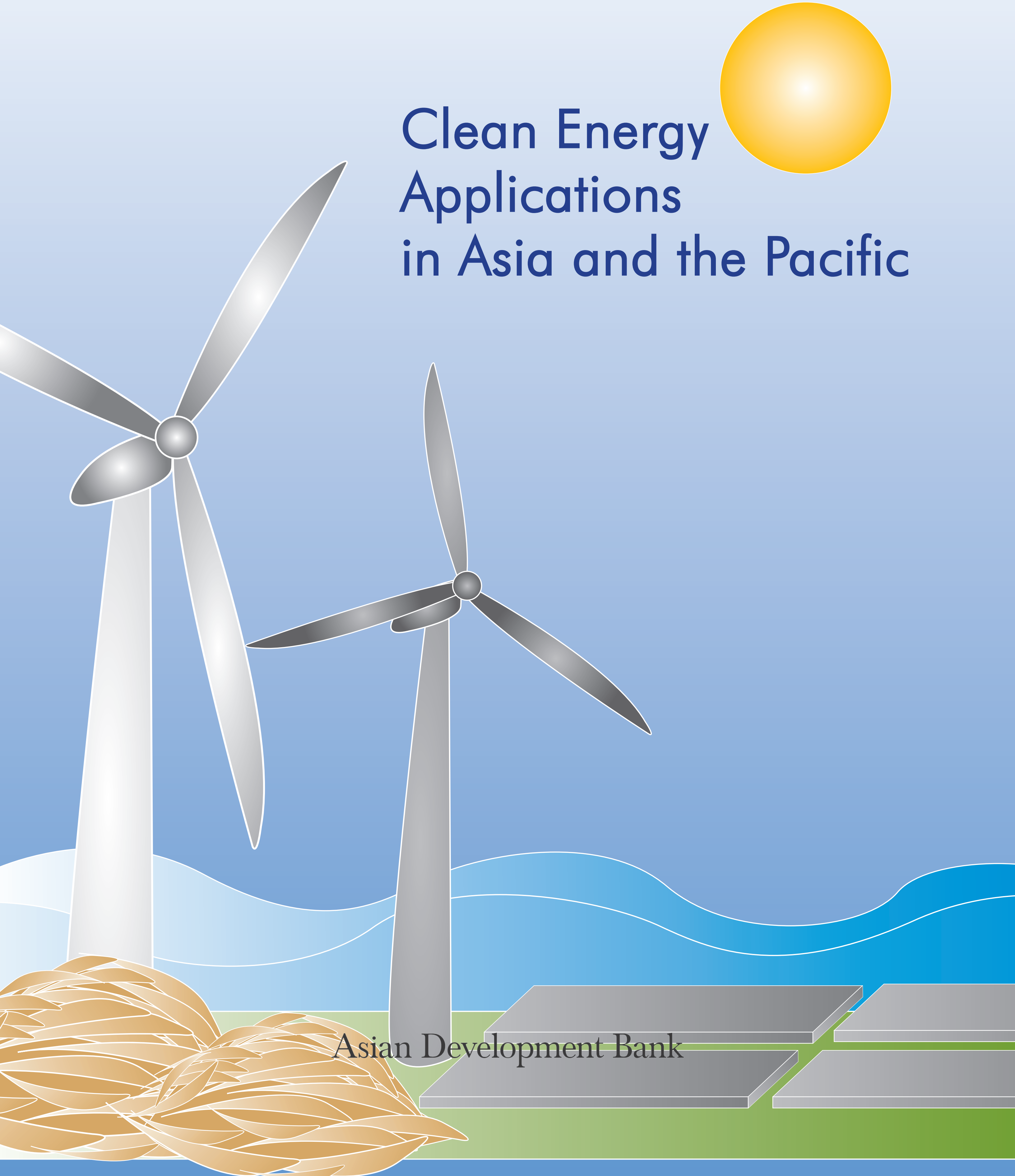
Clean Energy Applications in Asia and the Pacific



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Abbreviations

AC	air conditioning
ADB	Asian Development Bank
AHU	air handling unit
CDM	Clean Development Mechanism
CER	certified emissions reduction
CRE	Centre for Renewable Energy
CO_2	carbon dioxide
DANIDA	Danish International Development Agency
DMC	developing member country
EE	energy efficiency
EIRR	economic internal rate of return
EV	electric vehicle
FIRR	financial internal rate of return
GEF	Global Environment Facility
GHG	greenhouse gas
GW	gigawatt
HVAC	heating, ventilation, and air conditioning
ICS	improved cook stoves
IPP	independent power producer
kW	kilowatt
kWp	kilowatt peak
MW	megawatt
MWe	megawatt electrical
MWp	megawatt peak
NCA	national counterpart agency
NGO	nongovernment organization
NTE	national technical expert
O&M	operations and maintenance
PDD	Project Design Document
PIN	Project Idea Note
PRC	People's Republic of China
PREGA	Promotion of Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement
PV	photovoltaic
RE	renewable energy
REACH	Renewable Energy, Energy Efficiency, and Climate Change
REGA	renewable energy, energy efficiency, and greenhouse gas abatement
SHS	solar home system
TCD	ton cane per day
t	ton
TR	ton of refrigeration
UNFCCC	United Nations Framework Convention on Climate Change
UPS	uninterruptible power supply

Preface

The Asian Development Bank (ADB) has taken the leadership in regional initiatives to address the issue of sustainable growth and climate change. We have been working with many of our developing member countries (DMCs) to increase their awareness on the opportunities provided by the Kyoto Protocol and to strengthen their capacities in preparing least-cost greenhouse gas abatement plans and strategies, as well as identifying innovative approaches to promoting renewable energy, energy efficiency, and other greenhouse gas mitigation technology options.

The Clean Energy Applications in Asia and the Pacific summarizes the results and outcome of a regional technical assistance project on the Promotion of Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement, or PREGA, co-financed by the Government of the Netherlands and ADB, and participated in by 15 DMCs. This document discusses PREGA's key accomplishments in capacity building, outreach, and project development, as well as lessons learned in project implementation.

This publication presents 12 practical clean energy applications, in which specific project pre-feasibility and feasibility studies are briefly described. Barriers and issues to their effective implementation and recommended next steps are also presented. The full reports on these clean energy applications and other PREGA activities are available at www.adb.org/clean-energy.

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Executive Summary

Access to affordable energy services is a fundamental prerequisite to economic development and poverty reduction in Asia and the Pacific. At present, the region's energy supply depends largely on fossil fuels, and as populations grow and countries industrialize, Asia and the Pacific is projected to experience unprecedented growth in the demand for energy services. If the region continues to use fossil fuels in a business-as-usual manner, it will result in serious environmental and economic consequences both at the local and global levels. A new sustainable energy development and usage path must, therefore, be found.

The earth is likened to a greenhouse. Greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane, and nitrous oxide, help balance the Earth's temperature by trapping heat near its surface. However, emissions of these gases have significantly increased in the last 200 years mainly due to burning of fossil fuels, industrial processes, and increase in agricultural activities. To make matters worse, the ability of the Earth to absorb CO_2 has been reduced due to unsustainable use of agricultural lands and forests. With increased GHG concentrations in the atmosphere and less absorption capacity of lands and forests, more heat is trapped within the greenhouse, leading to global warming and climate change.

Global warming will result in an increase in average surface temperatures, sea level, and precipitation. Sadly, developing countries, especially poorer ones, will be particularly vulnerable to these changes because of their limited human, financial, and institutional capacity to adapt to such climate changes as well as their exposure to extreme climatic events.

Since 1992, the Asian Development Bank (ADB) has been working with its developing member countries (DMCs) mitigate and cope with climate change through technical assistance projects and by promoting clean energy initiatives.

The Promotion of Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement (PREGA) Project is one of these ADB technical assistance initiatives. Funded by the Dutch Cooperation Fund for Promotion of Renewable Energy, and Energy Efficiency, and implemented in 15 DMCs, the project aimed at strengthening the institutional capacity and technical capability of governments, consultants, academe, and other stakeholders in participating DMCs to develop and implement clean energy projects as a way to mitigate climate change. PREGA also sought to generate a pipeline of investment projects for financing consideration by commercial, multilateral, and bilateral sources, including specialized treaty-linked mechanisms, such as the Global Environment Facility (GEF) and the Clean Development Mechanism (CDM).

Key government agencies working on renewable energy and energy efficiency known as national counterpart agencies (NCAs) and a cadre of national technical experts (NTEs) that came from think tanks, nongovernment organizations (NGOs), research institutions, and the academe were directly involved in PREGA implementation in Azerbaijan, Bangladesh, People's Republic of China (PRC), Indonesia, Kazakhstan, Kyrgyz Republic, Lao People's Democratic Republic (Lao PDR), Mongolia, Nepal, Pakistan, Philippines, Samoa, Sri Lanka, Tajikistan, and Viet Nam.

Project Accomplishments

PREGA has successfully achieved its main objective of helping create enabling policy framework, developing local capacity, and providing knowledge-based advisory services for expanding access to energy services for the poor. It has helped participating countries built capacity in developing projects on renewable energy, energy efficiency, and greenhouse gas abatement (REGA).

