



TRANSFER OF ENVIRONMENTALLY SOUND TECHNOLOGIES: THE GEF EXPERIENCE



**GLOBAL
ENVIRONMENT
FACILITY**

INVESTING IN OUR PLANET



FOREWORD



Monique Barbut

The Global Environment Facility (GEF) is a unique partnership among 178 countries, international institutions, non-governmental organizations (NGOs), and the private sector. As the financial mechanism of the United Nations Framework Convention on Climate Change (UNFCCC), we address global environmental issues while supporting national sustainable development initiatives.

We began in 1991 and have evolved into the largest funder of projects to improve the global environment. Over our history, the GEF has provided \$7.6 billion in grants and leveraged \$30.6 billion in co-financing for more than 2,000 projects in more than 165 countries. And as part of our mission to act locally for worldwide impact, we also have become one of the largest public-sector technology transfer mechanisms in the world.

Promoting the transfer of environmentally sound technologies (ESTs) and know-how to developing countries is enshrined in Article 4.5 of the UNFCCC. As the financial mechanism of the Convention, the GEF has a mandate to provide financial resources to support such transfers under the guidance of the Conference of the Parties.

Much of our work has been devoted to supporting the deployment and diffusion of ESTs that address climate change mitigation and adaptation. This publication offers a progress report on the GEF's experience over the years in these areas.

Since the early 1990s, GEF activities on climate change have centered on removing barriers to the widespread adoption of energy efficiency, renewable energy, and sustainable transport technologies and practices. The GEF has played a catalytic role in supporting the transfer of ESTs that are both climate-friendly and country-driven in order to meet a wide variety of development priorities. During its 17 years of existence, the GEF has allocated \$2.5 billion to support more than 30 climate-friendly technologies in over 50 developing countries. This funding has leveraged an estimated additional \$15 billion in co-financing from the GEF's partner agencies, national and local governments, non-governmental organizations, and the private sector.

In addition, the GEF has provided funding for technology needs assessments and other enabling and capacity-building activities in over 100 countries throughout the world.

Today, we are at a critical crossroads, when consensus among international stakeholders is necessary to move forward with a new strategic roadmap. Put simply, we need to act in real time, in real places, to achieve real results.

It is important to remember that achieving this goal will not just be a matter of bringing new tools to a new location. All sides must understand that success will require a suitable policy environment, unobstructed markets, adequate financing, and capacity building.

Some of our success stories and lessons learned are in this document; what is perhaps most striking is that the variety of experience is so broad.

In Morocco, for example, we found that the market failure of first-generation solar water heaters was a relatively simple matter of poor materials and installation. In Bhutan, we contributed to highly complex efforts to reduce the risks of massive melt lakes created by receding glaciers. In China, we helped boost the manufacture of more energy-efficient refrigerators from 360,000 to 4.8 million units between 1999 and 2003.

All of my colleagues at the GEF and our partner institutions would agree that vitally important work is underway—and that far more remains to be done. It is our hope that the examples on the following pages will inspire new enthusiasm, new invention, and many more successes.



Monique Barbut

Chief Executive Officer and Chairperson





INTRODUCTION

Technology transfer is seen as playing a critical role in the global response to the challenges of climate change. Indeed, the transfer of environmentally sound technologies (ESTs) is embodied in the very fabric of the United Nations Framework Convention on Climate Change (UNFCCC). Article 4.5 of the Convention states:

“The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention.”

In order to pursue these goals, the Convention proposed the creation of a financial mechanism for the Convention. Article 11 of the Convention reads:

“A mechanism for the provision of financial resources on a grant or concessional basis, including for the transfer

of technology, is hereby defined. It shall function under the guidance of and be accountable to the Conference of the Parties, which shall decide on its policies, program priorities and eligibility criteria related to this Convention. Its operation shall be entrusted to one or more existing international entities.”

Since the time of the First Session of the Conference of Parties (COP), the Global Environment Facility (GEF) has served as an entity operating the financial mechanism of the Convention. It has responded to guidance given regularly by the COP on policies and program priorities, and has reported to the COP annually. Much of the COP’s guidance has addressed the financing of ESTs.

This brochure summarizes GEF strategies and policies that have evolved with respect to the transfer of ESTs and provides examples of GEF experience in supporting the transfer of climate change mitigation and adaptation technologies.

BOX 1. Definitions of Technology Transfer

In the Special Report of the UN Intergovernmental Panel on Climate Change (IPCC) Working Group III, *Methodological and Technical Issues in Technology Transfer*, the IPCC defined technology transfer as:

... a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs and research/education institutions. Therefore, the treatment of technology transfer in this Report is much broader than that in the UNFCCC or of any particular Article of that Convention. The broad and inclusive term “transfer” encompasses diffusion of technologies and technology cooperation across and within countries. It covers technology transfer processes between developed countries, developing countries and countries with economies in transition, amongst developed countries, amongst developing countries, and amongst countries with economies in transition. It comprises the process of learning to understand, utilize and replicate the technology, including the capacity to choose and adapt to local conditions and integrate it with indigenous technologies.¹

This definition includes a wide range of activities, extends to a broad range of institutions, and provides the basis for much of the current understanding of technology transfer. The IPCC describes three major dimensions necessary for effective technology transfer: capacity building, enabling environments, and transfer mechanisms. Barriers

to the smooth working of the market for a specific technology, such as limited capacity, an unsuitable policy environment, or a lack of a financing mechanism, will limit its diffusion.

The COP established the Expert Group on Technology Transfer (EGTT) under the Subsidiary Body for Scientific and Technological Advice (SBSTA). This COP decision defined a framework citing five key requirements for increased and improved transfer of ESTs and access to related know-how: (1) country-driven activities to determine technology needs and priorities through a widespread stakeholder consultation process; (2) availability of thorough, actionable technology information; (3) enabling environments defined by government actions, including the removal of technical, legal, and administrative barriers to technology transfer; sound economic policy; and regulatory frameworks that facilitate private and public sector investment in technology transfer; (4) capacity building, a process of building, developing, and strengthening existing scientific and technical skills, capabilities, and institutions in developing country Parties so they can assess, adapt, develop, and manage ESTs; and (5) a set of mechanisms that support financial, institutional, and methodological activities and enhance coordination among stakeholders. These mechanisms should engage stakeholders in cooperative efforts to accelerate the development and diffusion of ESTs while facilitating the development of projects and programs.

