (Kozloff 1995).

Multilateral Institutions

The World Bank, the Inter-American Development Bank, the Asian Development Bank, the EBRD, and the African Development Bank are important lenders for energy projects in developing and transition countries. The multilateral development banks provide loans to governments (and the private sector in the case of the IFC) at attractive interest rates. Also, recipient nations are able to obtain further loans at attractive terms once the World Bank or regional development banks give their "stamp of approval" to a project.

Financing at reasonable interest rates is often critical for the successful diffusion of end-use energy efficiency and renewable energy measures. For example, credit schemes are facilitating the adoption of off-grid household solar PV systems in many developing countries. The MDBs have contributed to some these programs (e.g., in India and Indonesia) but the banks could expand their support. The MDBs should consider providing both debt and equity capital to energy efficiency and renewable energy entrepreneurs, as the EBRD is doing through its financing of ESCOs in Central/Eastern Europe.

Historically, the vast majority of energy sector loans by the development banks was devoted to large-scale hydropower, fossil fuel, and energy infrastructure projects. Very little funding was devoted to energy efficiency or smaller-scale renewable energy technologies. For example, during 1992—1996, only one-third of one percent of World Bank power sector lending was dedicated to increasing the efficiency of electricity use, in spite of the enormous potential for saving electricity more cost-effectively than supplying electricity in developing countries (Strickland and Sturm 1998).

Recently the development banks have begun to improve on this record. The EBRD example mentioned above involved a total investment of about $45 million in three private ESCOs and one state-owned ESCO in the Ukraine. The World Bank indicated that during 1994–97 it approved $1.2 billion in loans for end-use energy efficiency projects, efficiency improvements in district heating systems, and non-traditional renewable energy projects—equivalent to about seven percent of total World Bank energy loans during this five-year period (World Bank 1998b). Furthermore, the World Bank indicated that $1.5 billion in energy efficiency and renewable energy loans are "in the pipeline" and are scheduled to be approved during 1998–2000.

This is a positive trend, but the World Bank and other multilateral development banks should devote an even greater portion of their energy lending to economically and environmentally sound sustainable energy technologies. As the markets for and capability to implement sustainable energy technologies in developing nations grow, the MDBs should phase out their funding for conventional energy projects and allocate these resources largely or solely to energy efficiency, renewable energy, and cleaner fossil fuel technologies. If developing countries prefer conventional energy technologies, project developers could obtain financing from commercial banks or other sources of capital.

To facilitate this transition in priorities, the MDBs should increase their own capacity and expertise in energy efficiency and renewable energy technologies. The Asia Alternative Energy Program (ASTAE) within the World Bank is a good model for this. The mission of ASTAE is to mainstream energy efficiency and renewable energy projects within World Bank energy lending to Asian nations. Major loans have been approved for India, China, Indonesia, and other countries, in many case together with grant funding from the GEF or bilateral donors for training, capacity building, and market development. Through 1998, ASTAE helped to develop and obtain approval for 24 projects involving about $750 million in loans from the World Bank and/or GEF grants (World Bank 1998a).

Climate Treaty Provisions

Article 6 of the Kyoto Protocol allows joint implementation between Annex 1 (i.e., industrialized and transition) nations. It also allows parties investing in such projects to receive transferable emissions reduction credits. This provision is intended primarily to allow western nations to invest in and receive credits for energy efficiency projects in Eastern Europe and the former Soviet Union (Flavin and Dunn 1998). This provision also could help to stimulate renewable energy projects in these countries but it remains to be seen if the Kyoto Protocol will be ratified and, if it is, how popular joint implementation will be and what overall effect it will have on clean energy development and efficiency improvement in these nations. Since energy waste is widespread and efficiency improvements are very cost-effective, energy efficiency upgrades in factories and buildings are already starting to be implemented in Eastern Europe and the former Soviet Union (Chandler et al. 1996). It is unclear if joint implementation will significantly accelerate this ongoing trend.

Article 12 of the Kyoto Protocol provides for a Clean Development Mechanism that could foster additional investment in renewable energy, energy efficiency, and natural gas projects in developing countries. The CDM allows parties in western nations to receive emissions credits for investing in projects that reduce greenhouse gas emissions in developing countries, as long as some benefits accrue to the host country. However, the Protocol only contains an outline of the CDM. The detailed structure and functioning still need to be worked out. One of the most controversial issues is the definition of baselines—the emissions that would have occurred without the project (Michaelowa and Dutschke 1999). Other issues that need to be resolved include who will do the certification, monitoring and verification of emission reductions, and whether or not there will be a limit on the extent to which Annex 1 nations can use credits to meet their emissions reduction commitments (Vine and Sathye 1999).

CONCLUSION

Increased energy efficiency, greater reliance on renewable energy sources, and use of cleaner fossil fuel technologies such as combined cycle natural gas power plants could have enormous economic, social, and environmental benefits worldwide. But a host of barriers are limiting the introduction and deployment of these resources in both developing and industrialized nations. These barriers pertain to technology availability and performance, consumer decisionmaking, market organization, financing, taxes, energy pricing, and regulatory issues.

Policy reform and action is needed at all levels—international, national, regional, and local—to overcome these pervasive barriers. Policies should be tailored to the conditions and political realities in each country and market. For example, some countries will favor tax and incentive approaches, others regulatory approaches. Policies should be combined and integrated into market transformation strategies, addressing needs for both "technology push" and "demand pull." Moreover, policies should evolve over time as some barriers are removed and others come to the forefront.

The case studies presented above show that it is possible to overcome the barriers and implement energy efficiency, renewable energy, and clean fossil fuel technologies on a large scale. In reviewing these case studies, it is obvious that adopting a national initiative or a set of national initiatives is a key feature of virtually all the examples. The case studies show that the private sector will respond in creative and effective ways when motivated by strong national policies.

The case studies also show that policies can have a significant impact on energy supply and consumption patterns. But much more needs to be done. Many of the successful policies and programs described above need to be expanded. For example, PROCEL is cutting electricity waste in Brazil 2 percent when the cost-effective efficiency potential is at least 20 percent and IREDA has financed about 400,000 PV-based lighting, pumping, telecommunications, and other power systems but hundreds of millions of Indians continue to live without electricity. Some policies and programs, such as vehicle efficiency standards in the United States, need to be updated. And all of these relatively successful policies and programs need to be replicated many times over. Comprehensive energy efficiency and renewable energy policies and programs like China's energy efficiency program, the Danish wind power program, Dutch industry agreements, U.S. appliance efficiency standards, PROCEL, and IREDA are needed in every nation, rich and poor.

While national policies and programs are the foundation for successful market transformation, the participation of state and local authorities and action at the regional and local level can be critical to the success of national policies and programs. This was evident from experiences such as the cookstoves and energy intensity reduction efforts in China and the regional energy plan of Upper Austria. Likewise, international agencies such as the MDBs and the GEF can play a key role in financing national efforts, as well as in supporting capacity and institution building. International cooperation should be expanded where appropriate, such as in promoting efficiency improvements in mass-produced products that are manufactured and sold worldwide.

Finally, the private sector should be involved in policy development since it plays a key role in implementation. Private sector cooperation can determine whether or not a policy (or set of policies) succeed(s). While some companies have a vested interested in maintaining an inefficient and carbon-intensive energy future, other companies are actively developing, producing, or investing in high-efficiency, renewable energy, and advanced fossil fuel technologies. Policymakers can work with these innovative companies to develop and implement progressive policies and programs that will lead to a more sustainable energy future.

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