Capacity Building and Outreach

Forty-five regional, subregional, and national training programs were conducted, and five international conferences/meetings were participated in by more than 2,300 representatives of relevant government agencies, NGOs, the private sector, financing institutions, the business community, and other stakeholders.

Thematic areas that were covered by the capacity-building activities included

- Identification of policy and institutional constraints against greater use of REGA technologies;
- Preparation of prefeasibility and feasibility studies that are promising and qualified for financing; and
- Development of specific financing schemes using existing and emerging national and international financing mechanisms to promote REGA project options.

In its outreach activities, PREGA conducted and participated in regional and international events and conferences, including putting on special events during annual meetings of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), the Southeast Asian Forum on GHG mitigation, market mechanisms, and sustainable development, and carbon fairs, among others.

Through its capacity-building and outreach activities, PREGA has enhanced awareness and motivation for promoting REGA projects in the participating countries. It has provided venues for the countries to know more about the modalities of the CDM and other financial flexibility financial mechanisms under the Kyoto Protocol even before the ratification of the Protocol. It has helped in creating enabling policy frameworks and programs at the country level by catalyzing policy dialogue and consultations among stakeholders to Identify and address institutional and regulatory barriers. It has built the capacity of government agencies, consultants, the academe, and other stakeholders by involving them in the preparation of project design documents specific to REGA projects to meet the requirements of international finance institutions, the GEF and CDM.

Project Development

Close to 60 prefeasibility and feasibility studies of specific REGA projects have been identified and developed under PREGA. For each technology option, the technical, financial, and economic viability, as well as environmental and social soundness were assessed. A number of Project Idea Notes (PINs) and Project Design Documents (PDDs) of potential CDM projects were also completed under PREGA. These reports were prepared using CDM and GEF templates to serve as examples on the requirements of these financing facilities. Each project study had to be consistent with the country work plan and development priorities. Studies were conducted on biomass for electricity, utilization of waste for energy, wind power, district heating, and energy efficiency in the building sector, among others. This pipeline of investment projects will now be considered for financing/ implementation by bilateral agencies, the private sector, governments, and CDM and GEF mechanisms.

The project's website www.adb.org/clean-energy/dutch.asp provides details on the PREGA project, access to project information, updates, and progress.

Lessons Learned

This report provides a summary of lessons emerging from the capacity-building and REGA project development activities to gain a better understanding of the factors that may have contributed to the success (or failures) of past PREGA project activities and provide guidance and identify approaches for enhancing the effectiveness and impact of future project-related activities.

Institutional

All the participating countries were found to have significant potential to develop REGA applications despite deficiencies in policies, weaknesses in policy implementation at the local level, and incomplete technical project development capacities. Though PREGA addressed these deficiencies through capacity building in the development of specific project opportunities, it was found that the local capacity to develop realistic, technically sound, bankable, and workable prefeasibility and feasibility studies is still inadequate and continue to need assistance.

All the projects developed under PREGA showed technical promise, but there is still much more to be done on the financial and cobenefit aspects. The majority of the projects were focused on renewable energy or other forms of energy supply, with almost no consideration for energy conservation or energy efficiency improvements. This may result in an overinvestment in new energy supply while cheaper energy efficiency opportunities to reduce energy demand are ignored.

PREGA showed that there are many widely applicable and mature REGA technologies and applications that can supply significant amounts of commercial energy at competitive prices. However, caution needs to be taken when identifying and initiating such REGA projects, as there was a tendency to be attracted to big and high-profile projects with too little attention given to equally promising but smaller and less glamorous projects. There was an almost exclusive focus on energy engineering and technical issues and an insufficient focus on the policy, social, and community aspects of the projects' development. There was also a general lack of focus on project ownership, especially in remote areas and villages where the renewable energy resource is community-owned. In most projects, there was limited or superficial consideration on operation and maintenance costs and issues, systems integration costs, and a future with energy tariffs.

For projects located in rural areas, the additional source of electric power generation could boost job opportunities and development. However, social acceptability—in terms of perceived benefits, performance improvements, and convenience—needs to be secured for project success.

The financial and economic returns of the projects were generally promising and CDM was shown to have the potential to increase a project's likelihood of success because it provides a positive contribution to ongoing project cash flows. However, the ability of a project to actually realize the benefits of CDM through carbon credits may become an issue when the level of emissions reduction is less than 60,000 tons (t) per year because transaction and verification costs could exceed the value of the carbon credits and bring down its financial Internal rate of return (FIRR). Bundling the carbon credits through a third party, such as an industrial users' group or industry-wide trade association, may be possible to mitigate this problem.

Technical

The projects were able to demonstrate which technology would most likely work for a specified electricity need of a specific country, and what would most likely fail. Considerable thought, however, must be given to the project's technical aspects, fuel source and availability, financial sustainability, CDM potential, environmental impacts, intended benefits, and project ownership.

A majority of the projects were technically viable in principle, given that their fuel sources were locally and readily available. This especially holds true for biomass, municipal waste, and bagasse. Fuel collection may be simple and transport is not a major cost, but fuels will not always remain free or have low value once they are fully integrated into commercial energy supply. Therefore, projects would need to consider purchasing these fuels in the future and incorporate their cost into their plans.

Wind power represents a feasible alternative form of energy source in regions that are predominantly fossil fuel dependent for their electricity needs. However, wind power projects need to be more carefully designed to match local conditions for successful execution and long-term sustainability.

The technical aspects of the projects need to be looked into a little further. Technical soundness and applicability of technologies to the specific countries and locations they are to be employed need to be carefully evaluated to ensure cost-effectiveness and maximum benefits to be derived. For example, major consideration should be given to the following before new technology options are identified and implemented:

- Energy audits on existing energy end uses and reviews of industrial processes,
- The impact of higher oil prices on the continued financial viability of the projects,

- System integration issues, and
- Long-term operation and maintenance costs and issues.

Finally, access to suitable technical peer review will assist projects in identifying and addressing social, technical, and financial weaknesses in the proposals prior to project implementation. This applies to all the projects in all the categories.

The lessons from each of the prefeasibility and feasibility studies are discussed in the individual summaries.

Practical Clean Energy Applications

Key practical clean energy applications were selected from the numerous prefeasibility and feasibility studies developed under PREGA and are summarized in the report. Each application briefly describes the specific projects, lessons learned, barriers to and issues of effective implementation, and next steps to wider implementation.

- Biomass energy in Sri Lanka and Viet Nam
- Waste–to–energy power generation in the PRC, Kazakhstan, Kyrgyz Republic, Lao PDR, Pakistan, and Philippines
- Sugarcane bagasse cogeneration in Bangladesh, Indonesia, and Viet Nam
- Wind power generation in Azerbaijan, PRC, Mongolia, and Viet Nam
- Solar photovoltaic system in Indonesia
- Small hydropower in Indonesia, Kyrgyz Republic, and Nepal
- Renewable energy-diesel hybrid power in Bangladesh and Mongolia
- Industrial cogeneration in Indonesia and the Philippines
- District heating in the PRC, Kazakhstan, and Mongolia
- Energy efficiency in buildings in Indonesia
- Energy efficiency in transport in Nepal
- Improved cook stoves dissemination in Bangladesh and Nepal

The full reports on these clean energy applications are available at www.adb.org/clean-energy.

Biomass Energy

Biomass-based energy generation has become widely accepted in recent years. It is perceived to be a more affordable, high-value energy output and has moderate-to-low environmental impacts. As an alternative fuel source, biomass is locally produced, is indigenous to its location, and can be produced in massive quantities. For developing countries in Asia and the Pacific, this alternative fuel source is essential to their sustainable development.

Two project studies on the feasibility of biomass-based energy production are highlighted here. One is the fuelwood-based 5–megawatt (MW) Biomass Project in Sri Lanka and the other is the Rice Husk Power Project in Viet Nam. Both studies present their project features, barriers, and next steps to wider implementation.

Dendropower

Wood is a critical component of the total energy balance in many countries in Asia and the Pacific region. In fact, the total national demand for fuelwood in Sri Lanka and Bangladesh comes close to 70%, while that of India is at 30%. National energy policies in these countries have seriously accepted that dendropower—or fuelwood-based energy production—provides a viable alternative to expensive oil imports, as well as a useful income to farmers and commercial growers.

Gliricidia is a fast-growing tree species found in Sri Lanka. It has been found suitable for various agroclimatic zones of the country, enriches the soil with its nitrogen-fixing capacities, and is one of the best species suitable for dendropower generation.

In a tropical country such as Sri Lanka, these fast-growing trees could be harvested 3–4 times a year, with an annual production of more than 25 tons (t) of dry matter per hectare. Its use is not merely confined to power generation but offers other productive uses as well. The lopped branches are left on the ground to dry then cut into pieces and transported to the electricity-generating site. While the main stem is used as fuelwood, the rest of the green vegetation can be used as fodder for dairy cattle, which could result in enhanced milk production.

The 5-MW Biomass Power project in Sri Lanka will incorporate biomass into power generation. With an estimated annual operation time of 7,000 hours, 35,000 megawatt hour (MWh) of electricity is projected to be exported to the grid and approximately 94,500 t of wood per year will be required (at 2.5 kilograms [kg] of fuelwood per kilowatt hour [kWh]). Overall estimates of the fuelwood production indicate that there should be an annual potential supply of more than 10 million t of fuelwood in Sri Lanka, thereby generating 10,000 gigawatt hour (GWh) of electricity. This amounts to double the total capacity of Sri Lanka's current major hydropower generation facility.