¹ Metz, Gert, O. Davidson, J.W. Martens, S.N.M. Van Rooijen, and L.V.W. McGrory, *Methodological and Technical Issues in Technology Transfer*, Cambridge, UK: Cambridge University Press for the IPCC, 2001.



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**EVOLUTION OF GEF
POLICIES AND STRATEGIES
RELATING TO TECHNOLOGY TRANSFER**

During the GEF's Pilot Phase (1991-94), projects focused largely on demonstrating a wide range of technologies that would be useful in stabilizing the concentrations of greenhouse gases (GHGs) in the atmosphere.

After the restructuring of the GEF in 1994, the GEF Council approved a strategy in the climate change focal area to "support sustainable measures that minimize climate change damage by reducing the risk, or the adverse effects, of climate change." The strategy also stated that the "GEF will finance agreed and eligible enabling, mitigation, and adaptation activities in eligible recipient countries."¹

The operational strategy approved by the Council in 1995 identified three long-term operational programs to support climate change mitigation and a window for cost-effective short-term response measures (STRMs).² The long-term programs were designed to support less cost-effective interventions and to allow for a distinction between technologies on the basis of their maturity and commercial availability. Both programmatic long-term approaches and short-term projects focused primarily on mitigation through the use of commercialized or nearly commercialized technologies that were not yet widely disseminated in developing countries or in countries with economies in transition.

Subsequent GEF operational programs focused on energy efficiency and renewable energy technologies that were

mature, available on the international market, and profitable, but were prevented from dissemination by human, institutional, technological, policy, or financial barriers. These projects were termed "barrier removal" projects, as they sought to remove such barriers to promote faster adoption of new technologies and practices.

In contrast to these projects, another operational program focused on reducing the long-term costs of low-GHG-emitting electricity generating technologies. The technologies included in this program were not yet commercially available and were very expensive relative to the baseline or conventional alternatives. In these cases, such as concentrating solar power (CSP) plants, fuel-cell buses (FCBs), biomass-integrated combined-cycle generation (BIG/GT), stationary fuel cells, and microturbines, significant incremental costs remained—the technology and its costs were themselves the barrier to greater dissemination.

Finally, a sustainable transport program was approved by the GEF Council in 2000 that contained a combination of approaches, including one focusing on cost-effective technologies and practices that were underutilized, and another on technologies that were not yet fully developed.

In 2004, with the benefit of several years of implementation and monitoring, the GEF's operational strategy focusing on

¹ GEF Secretariat, 1995, *GEF Operational Strategy*, p. 31.

² Short-term projects are considered extremely cost-effective, with a unit abatement cost of less than \$10/ton of carbon avoided, or roughly \$2.7/ton of CO₂ equivalent avoided.



barrier removal and renewable energy and energy-efficiency technologies was judged successful, but in need of codification. Five key potential barriers were identified that need to be addressed to move toward more efficient, market-driven dissemination of technologies in developing countries:

- a. Policy frameworks: Governments must play an essential role in setting policies favorable to the adoption of ESTs.
- b. Technology: Should be robust and operational. The more mature a technology, the easier it is to transfer.
- c. Awareness and information: National stakeholders, especially market participants, must be aware of the technology and have information on its costs, uses, and markets.
- d. Business and delivery models: Market-based approaches are preferred; businesses and institutions must be in place that can deliver to and service those markets.
- e. Availability of financing: Financing must be available for technology dissemination, though it is insufficient in itself to ensure uptake of ESTs.

As part of the GEF-4 replenishment process, the climate change strategy for mitigation was revised to focus primarily

on six strategic programs to promote: (1) energy efficiency in buildings and appliances; (2) industrial energy efficiency; (3) market-based approaches for renewable energy; (4) sustainable energy production from biomass; (5) sustainable innovative systems for urban transport; and (6) management of land use, land-use change and forestry (LULUCF) as a means to protect carbon stocks and reduce GHG emissions.

Historically, the GEF's strategy and development have meant that its work in climate change has always focused on ESTs. GEF approaches are closely allied to the UNFCCC's technology transfer framework.

GEF experience points to a number of conclusions about technology transfer that can be applied to future operations: (1) technology is transferred primarily through markets: barriers to the efficient operation of those markets must be removed systematically; (2) technology transfer is not a single event or activity but a long-term engagement, during which partnerships and cooperation, often requiring time to develop and mature, are mandatory for the successful development, transfer, and dissemination of technologies; and (3) technology transfer requires a comprehensive approach, incorporating capacity building at all relevant levels.





**GEF EXPERIENCE WITH TECHNOLOGY TRANSFER:
MITIGATION**



Since the creation of the GEF, about \$2.5 billion has been allocated to climate change projects. These resources have leveraged an estimated additional \$15 billion in financing, and resulted in over one billion tons of GHG emissions avoided. Altogether, the GEF has supported more than 30 technologies in the years of its existence. The following sections illustrate the range of those technologies as well as some lessons learned.

MITIGATION: ENERGY-EFFICIENCY TECHNOLOGIES

Table 1 summarizes the energy-efficiency technologies and technology sectors that the GEF has supported in various countries. This is not to claim that all of these technologies have been successfully transferred, but rather that the countries listed have expressed interest in growing markets for them. In some cases, technology transfer has been successful, while in others, barriers remain to market maturation.

Efficient Lighting

Since the mid-1990s, the GEF has supported the dissemination of efficient lighting technologies in more than two dozen countries. The types of intervention include sector-specific lighting initiatives, utility demand-side management (DSM)

programs, energy efficiency standards and appliance labeling, and building codes and standards.