The project will improve Sri Lanka's energy security by incorporating a new private-sector solution to severe power shortage and overreliance on imported fossil fuels.

Economic and financial analyses were completed based on the sale of 35,000 MWh of electricity to the grid at Sri Lankan rupees 8.5 per kWh (approximately $8.2 cents/kWh), along with the project's estimated capital, operating, and financial costs. The resulting financial internal rate of return (FIRR)—without the sale of certified emissions reductions (CERs)—will be 23%. In order to make the project commercially feasible and attractive to private investors, FIRR needs to be at least 24.99%. Additional income will come from sale of CERs, estimated at 26,040 t per year.

The concept for the 5-MW power plant in Sri Lanka was well done and complete, but the overall infrastructure to support a reliable fuel supply from a large number of fuelwood growers will require additional detail, especially regarding overall management and scheduling of fuelwood harvesting. Of greater overall value to the region and the 1,000–2,000 affected families will be the potential income stream from fuelwood plantations and fodder, cattle and milk production and processing, and the use of animal wastes. Milk production offers the greatest economic potential to the development of the region alongside electricity export, but would require additional thought to land allocation issues and development of a suitable milk collection and processing infrastructure. If all of the economic potential suggested for the project could be achieved, significant sustainable economic development will be realized.

Agricultural Residue

Methane comes from natural processes of decomposition of biomass and wastes. It is 21 times more potent than CO_2, and is one of the primary GHGs that contribute to global warming. Utilization of methane does not only reduce GHG emissions but also has the potential to meet energy needs. The Rice Husk Power Project in Viet Nam proposes to use 5,000 t of rice husks in a cogeneration power plant, avoiding 10 t of coal for the same period. Project economics included the sale of ash and the avoided cost of rice husk disposal. The economic internal rates of return (EIRR) and FIRR for the project were in the range of 20%, along with the reduction of 19.72 t of CO_2 per year.

The prefeasibility study showed good economic and financial returns for the project, due in part to the effectively negative cost of fuel. It has good CDM potential from the sale of CERs. The sale of ash from rice husk combustion may have a unique market in the glass industry because of its high silicon content. It also increases the income potential a little more.

Lessons Learned

Both projects are technically and financially viable to implement, especially when fuel collection is not a problem. Their economic and financial internal rates of return are high, even without CER sales, and the additional source of electric power, jobs, and incomes can promote sustainable development in their respective locations.

Barriers and Issues

The basic combustion technology for biomass exists. However, the nontechnical aspects of both projects bear down on their wide implementation and replication. Some of these barriers are

- Lack or absence of government policies to support small renewable energy Projects,
- "Unleveled" playing field for renewable energy with fossil fuels,

- High investment and equipment cost,
- High cost of collection and transport of biomass,
- Lack of technical know-how and experience on use of biomass for power generation,
- Access to land for energy plantations,
- Insufficient national grid electricity export, and
- Insufficient financial incentives.

The projects also fail to realize the full benefits of CDM because the level of emissions reduction is typically less than 60,000 t per year. However, bundling the CERs through a third party, such as an industrial user's group or an industry-wide trade association, may be possible to mitigate this problem.

Next Steps to Wider Implementation

A more detailed feasibility study to resolve the issues of fuel collection and reliability of fuel supply is necessary. For dendropower, specific attention must be paid to the reality of obtaining a long-term power purchase agreement rather than just basing the analysis on current electricity tariffs.

Waste-to-Energy

Interest in waste-to-energy technologies and processes has grown in recent years due to the fact that they respond to international concerns, such as pollution, waste management, and overdependence on fossil fuels. In fact, waste-to-energy facilities have been designed and established to produce clean and renewable energy, and control pollution. Waste-to-energy technologies and processes produce high-value energy outputs and useful waste products.

Agricultural and Animal Waste

Intensive farming operations produce massive quantities of dung and waste biomass and are a natural partner for waste-to-energy initiatives. Agricultural and animal waste processing involves the collection and decomposition of wastes in an anaerobic digester. This process naturally breaks down waste to produce biogas, liquid and solid organic fertilizers, and soil conditioners. Biogas typically is composed of methane, CO_2, and traces of other gases. Depending on the end use of the gas, the unwanted components are separated and are either used or discarded. Under normal circumstances, only the methane is retained for its energy value.

Options for the utilization of the gas output are considerable and depend on the requirements of the local population and prevailing market conditions. Smaller capacity systems, which can be as small as several cubic meters and take waste from only 5–10 cattle or equivalent, tend to use the gas for domestic cooking and heating. Larger-scale plants are more likely to invest in scrubbing and separating gas products, and investing in higher value-added processes for the gas outputs. The larger output would be sold to a local network.

The PREGA project supported the development of prefeasibility studies on agricultural and animal waste processing from the PRC, Kazakhstan, Kyrgyz Republic, Lao PDR, Pakistan, and Philippines. Their project studies all proposed to capture animal waste and process it to recover energy and fertilizer outputs, while simultaneously mitigating or eliminating negative environmental and/or social impacts.

All the projects provided sufficient data to assess their approximate gas and fertilizer outputs, but did not provide analysis of their actual calorific value (biological or chemical oxygen demand and the amount of volatile organic solids in the waste). Without this data, it is difficult to make accurate predictions on expected energy outputs or assess if the predictions are accurate. Furthermore, optimistic assumptions were generally made on the value of organic fertilizers. The proposals assumed a direct substitution of organic for mineral fertilizer, but are not supported by researched examples and lead to almost certainly overoptimistic financial predictions in terms of reduced mineral fertilizer consumption and increased crop yields.

The projects from Kazakhstan and the Kyrgyz Republic also assumed that project finances will be bolstered by improved economic conditions of the farms using the fertilizer, however, data on the market conditions for the predicted agricultural yield has not been provided. Data supporting the ability of local markets to absorb increased crop volumes would be advantageous. Both projects showed solid FIRRs, but were based on optimistic financial assumptions in revenue generation from carbon credits, fertilizer savings, energy savings, and improved agricultural outputs.

Most lacking were market and technical analyses of the raw resources and social considerations, such as community initiatives. Issues related to the ownership of assets, management structures, service, and support facilities were not well-covered. In fact, community infrastructure projects tended to be the major source of project weakness.

The Vanith Pig Farm Company in the Lao PDR undertook a much more comprehensive analysis of the overall operation but was let down in the financial and economic analyses, which were more of an academic overview of the process rather than a specific study of the planned activity.

The Philippine animal waste project was technically acceptable in most areas; however, it also lacked depth in the financial analysis. Barriers to wider acceptance of biogasification technology in the Philippines were identified, but were not addressed in the proposal.

The financial analysis of the Landhi cattle colony project in Pakistan is not comprehensive as some variables impacting on project output are yet to be defined.

The investment cost required by the methane recovery and utilization project in Muyuan Swine Farm is high due to advanced manure management technology to be adopted. The PRC does not offer incentives to electricity that is generated from biogas; thus, electricity from biogas is much higher than electricity prices in the market. Without the revenues from the sale of CERs, the banks would be unwilling to finance the project without government guarantees.

A degree of uncertainty is acceptable in prefeasibility studies. However, there should be a demonstrated awareness of the unknown. This was clearly not evident in the studies submitted.

Municipal Solid Waste

Solid waste management shares many of the same processes as biomass and animal waste processing, but differs in the variability and nature of the raw input materials. The inclusion of toxic, hazardous, and recyclable materials, and complex and generally inadequate collection and transport systems, makes solid waste management much more complicated than agricultural and animal waste processing. Municipal solid waste management requires the handling of multiple and variable waste types, ranging from simple organic materials to metals, chemicals, biological, and industrial wastes. Landfills are a traditional method of disposing household and other municipal wastes. Valleys, gulleys, and swamps are filled with refuse, then compacted and covered with soil. The organic materials decompose and release methane and other gases, and liquid residues—called leachates —follow natural watercourses at the base of the valley and contaminate streams and groundwater. The very wide and frequently uncontrolled materials disposed of in the landfill can result in leachates being particularly unhealthy to local populations.

As an alternative fuel, landfill gas can be extracted for power generation. The PREGA projects reviewed proposed variations in the handling of waste, but not all the methods assessed seemed feasible to produce both landfill gas and useful fertilizer outputs.

The projects from the cities of Dhaka and Khulna in Bangladesh recommended the construction of 50 small digesters to hold and digest the waste, but did not consider sorting municipal wastes prior to digestion. The digesters will ensure high rates of leachate and gas capture, but will add to construction, and if the waste is not sorted, it could result in the mixing of toxic wastes, such as asbestos, heavy metals, and biological contaminants, with resultant fertilizer outputs.

By comparison, the project from Roxas City, Philippines, will sort the waste prior to compaction and digestion in landfill cells, which then be drained to capture leachate and maximize gas capture, resulting in reduced GHG and power generation potential.

Gas values from the various waste-to-energy methods are similar, involving the decomposition of similar base materials under similar anaerobic conditions. Methane percentages are expected to vary from 45% to 65%, with lower values occurring in landfill gas systems where extraction rates are dependent on the rate of evacuation.

All the projects operated in the context that there is little effective legal incentive to sustainably process waste products. Environmental law is, theoretically, in place, but its enforcement is weak—leading to the status quo being the less financially expensive option and probably being viable for the foreseeable future as well. This is demonstrated in the Philippines by all of the 734 open municipal dumpsites still operating well after their deadline for closure. Lack of financing and access to expertise are also critical limiting factors, but these capacities are unlikely to be developed without strong incentives for investment, such as sale of energy, carbon credits, and organic fertilizers/soil conditioners.

Lessons Learned

The projects all pointed to a widespread underutilization of biomass, animal, and municipal wastes in developing countries. Environmental problems are common, with massive overnutrification and pollution of surrounding land and waterways being typical. Community complaints are strong and refer to very serious local odor, water, and air pollution levels.

Biodigester system designs are relatively easy to obtain. However, the general lack of enforcement of environmental law and the perceived high cost of building quality structures have led to underinvestment, poor performance, and the low utilization of this technology.

Low-cost and workable designs for household or biogas digesters are available. Without sufficient attention to the social context they are operated in,

however, the risk increases significantly. This is a common thread in most of the projects. The projects were technically driven and written by experts that see the wasted raw resources and the need for energy and fertilizer. A technical solution was put forward to cover most of the basic operating parameters, and the unexplained engineering details were assumed to be simple. However, community mobilization and consultation were overlooked as critical factors to sustainable operation, despite being responsible for the majority of community infrastructure failures.

A social dynamic is also present in smaller systems, where richer households are more likely to have sufficient heads of cattle or pigs to afford alternative sources of domestic energy, such as kerosene or liquefied petroleum gas. This has resulted in the failure of Utilization and long-term operation of household-scale biogas systems in India and Viet Nam in the past.

Larger-scale systems or community-based farming entities use more energy and have greater volumes of waste to address. But the farming entity is frequently physically and financially separated from the supplier of the fodder. Transporting wet dung back to the fields where the fodder originated is not welcomed by transport companies. Linkages and financial or legal incentives to capture and process waste into saleable products are required. This will motivate the commercial sector and farm owners and operators to modify their current practices.

A systematic peer review of projects to ensure key social, financial, and technical components are adequately addressed is needed. This will raise project standards and mitigate common reasons for failure. While most projects tend to overestimate project benefits and financial performance, a peer review process should ensure that projects succeed and do not fail prematurely.

The lessons learned may be summarized as follows:

- The problem of sustainable handling of organic wastes is widespread.

- The production of energy and organic fertilizer is technically possible and socially, economically, and environmentally desirable.

- Technical solutions need to be assisted with social development input, particularly for household and community-based operations, as nontechnical impacts are the primary source of project risk and, hence, project failure.

- In the absence of effective legal or regulatory drivers, the GHG or fertilizer income streams need to be attractive enough to generate investor interest.

- Information dissemination mechanisms to support successful installations will ensure that the technical data is accessible and that the applications are sufficiently well-founded.

- Peer review functions will help ensure successful applications for funding and demonstration projects.

Barriers and Issues

There is a lack of encouragement to develop biogas resources despite rising energy prices, increasing fertilizer costs, and growing awareness of environmental degradation. Landfill gas investment is more pressing as the scale of the problem is simply too large to disguise. If successful demonstration projects can be developed within realistic budgets for the scale of operation they are targeted at or operated in parallel with available funding mechanisms, then replication becomes possible.

Other barriers include

- *Lack of technical resources.* Smaller farming operations do not have ready access to information needed to develop biogasification/fertilizer installations. Funding channels that may be available require demonstration or verification of predicted performance of gas and fertilizer values, but this data is often not available. Municipalities also struggle with access to expertise and funding for solid waste management projects. However, the private sector is beginning to invest in waste-to-energy technology to reduce energy costs.

- *Inefficient community installations.* Community-based initiatives need to use proven models of mobilization, asset management, training, and support in order to create sustainable operations. Projects that start with a purely technical agenda do not address the most common reasons for failure of community infrastructure projects. Project funding mechanisms generally understand this and are less likely to fund socially oriented projects that address only technical issues.

- *Lack of access to financing.* Community infrastructure projects are regarded as high-risk, partly due to the high failure rates influenced by factors mentioned above. Introduction of accessible and demonstrable funding mechanisms that reward sustainable waste-to-energy activities will promote investment by both private and public sectors.

- *Poor enforcement of environmental law*. When project financial performance is viewed as marginal, there is little incentive for farm owners to invest because there is less likelihood of attracting negative legal or financial impact.

Next Steps to Wider Implementation

Information dissemination mechanisms to provide basic technical support and access to funding options for various activities need to be developed. This mechanism may also reduce risks and improve project performance.

While economic benefits may be very significant, they tend to accrue to the state or local population, and the financial cost and return on investment is borne by the investor. Therefore, if the state wishes to see economic benefits, it needs to work toward reducing financial hurdles for other investors. Additionally, environmental laws need to be enforced. The avoidance of the negative impact of legal action creates an additional positive driver.

Sugarcane Bagasse Cogeneration

Sugarcane bagasse is another alternative fuel source that can provide multiple benefits to various stakeholders—increased profits for the sugar mill, higher prices for the cane grower, competitively priced electricity for local electric distribution companies, reduced grid electricity supply shortages, reduced local pollution, and reduced CO_2 emissions.

Sugar mills generally utilize bagasse-fueled cogeneration systems inefficiently, mainly due to a lack of concern with process energy efficiency as bagasse is seen as waste material with no apparent value. What is not recognized is that process energy efficiency could provide sufficient power to the sugar mill operation and, at the same time, sell excess electricity to the grid, increasing the mills' profits and income streams.

The prefeasibility studies from Bangladesh, Indonesia, and Viet Nam demonstrated sufficient bagasse resources in each of the countries and the potential for exporting electricity from sugarcane bagasse cogeneration to local distribution facilities. The power supplied to the grid will displace power generation requirements from other fossil fuels and result in net reductions of CO_2 emissions. With CDM, it appears that additional income may come into each of ADB's sugar-producing member country.

The Viet Nam Joint Venture Company, Nghe An Tate & Lyle, featured a new plant and, on the overall balance, showed better efficiencies with an excess bagasse of 18%. However, the excess bagasse was still sent to landfills. The Bangladesh and Indonesia prefeasibility studies, on the other hand, proposed new boilers and extraction/condensing steam turbines. However, both projects still plan to retain and utilize their existing and highly inefficient equipment.

The studies did not consider electric or steam energy conservation, which would have allowed more steam to be used on-site instead of electricity, yielding increased electrical output for export. For an investment grade feasibility study, at least average monthly operating conditions, including the development of load duration curves, should be evaluated in order to give a better representation of the total electric energy available for export.

Table 1 shows each country's gross electrical energy if the energy potential of the available bagasse is maximized. There would also be export electricity potentials to the PRC, India, Pakistan, Philippines, and Thailand.

The prefeasibility studies showed excellent potential economic viability because the value of electric energy sales was sufficient to generate an acceptable economic internal rate of return (EIRR), even with an annual capacity utilization factor of less than 50%. Electricity supplied to the grid would usually displace large thermal electricity, making such projects very receptive to obtaining an extra hard currency cash flow from CDM.

Table 1. Country Gross Electricity Generation Potential from Bagasse

	Sugarcane Production (tons/yr)	Potential for Electricity Production (tons/yr)	Annual Country Electricity Consumption (GWh/yr)	Bagasse Potential as Percentage of Electricity Consumption
Bangladesh	6,700,000	670	17,400	3.8
Indonesia	27,000,000	2,700	110,000	2.4
Viet Nam	11,600	1,160	36,900	3.1

GWh = gigwatt hour, yr = year.

Lessons Learned

The projects are technically and economically viable, but the excess electric power from new or improved cogeneration plants in sugar mills need to be exported to the grid if increased financial and economic internal rates of return are to be generated. There is sufficient bagasse available in these countries so much so that a significant extra quantity of electric energy can be delivered.

Barriers and Issues

Availability of suitable local and affordable technologies is not a serious constraint, nor is the lack of personnel experience in operating them. The primary barrier to the full potential of sugarcane bagasse-fueled power generation is obtaining a financially acceptable power purchase agreement for the exported electricity. However, most countries are proceeding with reforms of the electric power sector that will allow or require purchase of electric power from independent power producers.

Another key issue is the ability of the project to actually realize the benefits of CDM when the level of emissions reduction is typically less that 60,000 t per year. Bundling the CERs through a third party, such as an industrial user’s group or industry-wide trade association, may be possible to mitigate this problem.

Next Steps to Wider Implementation

More detailed feasibility studies are required of the proposed projects. Process energy efficiency, in addition to an improved understanding of energy use throughout the milling season, needs to be addressed. The reality of obtaining a long-term power purchase agreement rather that just basing the analysis on current electricity tariffs also needs specific attention.

Wind Power Generation

Wind power generation ranks among the world's fastest-growing commercial renewable energy technologies, with system costs exhibiting a steady decline in recent decades and improved machine performance factors and efficiencies. This has led to a strongly decreasing price per unit of wind-generated electricity, making it competitive with conventional wholesale generation costs. However, wind power markets are still limited to a few leading countries, with many developing countries just beginning to mobilize efforts to tap this resource.