Achievements of GEF-funded projects include: (1) major transformation of the efficient lighting market in the residential sector; (2) significant project replication and extension, both in the countries themselves and in surrounding countries; (3) significant benefits for consumers in cost savings and improved product quality; and (4) development of capacity for DSM and energy efficiency within government institutions.

The GEF has also launched a global efficient lighting initiative, approved by the Council in 2007, to accelerate the phase-out of inefficient lighting through UNEP and UNDP, while it is extending support to more countries and programs at the national level.

Energy-Efficient Appliances

The GEF has built a portfolio promoting energy-efficient appliances and technologies in developing countries. GEF-supported interventions typically focus on instituting energy-efficiency standards and labels, consumer education, and testing and certification of appliances. In countries where there is substantial manufacturing capacity, the GEF has also supported enterprises in developing new energy-efficient appliance

TABLE 1. Energy-efficiency technologies and countries supported by the GEF

Energy-efficiency technology	Countries supported
Efficient lighting (compact fluorescent lamps, efficient street lighting, light-emitting diodes, etc.)	Argentina, Bangladesh, Brazil, China, Czech Republic, Egypt, Ghana, Hungary, Indonesia, Jamaica, Kenya, Latvia, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland, Russia, Slovakia, South Africa, Thailand, Uruguay, Vietnam
Energy-efficient appliances (refrigerators, air conditioners, washers, dryers, cookers, stoves, etc.)	Argentina, Bangladesh, Brazil, China, Cuba, India, Indonesia, Kenya, Mongolia, Pakistan, Russia, Thailand, Tunisia, Vietnam
Energy-efficient building design	Belarus, Bosnia-Herzegovina, Brazil, Bulgaria, China, Cote d'Ivoire, Czech Republic, Kyrgyzstan, Lebanon, Mauritius, Morocco, Senegal, Tunisia
Energy-efficient building materials (windows, doors, perforated bricks, straw bales, etc.)	Bangladesh, Bosnia-Herzegovina, China, Mongolia, Pakistan, Poland
Industrial energy-efficiency technologies (steel, brickmaking, cement, ceramics, textile, foundry, rubber, wood, cokemaking, tea processing, food processing, pulp and paper, charcoal production, etc.)	Bangladesh, Belarus, Bulgaria, China, Costa Rica, Cote d'Ivoire, El Salvador, Honduras, Hungary, India, Iran, Macedonia, Malaysia, Morocco, Nicaragua, Panama, Philippines, Poland, Tunisia, Vietnam
District heating systems	Armenia, Belarus, Bulgaria, China, Croatia, Czech Republic, Georgia, Hungary, Kazakhstan, Latvia, Lithuania, Moldova, Mongolia, Slovenia, Slovak Republic, Ukraine, Poland, Turkmenistan, Romania, Russia, Uzbekistan
Power generation (rehabilitation) and distribution	Brazil, China, Ecuador, Guinea, India, Philippines, Sri Lanka, Syria
Cogeneration (including heat recovery for power generation from industrial processes)	China, Czech Republic, Ethiopia, Kenya, Malawi, Swaziland, Tanzania, Uganda, Sudan, Russia
Energy-efficient motors	Bangladesh, China, India, Indonesia, Poland, Thailand, Pakistan, Vietnam
Energy-efficient boilers	China, Poland, Russia
Energy-efficient CFC-free chillers	Brazil, Colombia, India, Thailand

models and in acquiring technical information and knowledge from more advanced countries.

In Tunisia, for example, 10 of 12 local appliance manufacturers are offering more energy-efficient models. In China, the GEF project to promote energy-efficient refrigerators adopted a two-pronged approach—technology push and market pull. Technology push is achieved through technical assistance to refrigerator and compressor manufacturers, technology upgrades, and designer training programs, while market pull is achieved through the promulgation of energy-efficiency standards. Participating refrigerator manufacturers improved their average energy efficiency by 23 percent between 1999 and 2003. The market's response—increased sales of top-rated energy-efficient refrigerators from 360,000 to 4.8 million units—helped drive increased production capacity.

Industrial Energy-Efficiency Technologies

The GEF has funded more than 30 projects in the industrial sector to promote technology upgrading and the adoption and diffusion of energy-efficient technologies. Some projects focus on the development of market mechanisms such as energy service companies, the creation of dedicated financing instruments, and technical assistance to stimulate investments in new technologies. Other projects identify one or more sub-sectors and specific technologies to promote. The range of industries includes construction

materials (brick, cement, and glass), steel, cokemaking, foundry, paper, ceramics, textiles, food and beverage, tea, rubber, and wood. A number of projects also promote energy-efficient equipment such as boilers, motors, and pumps, as well as cogeneration in the industrial sector.

In some projects, the GEF has promoted South-South technology transfer, as in the transfer of energy-efficient brick kiln technology from China to Bangladesh. The technology was developed, adopted, and disseminated in China, and is being transferred to Bangladesh.

District Heating Systems

The GEF has financed projects to promote energy-efficient district heating in more than 20 countries, most of them in Eastern Europe and the former Soviet Union, but also in China and Mongolia. Most of these projects involve demonstrating technologies and practices that improve the technical and operating efficiency of heat and hot water supply; creating enabling policies and regulations; and facilitating access to financing and investment. Some of the projects in Eastern Europe have also led to switching fuel from coal to biomass.

High-Efficiency Boilers

The China Efficient Industrial Boilers project received a \$32.8 million grant from the GEF to (1) upgrade existing boiler

models by introducing advanced combustion systems and auxiliary equipment from developed countries; (2) adopt new high-efficiency boiler models by introducing modern manufacturing techniques and boiler designs; and (3) provide technical assistance and training for boiler producers and consumers. Completed in 2004, the project successfully supported international technology transfer of boiler technologies that benefited nine boiler manufacturers and nine boiler auxiliary equipment makers. With GEF support, the Chinese manufacturers acquired advanced efficient boiler technologies, built prototypes, and began commercial production. Through technical assistance, the project also led to the revision and formulation of national and sector standards while it strengthened the technical capacity of the Chinese boiler sector.

Energy-Efficient CFC-Free Chillers

In several countries, including Thailand, Brazil, and India, GEF support has aimed to accelerate the replacement of old CFC-based chillers with CFC-free energy-efficient models. These projects have also created synergy, pooling the resources of the GEF and the Multilateral Fund under the Montreal Protocol on Substances that Deplete the Ozone Layer.

In Thailand, a GEF project successfully demonstrated the technical feasibility, financial viability, and benefits of chiller

replacement. Financial return from energy savings and reduction of ozone-depleting substances (ODS) and GHGs have exceeded expectations, and replication and market transformation have taken place rapidly post-project.

MITIGATION: RENEWABLE ENERGY TECHNOLOGIES

From 1991 to 2007, the GEF approved grants totaling more than \$800 million for approximately 150 projects that promote the transfer of renewable energy technologies in developing and transition countries (Table 2).

Off-Grid Photovoltaics

Since its inception, the GEF has helped deploy renewable energy technologies to those lacking access to electricity—and to those whose use of kerosene for lighting and wood for cooking produces GHG emissions. As these people often live in remote areas, expansion of the power grid is neither cost effective nor affordable by governments. In response to this need, the GEF funded a number of projects that provided access to electricity through the use of Solar Home Systems (SHS).

Several lessons have emerged from these projects, including: the importance of the technical quality

of the SHSs; the need to raise awareness of the technology; the importance of system maintenance and business infrastructure; and the need for sustainable financing in appropriate instruments. Though solar photovoltaics (PVs) and SHSs are a least-cost option for remote electricity supply, they are not necessarily affordable to those who need them. In such a case, financing is needed according to customers' ability and willingness to pay for the services provided.

The Transformation of the Rural Photovoltaic Market in Tanzania project was designed to incorporate the lessons learned from earlier rural PV projects. Reports indicate that this project has contributed to the removal of taxes and VAT on all PV components. Standards and a code of practice have been approved and are now in place. A Rural Energy Agency has been put in place and a Rural Energy Master Plan has been developed. PV awareness among key government decision makers at district level has been raised through a series of seminars. Most importantly, the private sector has been responsive to the project and a PV curriculum has been adopted by the Vocational Education and Training Authority of Tanzania. Technicians have been trained in sizing, installing, repairing, and maintaining the systems, 60 percent of which are operational. Financial models for supply-chain and consumer financing are being developed to increase the number of consumers and companies that request financing for their PV investments.



TABLE 2 . Renewable energy technologies and countries supported by the GEF

Renewable technology	Countries supported
Off-grid photovoltaics (PVs)	Bangladesh, Bolivia, Botswana, Burkina Faso, China, Costa Rica, Ethiopia, Eritrea, Ghana, India, Kenya, Lesotho, Morocco, Malawi, Namibia, Nepal, Peru, South Africa, Sri Lanka, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe
On-grid PVs	India, Mexico, Philippines, <i>(also considered as OP7)</i>
Solar water heating	Albania, Algeria, Chile, India, Lebanon, Mexico, Morocco, South Africa, Tunisia
Wind turbines	Azerbaijan, Bangladesh, Brazil, China, Costa Rica, Cuba, El Salvador, Eritrea, Ethiopia, Ghana, Guatemala, Honduras, Iran, Jordan, Kazakhstan, Kenya, Korea DPR, Madagascar, Mauritania, Mexico, Nepal, Nicaragua, Pakistan, Russian Federation, South Africa, Sri Lanka, Tunisia, Uruguay
Geothermal	Armenia, Bulgaria, Djibouti, Eritrea, Ethiopia, Indonesia, Hungary, Kenya, Lithuania, Philippines, Poland, Romania, Russian Federation, Tajikistan, Turkey, Ukraine, Tanzania, Uganda
Methane from waste (mixed municipal and/or liquid biological)	China, Czech Republic, Jordan, Latvia, Mexico, Uruguay <i>(some also qualified under STRM; see below)</i>
Small hydro	Benin, Bhutan, Burundi, Cameroon, Central African Republic, Congo, Congo DR, Gabon, Haiti, Hungary, Indonesia, Macedonia, Mali, Montenegro, Nicaragua, Rwanda, Togo
Biomass cogeneration	Hungary, Malaysia, Thailand
Biomass boilers (heat production)	Belarus, China, Egypt, India, Kenya, Latvia, Poland, Slovak Republic, Slovenia, Sri Lanka
Biomass gasification for electricity	Chile, India, Uruguay

Solar Water Heaters

Although solar water heater technology is sometimes considered simple, that perception can be misleading. The quality of the fittings, the solar collectors, and the installation has substantial impact on satisfactory operation. Accordingly, inexpensive materials, poor workmanship, and shoddy installation have often resulted in nonfunctional units and abandonment of installations. The GEF's experience has shown that knowledgeable staff and the observance of high standards are critical to the successful dissemination of this technology.

In Morocco, for example, early solar water heaters tended to be of low quality. As a result, they fell into disuse and the market languished. Through a GEF project, the older nonfunctioning installations were repaired; new higher-quality standards were adopted; and technicians and staff were trained to ensure future installations would be of satisfactory quality. In addition, to encourage production and sale of the higher-quality units, a subsidy was offered to early adopters of water heaters meeting the new standard. These initiatives revived the market, which is now growing rapidly, along with the industry as a whole.