Establishing a viable wind power market in countries with little or no prior experience in wind power generation requires an evolutionary approach. A conducive policy and incentives environment is necessary to address complicated issues, such as electricity market restructuring/deregulation/liberalization; tariff rationalization; fossil fuel prices set by international markets; and growing local, regional, and global environmental concerns. Additionally, mechanisms to monitor project performance and promptly respond to the industry's needs have to be created in order for wind power to ultimately operate without subsidies under competitive and transparent energy market conditions.

The PREGA wind power prefeasibility studies in Azerbaijan, PRC, Mongolia, and Viet Nam presented initial, pioneering project analyses in countries generally lacking extensive wind technology experience. As such, they addressed both specific project technical and economic feasibility in the local context—driven by design, equipment, and cost—and the overall 'fit' of these projects within the existing or expected national renewable or wind power policy and market context.

Although wind power technology is making rapid gains worldwide, with unit costs of electricity production currently at \$0.04–\$0.05/kWh, the economics of wind power varies widely, depending on actual site conditions and the intermittent nature of the wind resource. However, the main benefits of wind power—fuel independence and nearly zero emissions—are compelling factors in its favor. An assessment of such external costs and benefits within a country or regional context is, therefore, essential to ascertain the overall feasibility and optimum deployment of wind energy and the development of an appropriate policy environment.

Each of the studies served as useful proof-of-principle business demonstrator models under incipient wind industry conditions, where initial transaction costs are high, markets are not configured for its special features, and additional government and external support are essential to ensure project viability.

Table 2. Wind Power Generation Project Characteristics

Project	Total Capacity (MW)	Number of Turbines	Turbine Type (Rating, MW)	Plant Capacity Factor	Annual Output (GWh)	Project Cost (mn USD)	Total CO_2 Abated, kt (Lifetime, Yrs)
Azerbaijan	24	12	Vestas V66 (2 MW)	38%[1]	78.0	26.4	1,750 (25)
PRC	22.8	38	USP. Chinese (0.6 MW)	30%	58.6	20.3	1,171 (20)
Mongolia	40	47	Gamesa G58 (0.85 MW)	29–35%	123.19	45.7	2,422 (20)
Viet Nam	0.75-1.5	3-6	Fuhrlander (0.25 MW)	NA	NA	NA	86.5 (25)

[1] May be overestimated. 35% more feasible upper limit based on reported turbine data.

CO_2 = carbon dioxide, GWh = gigwatt hour, kt = kilo ton, mn = million, MW = megawatt, NA = not applicable, PRC = People's Republic of China, USD = US dollar, yr = year.

All four studies proposed modern, state-of-the-art wind farms that will feed into local or regional power grids and situated in locations that suffer from serious electricity-generation shortfalls. They will employ commercially proven, horizontal-axis turbines in varying numbers, capacities, and configurations (see Table 2). Based on energy outputs and baseline emissions, the average annual GHG savings have been estimated at 70, 121.1, 58.5, and 3.4 thousand t of CO_2 per year for the Azerbaijan, PRC, Mongolia, and Viet Nam projects, respectively.

The Azerbaijan wind project will be located in a windy and energy-deficient region of the country that imports up to 76% of its power. The project could offer additional benefits of reduced transmission losses and supply price variability, but it would not contribute more than 1.2% of the electricity in the grid, thereby keeping issues of power quality and frequency to manageable limits.

Mongolia, on the other hand, also faces power shortages and imports electricity from the Russian Federation. Although Mongolia relies heavily on diesel generation for off-grid townships and has limited hydropower potential, it has excellent wind resources. The central regional grid in Mongolia is smaller, and the proposed wind project there could account for as much as 8.5% of its power capacity.

The PRC wind project is the only one representing an extension of an existing wind plant (the 12.1-MW Debancheng No. 1 wind farm) and will feed into the regional grid. However, it will not exceed the 8% regulatory cap on wind-generated capacity on the grid.

The Ly Son Island project in Viet Nam is located in a small, isolated diesel-fed grid. It will need to be carefully phased and matched to loads in order to provide an optimum wind-diesel hybrid solution. This will present complex systems integration issues that were not considered under the PREGA study.

Meteorological wind data for three of the proposed project sites indicate good-to-excellent wind resources. The Azerbaijan, PRC, and Mongolia, wind power studies were based on recent, high-quality wind data over at least two calendar years (Table 2). The Mongolia study provided an addition al 12 months of on-site wind speed monitoring prior to project construction, while the PRC project will benefit from the existing farm's operational data starting from year 2000. The data for Viet Nam's Ly Son site were less reliable and consisted of longer-term reference meteorological readings.

On technical grounds, the Azerbaijan, PRC, and Mongolia projects appeared to be feasible although they will be dependent on additional transmission line investments by the government (Azerbaijan and Mongolia), while the Viet Nam project presented a qualitatively inferior wind resource and a different grid integration scale. The selection of technology (turbine size, output, efficiency, make, etc.) in each case was based on operational requirements as well as proven machine reliability.

Although situated in a developed region of Azerbaijan with good transportation infrastructure and site access, topographical conditions were not mentioned in the study. The installation of large turbines may present some construction, as well as maintenance challenges. On the other hand, the road network in Mongolia is underdeveloped, and moving even the smaller-sized turbines to the remote project site may prove difficult and/or require additional expense on road rehabilitation and construction. This has been acknowledged in the study and presumably accounted for in the cost calculations, thereby recommending the smaller Gamesa turbines over the larger, higher-output Vestas machines. Such difficulties were not expected in the case of the PRC due to the infrastructure for the existing wind farm. Site access, equipment transportation, and turbine installation requirements were not addressed in the Viet Nam study.

Only the Mongolian study flagged other project requirements, such as power conditioning and stability, monitoring and communications systems, operations and maintenance (O&M), and personnel training. Bearing in mind that these projects represent first-off examples of their kinds in countries where little relevant expertise and experience in wind power production exists (except for the PRC), such considerations cannot be underestimated during project design. Similarly, micrositing and public acceptance criteria have not been specifically mentioned in any of the studies, although both Azerbaijan and Mongolia provided site selection within their overall 2–year project schedule.

The Azerbaijan, PRC, and Mongolia studies also included the results of a preliminary environmental assessment, but did not indicate significant impacts. A more detailed environmental evaluation is recommended during detailed project design. Conducting public consultations and community scoping sessions during the detailed project design stage is also suggested.

The additional implications of coastal locations were not addressed in the Azerbaijan and Viet Nam studies. The latter, being on a small, isolated grid, will need to match farm output with the local electricity demand profile. The extent to which natural diurnal wind patterns at the project site facilitate or exacerbate this issue was not clear from the study, while the provision of an inverter and battery bank to store off-peak wind power, smoothen fluctuations, provide frequency stabilization, and allow for uninterrupted crossover to diesel backup were not dealt with either. Therefore, the quality and reliability of the power produced by the Viet Nam project will need to be much more carefully analyzed, as will the additional investment and maintenance requirements of keeping a perpetual diesel generator backup, and aggravated wear from frequent startup and switchover. The avoided cost will not be the full fuel and O&M cost of alternative diesel generation as assumed, but rather only the fuel saved when the wind turbines are operational. The financial analysis for the project will need to be strengthened based on these additional costs, peculiar to small-grid operation with hybrid wind-diesel generation.

Financial analysis indicates that for the Azerbaijan project to be feasible, a wholesale tariff of \$0.0327/kWh (with a 5% annual inflation factor and without carbon credits) is necessary. This is above the currently applicable wholesale tariff rate of \$0.0154/kWh and avoided average grid electricity production cost of \$0.024/kWh. The difference could be financed through a CDM income of \$0.39 million a year (at a CER price of \$5.63/t of CO_2) to maintain the project's FIRR above 12%. Annual economic benefits from avoided fuel (furnace oil and gas) savings amount to more than \$3 million per year.

The PRC project calculated a production cost of \$0.064/kWh, an annual CER income of \$0.29 million (at \$ 5/t of CO_2) by displacing coal-fired thermal generation, and a project FIRR of 11.41%

without CDM benefits. The generation cost for the Mongolia project is at \$0.028/kWh without carbon credits, which is less than the assumed avoided coal-fired grid fuel cost of \$0.033/kWh and the local tariff of \$0.042/kWh. After-tax FIRR—with and without CDM income of \$0.6 million per year at \$5/t of CO_2—are 14.3% and 11.6%, respectively. The Mongolia report did not include an economic cost–benefit analysis.

The Viet Nam project indicated feasibility at a wholesale tariff of \$0.11/kWh (compared with local diesel generation cost of \$0.132/kWh), with FIRR of 7.38% when carbon credits of \$17,310/year at \$5/t of CO_2 are taken into account and a cost–benefit ratio of 1:23. However, as noted earlier, these financial indicators will deteriorate once the full cost of operating the wind farm in tandem with the diesel backup in a hybrid mode, an inverter and battery storage capital, energy losses, and O&M costs are taken into account.

Additionally, the ability of this project to attract CDM benefits for such limited CO_2 savings remains doubtful.

Lessons Learned

The four wind power projects represent potentially feasible alternative forms of power generation in regions that are energy-deficient and predominantly fossil fuel-dependent. However, for successful execution and long-term sustainability, the projects need to be more carefully designed to match local conditions and adequate government support would be required as part of a longer-term wind power development strategy.