On-Grid Photovoltaics

The GEF-supported CEPALCO Distributed Generation PV Plant in the Philippines aimed to demonstrate PV's effectiveness in addressing distribution system capacity challenges. A 1-MW

distributed-generation PV power plant was built and integrated into the 80-MW distribution network of the Cagayan de Oro Electric Power & Light Company (CEPALCO), a private utility on the island of Mindanao in the Philippines. The PV system operates in conjunction with a 7-MW hydroelectric plant with dynamic load control, enabling the joint PV/hydro resource to reduce distribution-level and system-level demand, effectively providing reliable generating capacity. The PV plant helped postpone the need for additional substation installations in the distribution system for up to three years, reducing the need for CEPALCO to purchase additional thermal-plant-based power and reducing its GHG emissions. More importantly, the plant provides the first full-scale demonstration of the environmental and, ultimately, economic benefits of the conjunctive use of hydro- and PV-based power and represents the first significant use of grid-connected PV in a developing country.

This project marks significant progress toward solving the storage issue faced by many renewable energy technologies. If conjunctive use allows current hydro facilities to be used for storage, many renewables, including PV and wind, can be viewed in combination as a "firm hybrid"—a completely renewable source of power.

Wind Power

The GEF has supported a variety of wind energy projects around the world. Experience has shown that resource



availability as well as familiarity with the technology are important considerations. However, the most significant barriers to successful growth in the wind market are the regulations on renewable generators' access to the grid and the incremental costs to distributors of turbine-generated electricity.

Worldwide experience shows several successful approaches to this problem, including the creation of a renewable portfolio standard and a guaranteed renewable "feed-in" tariff. The GEF has helped countries understand and adopt these regulations. In Mexico, for example, GEF agencies provided: (1) support to assist in improving windspeed measurements; (2) training and capacity building; and (3) regulatory changes that provide a "green energy" fund to help pay the incremental costs of renewable generation.

One of the most visible and successful GEF projects supporting the fledgling market for wind energy in developing countries is the China: Renewable Energy Scale Up Program (CRESP). It adopted a programmatic approach to secure long-term structural change and provided support for the creation of the Chinese Renewable Energy Law in 2007, which included an important renewable portfolio provision.

The main global benefits of the project are: (1) the removal of multiple barriers to the introduction of cost-effective renewables, especially wind energy, in China; (2) the reduction in cost and improvement in performance of small

hydro, wind, and selected biomass technologies; and (3) increased market penetration by renewables, with subsequent reduction in GHG emissions from power generation. It is estimated that by 2010 the scale-up will result in incremental annual production of electricity from renewable sources of 38 terawatt hours (Twh), equivalent to about 7.9 gigawatts (GW) of installed capacity. The carbon savings of the project are estimated at 187 metric tons (MtC). China now hosts the world's sixth largest wind energy market, with an estimated installed capacity of 2.6 GW, a figure that doubled during 2006.

Geothermal Energy

The GEF has supported a number of projects to help countries exploit their geothermal energy potential. This experience has shown that, in addition to the barriers to access of renewable energy generators to the grid, an additional—and especially difficult—barrier is the cost of confirming the presence and location of exploitable geothermal resources. Traditionally, each site is confirmed exploitable by drilling—at a cost of up to several million dollars. To deal with this barrier, the GEF has established several contingent funding mechanisms to reimburse the costs of drilling nonproductive wells.

A more recent approach to this barrier is found in the Joint Geophysical Imaging for Geothermal Reservoir Assessment project in Kenya. In this project, advanced geophysical

imaging techniques have been used to locate commercially exploitable geothermal power in Kenya and East Africa. Microseismic event sensing, electromagnetic sensing of lightning strikes, and Earth's magnetic field help locate steam trapped in fractures underground.

Results to date indicate that wells targeted using this approach, when combined with directional drilling, yield 4 to 6 MW per well as opposed to the previous 2 MW per well. The success rate for test wells has also improved, as has targeting of wells for re-injection of spent geothermal fluid—which creates sustainable geothermal field output over time. This will result in substantial savings for the planned development of 512 MW from geothermal resources in Kenya. The project has helped establish sustainable, world-class capacity using these advanced techniques at KenGen's Olkaria facility; KenGen is now able to provide these services to other countries in the region.

Waste to Energy

A number of projects have supported utilization of methane from municipal waste, either from solid wastes in landfills or from liquid biological wastes. Many of these projects have qualified for GEF support as both renewable energy projects and short-term response measures because of their cost-effectiveness. The GEF played a role in helping increase the uptake of these technologies; now its support is no longer

needed, as the projects are eligible and highly profitable when implemented under the Clean Development Mechanism (CDM).

The India Biomethanation project, proposed in the early 1990s, addressed endogenous capacity in India to adapt and replicate biogas technology for industrial wastes. A pre-existing challenge was that biological waste from agroprocessing and related industries deposited substantial quantities of methane and other pollutants into nearby waters. The project's intent was to produce the methane in a controlled environment, capture it, and use it to produce energy.

The GEF project supported capacity building at five national R&D laboratories and other institutions that were involved in the project as a network. In addition, the GEF co-financed more than a dozen demonstration units in a variety of industries, including agroprocessing, pulp and paper, tanneries, slaughterhouses, rice mills, and commercial dairies.

These capacity building activities were successful and sustainable, and the demonstration units clearly indicated which industries could reach the highest levels of GHG abatement. The project also clearly illustrated the need to continue after the initial development or local adaptation of a technology. When suitable technologies have been

identified and tested, it is vitally important to continue to the dissemination stage. Systematic integration into national policy, coupled with the buildup of a national industry, provides the equipment and services needed for sustainable production and dissemination.

Mini- and Micro-Hydro Power

Small hydro is a mature technology, but it is not well disseminated. The GEF has supported this technology around the world from early on and has identified several barriers to its adoption, including lack of information about the technology and about the resource; unsupportive institutional frameworks; regulatory obstacles; and absent or inadequate financing.

One promising project is The Integrated Micro-Hydro Development and Application Program in Indonesia, which aims to reduce GHG emissions from fossil fuel-based power generation. This will require accelerating the development of micro-hydro resources and optimizing their utilization by eliminating or reducing current barriers.

The four main outcomes of the project are expected to be: enhanced private-sector interest and involvement in capacity building in the micro-hydro business community; capacity building in small residential communities to increase micro-hydro utilization; improved local knowledge and availability of the technology and its applications;

and increased implementation of micro-hydro projects for electricity and productive purposes.

The project targets a cumulative GHG reduction of 304 kilotons of CO₂; the establishment of at least 40 community-based micro-hydro projects for productive use each year; and cumulatively, in 3 years, 130 gigawatt hours (GWh) produced, with 100 GWh sold.

Biomass Cogeneration

Biomass waste from agricultural and forestry production can provide significant energy for heat and electricity generation. Typically consisting of either crop residues or sawmill waste, biomass can provide opportunities for carbon-neutral energy production, as the CO₂ released through combustion is originally grown and fixed as part of a closed cycle. If this energy source is used instead of fossil fuels, the benefits are even greater.

Common barriers to biomass waste utilization are the regulatory framework's non-recognition or inadequate acceptance of small-scale renewable generators and lack of financing, technology, and information. The GEF has supported a number of projects that have contributed to the cogeneration of heat and electricity using biomass residues.

One instance is The Removal of Barriers to Biomass Power Generation and Cogeneration in Thailand project, which is

helping local commercial partners reduce 4 million tons of GHGs (carbon equivalent) by accelerating the growth of biomass cogeneration and power generation technologies to replace fossil fuel consumption.

The project: (1) builds capacity to provide information and services to potential biomass project investors; (2) improves the regulatory framework to provide financial incentives for biomass cogeneration and power projects; (3) increases access to commercial financing for these projects; and (4) facilitates the implementation of two initial biomass power pilot plants by supporting commercial guarantees. The project generates 65,520 megawatt hours (MWh) of electricity annually from renewable energy.

Heat from Biomass

Issues related to the use of agricultural and forestry wastes to generate heat are similar to those related to biomass cogeneration. In both cases, changes in the regulations governing heating networks are required. And in both cases, such projects can improve overall resource-use efficiency and reduce GHG emissions.

The Economic and Cost-Effective Use of Wood Waste for Municipal Heating Systems in Latvia project addresses several of these issues. The project aims to: (1) promote the use of wood waste by removing or reducing barriers to replacing

imported heavy fuel oil (mazut) with local, sustainably produced wood waste in municipal heating systems; (2) promote the development and implementation of an economical, commercially run, municipal heating system, providing generation, transmission, and distribution in the municipality of Ludza; and (3) help remove or reduce technical, legislative, institutional, organizational, economic, information-related, and financial barriers related to the replication of a pilot project in the municipality.

Since project inception, 11,200 tons of CO₂ emissions have been avoided annually in Ludza, accounting for about 80 percent of the emissions from using heating oil. The project and the financial scheme developed through the project have encouraged more than 12 other municipalities to make use of forest wastes in their district heating networks, resulting in over 100,000 tons of CO₂ avoided annually. GEF funding was \$0.75 million, with \$2.73 million in co-financing.

Biomass Gasification for Electricity

The biomass gasification process has been known for many years. Historically, the technology has faced an engineering challenge in the need to clean the gases to prevent obstructions in the system. New gasifiers are becoming more effective at solving this issue. Especially in rural areas where biomass residues are plentiful, this provides a promising new opportunity for generating electricity.

There are signs of success in the Biomass for Rural India project, which aims to develop and implement a GHG-reducing bioenergy technology package that will provide a sustainable and participatory approach that meets village energy needs. The project is implemented mainly in 24 villages in Karnataka's Tumkur district.

Project goals include: (1) demonstrating the technical feasibility and financial viability of bioenergy technologies—including biomass gasification for power generation—on a significant scale; (2) building capacity and developing mechanisms for project implementation, management, and monitoring; (3) developing financial, institutional, and market strategies to overcome barriers to large-scale replication of the bioenergy package for decentralized applications; and (4) disseminating bioenergy technology and relevant information on a large scale.

The project has stimulated significant forest growth in the form of energy plantations (2,965 acres), forest regeneration (2,100 acres), and tree-based farming (about 2,471 acres) by villagers. The wood is used to generate electricity in locally manufactured gasifiers. The power generated is sold to the regional electrical distribution company to supply the local population. The project has also resulted in 171 families replacing fuel wood with biogas—reducing GHG emissions by 256 tons annually over the past 3 years.

MITIGATION: NEW LOW-GHG-EMITTING ENERGY TECHNOLOGIES

The GEF's objective in this field was to provide support for early technology demonstrations in developing countries (Table 3). Increased experience with these technologies accelerates reductions in the cost of subsequent installations. The most significant technology to receive support has been Concentrating Solar Power (CSP) technology.

Concentrating Solar Power (CSP)

The GEF, together with India, Mexico, Morocco, and Egypt, developed a portfolio of four CSP demonstration plants. The projects built solar fields, typically of 30 megawatts (MW), as part of hybrid gas-turbine plants. Successful hybridization of the gas turbine and the solar power plants would enable the projects to dispatch power at will, making them more economically attractive.

However, the projects have progressed very slowly, indicating that the technology did not meet with the enthusiastic uptake originally anticipated. Only recently have new plants been planned and constructed in developed countries, most notably in Spain, where generous incentives were provided through a high feed-in tariff for solar energy. Now, spurred by these activities in developed countries, the projects in Egypt, Mexico, and Morocco are moving forward.

TABLE 3 . Low-GHG-emitting energy generating technologies and countries supported by the GEF

Low-GHG-emitting energy technology	Countries supported
Biomass-integrated gasification combined-cycle generation	Brazil
Building-integrated photovoltaic power production	Malaysia
Concentrating solar power production	Egypt, Morocco, Mexico
Externally fired combined-cycle generation	Brazil
Microturbine cogeneration	Indonesia
On-grid PV power production	Mexico, Philippines
Stationary fuel-cell power generation	South Africa

One lesson from these experiences is that it is difficult for developing countries to adopt technologies from developed countries that are not fully commercialized. Failure to achieve market viability in developed countries damages the technology's credibility elsewhere. In the case of the CSP plants, construction costs increased as the projects progressed. Host countries were burdened with both additional costs and the risk that the projects might not

produce the rated power on a firm basis. In fact, in two cases, the additional costs exceeded the GEF's funding. Both countries have had to provide significant cash subsidies to enable the plants to move forward.