Barriers and Issues

A suitable and commercially proven technology is readily available in the market, but additional barriers to project implementation—such as the lack of local technical expertise, O&M capacity, and grid-integration issues—can present temporary hurdles. However, these barriers could, in principle, be managed through appropriate provisions within the project budgets and external buy-in.

Project financing may present more formidable challenges, as private capital would be averse to such new, high-risk investments without highly attractive terms and guarantees. This ties in with the necessary enabling factors mentioned earlier—favorable tariffs and grid interconnection arrangements, direct subsidies, production or capacity incentives, duty and tax rebates, and environmental credits that contribute critically to the successful execution and sustainability of wind farms. Only the Mongolia study explicitly referred to the incentives and relevant policy frameworks necessary for overcoming some of the initial barriers. For the Viet Nam study, the quality of baseline wind data, grid integration, balancing, and backup requirements could also have serious implications on project feasibility and operation. Additional cost elements, such as dedicated transmission lines and substations, will probably raise the financial barriers further for all three projects.

Next Steps to Wider Implementation

Detailed site selection, further wind resource assessment, more comprehensive project design, and environmental assessments will be required for each case. These requirements may be less severe in the case of the PRC where the plant represents capacity expansion based on good operational experience and a more advanced local wind industry. However, initial government policy and regulations regarding bulk power purchase terms and lifetime agreements, dispatch priority, and grid interconnection rules will be needed to make the projects bankable and replicable. CDM credits will also be necessary to make them financially viable.

Solar Photovoltaic

Solar energy has immense energy potential with an average global radiation of about 5 kWh per square meter per day. With most countries having about 250–300 clear sunny days a year, the market potential of solar photovoltaic (PV) systems has steadily grown. Production volumes have increased and costs have steadily dropped, and this trend is expected to continue to a point where PV systems will be used for grid and off-grid applications.

The primary demand for solar PV systems in developing countries is for off-grid applications, most of which are for individual solar home systems (SHS). While some manufacturers and dealers use financing, microcredit, and leasing to successfully sell their products directly to end-users, most solar PV sales in the developing world have been partially or fully subsidized by donor-funded development programs. Such programs face barriers of high investment and transaction costs, such as expensive and time-consuming project identification, social development, billing, replacement of batteries, supply of efficient lights and appliances, and other project sustainability elements.

Analyses of a centralized, grid-connected solar PV system in Indonesia and decentralized small solar PV systems in Nepal were undertaken under PREGA to explore the CDM potential of PV systems in developing countries.

The 1-megawatt peak (MWp) grid connected PV system was proposed for Jakarta, Indonesia, where almost 85% of its installed grid capacity relies on fossil fuels. The project proposed both direct coupling and battery coupling system configurations. The trade-off between the approaches is that direct coupling is the least-cost option, but requires a reliable grid in terms of voltage and frequency. Battery coupling, on the other hand, will be clearly more expensive because of the extra investment in battery storage, but is more appropriate for a less reliable grid. There was no comparison of per-MW cost in Indonesia in the report, but the total project cost of $6 million for a 1-MWp and 1,300-MWh per year is clearly an expensive option in terms of financial returns. This will only make sense if solar PV projects could directly substitute expensive peaking power stations, but this does not seem to be the case for this project.

The load profile of the project area showed that peak demand occurs during nighttime, which is not when a PV system would generate any electricity. The project could potentially reduce up to 1,000 t of CO_2 per year, but the yearly carbon revenue of about $5,000 will hardly make any difference to the 2.5% FIRR, which is far below the necessary threshold of 12%, and the economic cost–benefit ratio will not be sufficient to attract private investments. The financing plan proposed large equity and grant components from the Government or from international donors, although it was not clear how the grant component can be increased from the permissible limit of up to 20% of the total investment. This first-of-its-kind project in Indonesia will provide some positive impacts on technology transfer, awareness, employment generation, replication, local environmental protection, and reduced dependency on fossil fuels. However, the project is clearly only viable as a donor-led demonstration of technology application and not as a commercially replicable one.

The White Light-Emitting Diode-based decentralized solar PV system (Solar Tukis) for 50,000 households in Nepal was a prefeasibility study undertaken in the form of a CDM Project Idea Note. The Centre for Renewable Energy (CRE) was proposed to be the implementer of this project and has already launched the "Light for All" campaign toward this goal. CRE will develop quality standards, a guarantee mechanism, and will promote Solar Tukis among poor households throughout the country. Each set of Solar Tuki costs about $50 and can reduce about 0.2 t of CO_2 per year. Revenue earned from CDM credits is envisioned to support this campaign.

The project also highlights the use of environment-friendly Nickel Metal Hydride batteries. These will be collected by local service centers to minimize careless disposal. Since the emissions reduction potential is very small per unit, the cost-effective monitoring of the project is seen as a challenge.

Solar Tuki

Lessons Learned

Embedding small solar PV systems within a grid network can provide a number of benefits, including reduced GHG emissions, increased energy security and diversity of supply, and reduced losses.

Most of the target population for decentralized solar PV systems lives in extreme poverty. This means subsidies and/or other aggressive measures are essential to reduce the first-cost barrier. Furthermore, the solar PV industry needs to develop and establish specialized financing vehicles, such as micro- and vendor-financing, for potential customers of off-grid solar PV systems, and the private sector is anticipated to lead the promotion and sustainability of the sector. However, sustainability will also depend on strong quality control mechanisms and a satisfactory level of after-sales service from manufacturers.

CDM and the emerging carbon market could contribute to the financial viability of solar PV projects, although would not necessarily make them fully viable.

Barriers and Issues

Solar PV systemsare more capital-intensive than their conventional counterparts which have lower operating costs. Therefore, solar PV systems will remain dependent on grants and subsidies, in addition to CDM, to become sustainable. Additionally, the high cost of solar PV systems and lack of productive applications make them unaffordable, especially to the poor.

The existing regulatory frameworks often fail to recognize, allocate, or evaluate the additional benefits of grid-connected solar PV systems, such as deferred transmission upgrades, reduced distribution losses, and increased network support.

Given the current competitive nature and modalities of CDM, high transaction costs and low per-installation carbon abatement can make it challenging for off-grid solar PV projects to derive value from CDM unless a large number of systems are bundled together. Even so, efficient and effective management to implement and monitor decentralized solar PV systems is required.

Next Steps to Wider Implementation

The following are the necessary first steps toward successful promotion and wider implementation of solar PV projects:

- Set national level targets for solar PV systems;

- Leverage other funding sources through CDM and formulate nondiscriminatory policy environments for solar PVs;

- Provide fiscal incentives by reducing import tariffs on PV modules and associated equipment;

- Facilitate significant private-sector involvement in the promotion of solar energy and build the capacity of the central-level quality assurance institution;

- Facilitate linkage between the solar PV industry and financial institutions (both commercial banks and microfinance institutions) to create customized financing vehicles that will help achieve broader market-based solar PV penetration;

- Ensure availability of good after-sales service for PV systems; and

- Provide capacity-building support to potential solar PV project developers on CDM prospects and assist in the preparation of documents necessary for CDM project development.

Small Hydropower

Hydroelectric power generation is a conventional and mature form of power generation. Microhydro is under 100 kW, small hydro is between 100 kW and 5 MW, and large hydro is more than 5 MW. Small hydro is clean and non-GHG producing, and when properly designed, constructed, and maintained, it offers a reliable, predictable output, and low operating cost power generation for isolated grids or as distributed generation resource of a larger network.

Microhydro and small hydro often operate on a 'run-of-river' principle, meaning the turbine draws water from a stream or river and runs it through the turbine before returning it to the original watercourse farther downstream. This mode of operation does not require the construction of dams or water storage infrastructure, which reduces cost and environmental and social impacts. On the downside, this mode reduces the quantity and value of electricity generated because it has less ability to vary water flow rates to maximize generation and match power demand curves.

Run-of-river generally means no relocation of local populations or flooding of lands; thus, the environmental and social footprints are typically smaller but still not without impact on local communities. Run-of-river designs are more likely to work around the existing natural features than would be expected of large hydro systems. Small hydro systems use diversion structures, penstocks, and channels to divert and carry water out of its natural watercourse and into a location where it can be harnessed. This often leads to compromises and the need to build project structures across varying terrain and, sometimes, community/political boundaries.

In some cases, hydropower does not necessarily produce electricity, as in the case of the project in the Kyrgyz Republic. Instead, hydropower will be used to power irrigation pumps and replace diesel- or electric-powered irrigation. It can also be combined with other purposes, such as community water provision. Community-scale projects are often designed to provide shaft power for driving agricultural processing equipment during the day, and then drive belts are connected to an alternator to provide lighting and entertainment during the night.

Small hydro technology continues to develop new materials and control systems that improve reliability and reduce O&M overhead. However, the social development aspect of small hydropower systems is a widely recognized weakness in project planning. With turbine, alternator, and control technology well understood, and civil engineering services generally accessible, technical difficulties primarily occur through poor planning or insufficient budgets. Civil engineering failure is a frequent cause of small hydro difficulties and mechanical failure is frequently a symptom of managerial failure. Design errors are possible and have been noted in the proposals but it is expected that these would be corrected in a full feasibility stage document, given suitable peer review.

In general, the PREGA hydro proposals demonstrated a sound understanding of the engineering tasks involved. But the primary risk is insufficient community planning and consultation. Small hydro is more likely to work into and around local communities than displace them; hence, community consultation must be adequate and open to all concerned and compensation procedures must be clearly defined. For example, most of the small hydro projects in Samoa have encountered serious community-related problems, at times turning violent. Worldwide, there are examples of such community problems resulting in outright project failure.

Small hydro projects have a tendency to be dominated by technical and engineering inputs as this is where the bulk of the investment funds are expended. However, project managers must understand the importance of working through a sound community consultation process as this is where much of the project risk resides. Where PREGA project proposals are expected to work within or in close proximity to rural communities—as with the Kyrgyz Republic and Viet Nam proposals—this consultation process has been almost totally overlooked. This means that one of the most likely causes of project failure is excluded from consideration in the studies to date.

Project finances vary, depending on the expectations of project revenues. These are not always well-considered. The Issykata proposal in the Kyrgyz Republic is technically sound, but makes sweeping assumptions on social and financial parts of the proposal that are likely to result in a pilot project not meeting the predicted result. Not being connected and not selling to a grid means the system must estimate its value-added results and include a wider range of considerations when calculating revenue streams. Selling electrical power into a national power network—as with the Nepalese West Seti and Indonesian Wangan Aji proposals—provides the hydro scheme an accessible market and a predictable unit price. In the case of the Kyrgyz Republic, the hydro output is directed toward improving local agricultural outputs. In remote and rural locations, the ability of local agricultural markets to absorb, process, and/or transport the increased production must be taken into consideration.

The scale of the project proposals varied from 4 kW in the Kyrgyz Republic to 750 MW in the Nepalese West Seti project. The ability of hydroelectric projects to attract CDM revenues is also linked to scale. At 4 kW, the transaction and verification costs would exceed the value of the carbon credits, if they were taken into consideration. For the West Seti project, the CDM potential is clearly bigger, feeding into a metered and monitored grid, and would be easier to verify. The scale of the project is also easily able to absorb the transaction costs. All projects, including the 3-MW Vietnamese Suoi Chum proposal, include proportionally significant potential CDM income, which contributes to the positive FIRRs shown. The ability of the individual projects to demonstrate CDM value is, in part, dependent on the project's ability to directly demonstrate correlation with reduced GHG emissions elsewhere. Projects, such as in the West Seti, have a simpler task to achieve this compared with that in the Issykata because the former will feed into the North Indian grid with measurable GHG results.

Lessons Learned

The primary lesson to draw from the projects in the small hydro category is the impact of nontechnical considerations.

- When the construction stage is complete, it is the local community that will have the largest impact on the project's sustainability. If the community feels excluded, taken advantage of, or poorly compensated, then the project will usually suffer. Project managers need to include professional social development inputs to avoid conflicts with host communities.

- Social development inputs are seen as an expense rather than an investment. In projects where the human factor cannot be engineered out of the way, community inclusion in the planning process will have a measurable effect in reducing political interference in plant management in future.

- Where project revenues are not based on selling power to an existing network, care is required in making assumptions about expected project revenues, particularly in isolated and rural communities with limited market ability to absorb and grow from increased energy resources.

- Where community-scale systems are installed, some external management support mechanisms are very advantageous to assist power system managers to maintain control of the system assets and adhere to scheduled maintenance and financial procedures. Community power system operators are secondary to community politicians. External support mitigates this influence.

- Isolated installations do not achieve commercial critical mass. Service and support industries will not appear to support single, small installations unless they are clustered to achieve sufficient commercial interest.

Barriers and Issues

The key barriers to the development of small hydro technology are generally not technical. The civil engineering techniques and the electro-mechanical technology are proven and reliable—assuming competent system design and peer review. With correct system design and budget, access to technology should not pose a barrier to the development and success of small hydro projects.

Barriers to small hydro primarily stem from social, financial, and political hurdles. The physical construction of a hydroelectric system is a more predictable exercise than the dynamics of the community it serves. Yet, engineers developing small hydro projects are often unaware of the impacts and risks of the nontechnical aspects to long-term project sustainability.

The problems encountered in the five small hydro projects in Samoa are a clear example of social and political pitfalls. While not directly a barrier to development, the additional security risk in these projects is a warning to investors considering other projects. Therefore, it can create a barrier to investment. Specifically, the Samoa experience highlights the end result of technically driven projects without adequate community consultation and education, poor compensation documentation, and a lack of real or perceived political consistency. The West Seti proposal is not in danger of making these errors. However, the Krygyz Republic and Viet Nam proposals would benefit significantly from demonstrating a wider and more realistic understanding of the impact of the projects on local communities. To achieve this, professional economic and social development input at early project development phases is necessary. Good engineering will not survive bad management but, conversely, poor quality engineering can frequently survive for extended periods given good quality management.

Financial barriers exist where projects are to be constructed in areas or countries that do not offer political stability. Installation costs for small hydro can range from $1,500 to $2,500 per kW, depending on the terrain and technology deployed. Project financial performance can be influenced by politics and this is particularly so in smaller systems operating in traditional, tribal-based communities. Finally, isolated small hydroelectric systems run the risk of becoming orphans, isolated from normal commercial avenues of service and support. This is not a risk for larger systems; however, small and micro hydro installations need to factor in the higher costs of servicing sites that may be difficult to access.

Next Steps to Wider Implementation

Given that the primary barriers to the sustainable development of small hydro are not technical—although sound engineering input is required to prevent design errors—the next steps to wider implementation should logically focus on political, social, and financial barriers.

Government agriculture or energy departments have existing service and financial management mechanisms, and capable staff that could assist to survey and support community-scale hydro projects.

Access to the national power grid at preferential or preferred rates will provide improved commercial confidence in investments. Assistance to meet or mitigate critical project activities, such as management planning and service and support functions, may also assist to reduce entrance costs for commercial investors.

The clustering of smaller installations to reduce CDM transaction or verification costs may allow the participation of a wider number of installations to benefit from additional revenue streams.

Renewable Energy-Diesel Hybrid Power

Diesel generator sets (gensets) are the most common means of providing electricity in remote and sparsely populated regions of developing countries, where grid connection is not economical due to the low loads and long distances involved. Gensets are a mature technology, readily available, fully configured and relatively inexpensive, durable with straightforward and widely understood operation. They provide good frequency and voltage control, can provide full power in 30 seconds from cold start, and provide instantaneous power for direct-starting motors and welding sets. However, there are circumstances where transportation and on-site storage of fuel supply, spare parts, and regular O&M are not available locally or affordably. Additionally, the extra wear on the generators, together with poor fuel efficiency and cost recovery, may pose a challenge to operators.

Combining wind and/or solar photovoltaic power with gensets and some form of energy storage could, in theory, cut down on running or overall costs by substituting renewable energy (RE) resources for significant amounts of diesel. The genset could then be utilized only as backup power or source of uninterrupted supply. In principle, this could not only lower diesel fuel and O&M costs and reduce GHG emissions, but could also improve the reliability and quality of the power produced because one system component could augment the other during RE availability fluctuations. However, this is not simple to achieve. The technical and operational demands of such a multi-component power supply arrangement are much more complicated than pure diesel generation. Design and management requirements are complex and generally not taken seriously. Thus, while hybrid RE-diesel systems could potentially provide 'grid quality' electricity in off-grid situations, they are prone to failure through lack of appropriate conception, implementation, maintenance, and operation.

The PREGA project studies from Bangladesh and Mongolia represent bold attempts to devise such hybrid solutions to serve remote rural communities that cannot access grid electricity. In both countries, approximately 70% and 33%, respectively, of their national populations live in unelectrified villages and are served by limited and intermittent, inefficient, and costly diesel-generated power. Therefore, hybrid RE-diesel off-grid systems could provide an immediate and widely applicable solution. The social and human development impact of a reliable electricity supply is very high in each case, yet no current plans exist to extend or strengthen the grids to these locations.

The Bangladesh project site experiences moderate-to-low wind, peaking during the monsoon months when average solar insolation drops from its normally high levels. Thus, the project proposed to utilize a combination of two 50-kilowatt (kW) wind turbines and 25-kilowatt peak (kWp) solar PV system, along with two 20-kW backup diesel generator sets, batteries, and inverters to provide reliable 24-hour, 220V AC power. The Mongolian site has better wind and can dispense with the PV component.

Both projects have the same objective—deliver reliable electricity to isolated rural communities at lower operating costs. However, the Mongolia project was conceived more as a pilot test of available wind power technology supplementing the existing energy infrastructure, while the Bangladesh project seeks a complete, self-contained standalone solution supplying all of the community's electricity needs. In this respect, the feasibility criteria for the Bangladesh project would necessarily need to be more rigorous.

Hybrid RE-diesel systems have traditionally proven to be difficult to implement successfully for a number of reasons. When supplying AC power, voltage and frequency control on the output can be problematic because load and equipment variations can dominate such small-scale power grids. Any surplus power resulting from a drop in loads can quickly drive up the frequency—and vice versa—as the gensets have insufficient inertia to absorb such variations. Since the system frequency is determined primarily by real power flows, the generator must either follow the load profile or utilize some form of an energy store. In the first case, since wind and PV output cannot be controlled to give firm power, a genset must be run continuously to supply the differential, and in the second case, battery storage and inverters must be used. In theory, the wind turbines could be oversized so that they meet instantaneous and peak demands, where energy would be dumped to maintain system frequency when loads are lower. But this would only be cost-effective under favorable wind conditions.