In the future, projects of this sort should look to multi-country partnerships for information and experience sharing.

MITIGATION: TRANSPORT SECTOR TECHNOLOGIES

The GEF program on sustainable transport was approved by the Council in 2000. It combines support for new technologies with efforts to remove barriers to well-established technologies that are not disseminating well. The technologies and countries where GEF has supported activities are in Table 4.

Fuel-Cell Buses

When the operational program on sustainable transport was approved in 2000, fuel-cell buses were included as eligible under that program. A portfolio of fuel-cell bus projects in Brazil, China, Egypt, India, and Mexico was developed. All five were approved by the GEF Council, but three faced limited industry interest in the form of limited or no response at the "expressions of interest" stage of the procurement process.

TABLE 4 . Transport sector technologies and countries supported by the GEF

Transport technology	Countries supported
Bicycle paths, non-motorized transit	Botswana, Chile, Nicaragua, Peru, Philippines, Poland, Vietnam
Bus-rapid transit systems	Argentina, Brazil, Ghana, Senegal, South Africa, Tanzania,
Dedicated bus lanes	Argentina, Brazil, Chile, China, Ghana, India, Indonesia, Iran, Mexico, Peru, South Africa
Electric three-wheelers	India
Hybrid buses	Egypt
Hydrogen-based fuel-cell buses	Brazil, China
Traffic demand management	Argentina, Brazil, Ghana, Mexico

In the end, the projects in Egypt, India, and Mexico were cancelled.

Of the two projects that progressed to implementation, China was the first to receive buses; they have been in operation since 2004. Brazil also received buses, which appear to be operating well. However, it is not clear that either project will lead to a sustainable fuel-cell bus industry absent rapid advances in the technology and reductions in the production costs of hydrogen.

MITIGATION: THE SHORT-TERM WINDOW

The Short-Term Window in climate change was established to support opportunities that were considered “too good to refuse” (Table 5). Projects were eligible if they yielded \$10/ton of CO₂-equivalent avoided.

Coalbed and Coal Mine Methane

Coal deposits yield a significant amount of methane, which is released to the atmosphere when coal is mined. Because methane (CH₄) is a GHG with a Global Warming Potential (GWP) more than 20 times that of CO₂, using it as fuel offers several benefits: (1) it converts the CH₄ back to less harmful CO₂; (2) it reduces CH₄ presence in the atmosphere, and (3) it reduces dependence on other fossil fuels.

The GEF has supported coalbed and coal mine methane projects in China, Russia, and India. In China, the project led to the creation of the National Coalbed Mining Authority, which has fostered methane tapping and is utilizing joint venture investments in several large coal deposit areas. The process is similar to that of tapping and utilizing natural gas, and holds promise for improving China’s gas reserves.

TABLE 5 . Technologies as short-term response measures (STRM) and countries supported by the GEF

Short-term response technology	Countries supported
Coalbed methane/coal mine methane	China, India, Russia
Coal-to-gas conversion	Poland
Landfill gas utilization	China, India, Jordan, Latvia, Uruguay <i>(also included above in OP6 Table)</i>
LPG substitution	Yemen
Natural gas system leakage repair	China, Venezuela



**GEF EXPERIENCE WITH TECHNOLOGY TRANSFER:
ADAPTATION**



Since the creation of the Strategic Priority on Adaptation (SPA) in the GEF Trust Fund, and the establishment of the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF), GEF-administered funding for adaptation has totaled about \$130 million. Technology transfer has been a major component in most adaptation projects funded under the SPA, SCCF, and LDCF, all of which are operated by the GEF under guidance from the COP.

Because the portfolio of adaptation projects is relatively new, there is less experience with successful technology transfer under it than there is under the GEF's mitigation portfolio. Recognizing that there are key differences between technologies appropriate for adaptation and those suited for mitigation, adaptation projects will require significant attention to technology deployment. As the adaptation portfolio evolves and matures, it will be important for the GEF to assess experiences and lessons learned, drawing on its own past work as well as that of others.

GEF-administered funding for adaptation technology transfers has gone to both "soft" and "hard" technologies. Soft technologies may include: technical assistance for pilot demonstration activities; wetland and/or mangrove restoration; beach nourishment; and institutional support for knowledge transfer to decision makers on how to mainstream adaptation concerns in sector development planning. Hard technologies may include innovative irrigation systems;

drought-resistant crops; climate-proofing investments in infrastructure; and the physical transfer of high-tech electronics for data logging and alert systems.

Adaptation projects also seek to build additional capacity to increase local participation and ownership and, ultimately, therefore, increase the sustainability of any interventions. Many adaptation pilot activities are also centered on improved management of current local or traditional knowledge and technologies, or on improved access to adaptation-relevant information that increases the efficiency of current management. Capacity building and public awareness are components of many GEF-administered adaptation projects.

Because of the differences between mitigation and adaptation, and because their respective use of hard and soft technologies differs, the following sections are organized by project activities. A wide variety of adaptation technology transfer activities are illustrated in Table 6, including those for: ecosystem management; agriculture; water management; disaster risk management; coastal zone management; and health.

Technology Information Transfer

The GEF, through its three sources of adaptation funding, has supported numerous adaptation activities related to technology information transfer. In Colombia, advanced climate and statistical models allow continuous evaluation

of the effects of global climate change on dengue and malaria transmission. The models will help guide appropriate preventive actions. In Cape Verde, a country expected to experience severe climate change-related water stress, a pilot demonstration of climate-resilient techniques for harvesting, storing, conserving, and distributing water will be implemented. This project includes several innovative technologies, such as wind traps, underground screens that prevent groundwater seepage, and new water treatment techniques.

Pilot activities such as these will help generate the awareness and experience necessary to successfully scale up activities at the national level.

Infrastructure and Hard Technology Transfer

Another group of activities involves direct investments (in modern physical infrastructure, for example) that specifically target climate change vulnerabilities. In West Africa, the GEF supported dissemination of alternative energy technology to local communities that previously collected firewood from sensitive coastal mangrove forests. Providing these communities with alternative energy sources significantly reduces human pressure on the mangrove forests—a natural buffer against the effects of climate change—induced sea level rise and storm surges.

In Bhutan, the GEF (through the LDCF) is funding measures to reduce the risks of glacial lake outburst floods (GLOFs) from massive lakes created by receding glaciers. The intervention is directly reducing the risk of GLOFs by installing pumps to artificially lower the water levels of lakes below dangerous thresholds, and by installing an automated monitoring and alarm system based on new technologies.

Capacity Building, Coordination, and Policy

Many technology transfer activities can be grouped under this heading. These activities do not involve the targeted transfer of specific information or physical investments, but rather the generation of general knowledge, experience, and capacity—which provide the necessary foundation for policy mainstreaming, project implementation, and eventual scaling up of pilot activities. In Eritrea, for example, GEF-administered resources will be utilized to train agricultural extension staff in climate-resilient rangeland management techniques. The successful implementation of these activities will give the country a flexible, sustainable pool of knowledge, as well as staff who can advise local communities on sustainable livestock and rangeland management under changing climates for decades to come.

TABLE 6 . Elements of adaptation technology transfer in ecosystems, agriculture, water management, coastal zone management, disaster risk management, and human health

	Ecosystems	Agriculture	Water Management	Coastal Zone Management	Disaster Risk Management	Health
Technology information transfer	Pest management technologies introduced into sustainable forest management to combat severe pest problems caused by decreasing rainfall (Armenia)	Improved seasonal forecasts and improved access to seasonal climate information for farmers through extension services (Niger)	Demonstration of small-scale innovative techniques for climate-resilient harvest, storage, conservation, and distribution of water (Cape Verde)	Planting /conservation of protective mangroves (Sri Lanka)	Improvement of drought early warning systems and coordination of food and forage banks (Burkina Faso)	Climate and statistical models developed to monitor and track the effects of climate on malaria and dengue. (Colombia)
Infrastructure and hard technologies	Dissemination of alternative energy technology to reduce human stresses on important mangrove ecosystems, previously used for firewood collection (West Africa)	Promotion and dissemination of drought-tolerant crop varieties and technology; knowledge for improved dry- land farming (such as dry seeding, minimum tillage, etc.) (China)	Upgrade of irrigation facilities to promote efficient usage of available water resources (Malawi)	Installation of breakwater/ sea walls at key vulnerable coastal locations (Pacific Islands)	Reduced risks of glacial lake outburst floods (GLOFs) through artificial lowering of lake levels and automated monitoring/warning system (Bhutan)	
Capacity building, coordination, and policy	Updating of coastal zoning and fisheries management based on detailed analysis of saline front changes induced by climate change (Uruguay)	Training of adaptation experts for agricultural extension services (Eritrea)	Development and implementation of integrated water management frameworks for rational prioritization of limited resources (Ecuador)	Improvements in human and technical capacity (such as GIS technology) for monitoring and responding to coastal erosion (West Africa)	Increased coverage of existing early warning system and improved flow of early warning information to vulnerable coastal communities (Bangladesh)	Increased capacity and understanding among local health professionals through pilot implementation of preventive and responsive public health programs specifically targeting climate change- induced illnesses (Samoa)



CONCLUSION



The GEF, over its 17-year history, has extensive experience in the transfer of climate change mitigation and adaptation technologies. A total of around \$2.5 billion has been allocated to support climate change projects in over 100 countries. These catalytic projects have addressed more than 30 technologies and leveraged \$15 billion in co-financing.

Transfer of environmentally sound technologies is playing a crucial role in the global response to climate change. Lessons learned at the GEF will help improve the efficiency and efficacy of future efforts to transfer ESTs to developing countries.

APPENDIX I . Abbreviations and Acronyms

BIG/GT	Biomass-Integrated Combined Cycle	LPG	Liquid Propane Gas
CDM	Clean Development Mechanism	MP	Montreal Protocol
CFL	Compact Fluorescent Lamp	MWh	Megawatt Hours
CIF	Climate Investment Funds	NGO	Non-Governmental Organization
COP	Conference of the Parties	ODS	Ozone-Depleting Substance
CSP	Concentrating Solar Power	PV	Photovoltaic
DSM	Demand-Side Management	SBI	Subsidiary Body for Implementation
EGTT	Expert Group on Technology Transfer	SBSTA	Subsidiary Body for Scientific and Technological Advice
EST	Environmentally Sound Technology	SCCF	Special Climate Change Fund
FCB	Fuel-Cell Bus	SHS	Solar Home System
GEF	Global Environment Facility	SMEs	Small and Medium Enterprises
GHG	Greenhouse Gas	SPA	Strategic Priority on Adaptation
GIS	Geographic Information System	STRM	Short-Term Response Measures
GWh	Gigawatt Hours	TWh	Terawatt Hours
GWP	Global Warming Potential	UNDP	United Nations Development Programme
IDB	Inter-American Development Bank	UNEP	United Nations Environment Programme
IGCC	Integrated-Gasification Combined-Cycle	UNFCCC	United Nations Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change	VAT	Value Added Tax
LDCF	Least Developed Countries Fund		

APPENDIX II . GEF Implementing and Executing Agencies

African Development Bank
Asian Development Bank
European Bank for Reconstruction and Development
Food and Agriculture Organization of the United Nations
Inter-American Development Bank
International Fund for Agricultural Development
United Nations Development Programme
United Nations Environment Programme
United Nations Industrial Development Organization
World Bank



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