Gensets operating continuously at low loads dramatically increases cylinder-piston-rings wear over normal operation. This will cause insufficient piston oil ring sealing pressure, resulting in higher maintenance costs. Even sustained operation at the allowable half-load levels increases fuel use per useful generation output. In order to achieve greater savings through RE substitution, the gensets must be shut down when loads are low and/or when there is sufficient wind/solar energy available. However, this can only be achieved with battery storage. Battery-inverters add considerably to the expense and complexity of the hybrid RE-diesel scheme. Given the variability of the RE resource and load profiles, genset startup times, as well as the need to minimize such startups, switching between wind/PV and diesel requires careful control system design and operation. Added to this are the cost and management overheads associated with routine maintenance shutdowns and major overhaul requirements of the gensets, maintenance and replacement of batteries, the need to build and maintain local technical capacity to operate and maintain the system, and provisions for component failures—especially the complex automatic interface between RE, battery-inverters, and diesel generators. Failure to adequately address these requirements and their considerable associated costs will generally lead to 'diesel creep' —a situation where the diesel energy component of the hybrid system is progressively used more and more as it is the easier and better understood option, undermining the basic rationale and economic feasibility of the renewable component of the complex and costly hybrid system.

Both the Bangladesh and Mongolia studies—while otherwise comprehensive and well conceived—seem to underestimate the particular technical complexities of designing and operating practical hybrid power schemes. More detailed investigation and a comprehensive consideration of the operational and financial requirements are recommended in both cases.

Lessons Learned

The Bangladesh and Mongolia projects are good candidates for further development, with potentially rich social and development dividends. The hybrid systems proposed seem suitable for such remote locations that are poorly served by diesel generation alone. The studies cover many of the basic requirements necessary for designing and evaluating such schemes; however, they fail to fully take into account important determinants of feasible energy mix and operational complexities of such tightly integrated systems.

The studies need to firm up some of the underlying determinants of hybrid power project design—wind conditions, electricity consumption patterns, correlation between wind and demand profiles, power quality requirements, system maintenance and spares, and integration with existing energy infrastructure and markets. These are important omissions that would need to be addressed through further investigations before the feasibility of such hybrid schemes could be properly determined. The PREGA studies have, at a minimum, helped highlight these additional needs and will contribute to build the necessary local capacity to address them in the future.

Barriers and Issues

Generic developing country barriers to RE deployment exist in Bangladesh and Mongolia, as both countries have only nascent RE capacities and experience. These include the absence of conducive policy and RE investment-friendly regimes, lack of supporting institutional capability, insufficient technical expertise and awareness of workable RE alternatives, and difficulties with financing and cost-recovery mechanisms.

The Bangladesh study, for instance, did not contain a sufficiently detailed wind data analysis on which a 60:10:30 proportion of wind:PV:diesel mix can be assured. The expected contribution from wind to the total energy supply appears to have been overestimated, which would have major repercussions on the amount of calculated annual diesel savings and CO_2 emissions. The financial and financing requirements of the project also need to be reevaluated. The additional O&M costs of operating gensets, such as regular oil changes, machine overhaul, breakdowns, and battery replacements, also need to be factored into the financial calculations. In particular, diesel shutdown frequency and battery backup during periods of low loads need to be properly assessed by matching RE resource availability with local daily load and RE availability profiles. Further considerations on efficiency ratings and losses associated with other system components (wind turbines, battery and inverter conversion losses, technical and nontechnical grid losses, etc.) are needed to arrive at realistic net saleable electricity levels as opposed to the gross output figures used. Other local factors—such as the occurrence of cyclonic and sandstorm conditions in Bangladesh and Mongolia, respectively, the ability of the wind turbines and associated structures to withstand these, and the consequent downtime due to wind turbine safety shutdowns—also require careful consideration.

Even with a better wind resource and a proposed 90:10 wind–diesel ratio, the Mongolia study was more tentative in its approach and never fully defines the project's main objective—to provide reliable 24 hour/day grid-equivalent power to the local community at lower costs or reduced subsidies. The study did not sufficiently address the causes for the poor quality of existing diesel generation, a concern which would be relevant and would almost certainly be further amplified in more complex wind-diesel hybrid generation schemes.

Another issue not adequately addressed in either study, but would have a bearing on the economic viability of both schemes, includes the consideration of existing and alternative power supply options. Both project sites could potentially be connected to the high-tension grid in the future, such as in the case of the Mongolia site, which is in close proximity to a proposed 220-kilovolts transmission line from Choir station to Oyutolgoi via Tavantolgoi. The Bangladesh

site is also presently connected to a weak regional grid and not physically distant from the national grid. Higher-than-estimated diesel generation costs could make such comparisons relevant, especially for pilot projects aiming to establish a case for future replication in the country. The existing tariff, tax, and subsidy structure in each country would impact on power sales, project sustainability, and—along with quality and reliability of existing and alternative supplies—on the consumers' willingness to pay for the energy produced. Ownership of the plants, management arrangements, and business models under which they would operate, metering and revenue flows, and social considerations would also need to be defined more clearly before such complex projects could be appropriately designed and successfully implemented.

The case for obtaining carbon credits under CDM in both studies is less than compelling, as the net diesel savings are not properly estimated and/or are too small. The Bangladesh study needs to reflect diesel and CO_2 savings more accurately. The low FIRR calculated in the Bangladesh case (6.47%) is expected to deteriorate further once full project costs are properly accounted for, while the Mongolia study (17%) pertains only to the wind component. Both studies assume unrealistic CER rates—$10 and $15, respectively—and it is unlikely that CDM revenues would add much to financial viability, assuming eligibility and proper assessment.

Next Steps to Wider Implementation

The Mongolia project led to an RE barrier removal concept paper under the GEF PDF 'B' study to evaluate the issues more thoroughly. The GEF proposal has now been subsumed in a separately developed World Bank GEF project.

Such GEF or bilateral funding would also be a relevant option for Bangladesh, where many of the generic factors affecting the practical development of hybrid RE-diesel projects need to be examined more closely under grant financing before commercially viable projects could be devised. The replication criteria for such hybrid alternatives would also require further examination, given that even partial diesel-based generation schemes would need overall deployment capacity limits and would be confined to regions with confirmed off-grid status. Finally, scaling up pilot hybrid projects to larger capacities involves nontrivial reengineering of system components and a reassessment of economic viability. This would demand careful thought when evaluating future replication potential.

Industrial Cogeneration

Cogeneration is defined as the sequential generation of two different forms of useful energy from a single primary energy source, typically mechanical energy and thermal energy. The mechanical energy is used to drive a generator to produce electricity, or sometimes to directly drive rotating equipment, such as compressors, pumps, or fans, to deliver various services. The thermal energy is used either for direct process applications or to indirectly produce steam, hot water, or hot air for process drying or cooling through absorption chillers.

Cogeneration systems utilize a wide range of prime-mover technologies, such as gas and steam turbines, and reciprocating engines. The different cogeneration technologies give large variations in electric generation efficiency as well as in the quality (temperature) and quantity of thermal output. Industries that have large and consistent on-site thermal and electrical requirements will find that appropriate cogeneration systems offer technical opportunities that are frequently economic. The price spread between the applicable cogeneration fuel and the ability to match the production of electricity and use of thermal energy for high hours of use per year will define the economic potential for cogeneration. The overall efficiency of useful energy in cogeneration systems could be 85% or more, resulting in overall reduced fuel consumption and overall CO_2 emissions reduction. Well-designed and -operated cogeneration systems could also increase the reliability of electric power supply to industrial sites.

Industrial cogeneration systems are typically designed to maximize the on-site use of the thermal and electrical output. Where there is a wide range of well-proven technical options available, there is a high potential for technical and financial viability and replicability. Electricity from industrial cogeneration systems has the potential to be bought from or sold to the grid, while thermal requirements must generally be met on-site. The profitable sale of electricity to the grid requires a suitable regulatory and policy environment, practical enforcement of grid export prices, and realistic interconnection conditions in contractually enforceable power purchase agreements.

Four specific industrial cogeneration project opportunities were studied under PREGA—three from the Philippines (dual-fired cogeneration in a distillery, cogeneration in the food industry, and waste heat recovery from the flue gases of diesel-generating sets) and one in Indonesia (energy efficiency and energy conservation implementation at an integrated textile plant). Two of the projects in the Philippines will be using backpressure turbines at 1.2 MW and 6.5 MW to generate electricity, and the other one will add waste heat recovery equipment to two 5.5-MW diesel generators. These projects provided sufficient information to conclude that the correct technology was chosen to match the annual thermal and electric requirements. However, no data on the relevant industrial process' measured thermal and electric usage profiles was presented.

Based on typical annual electricity and thermal energy requirements and the existing cost of electricity, the projects have very good economic and financial internal rates of return. The EIRR and FIRR values show that the projects could absorb a significant increase in fuel costs and still provide good returns. CO_2 emission coefficients assumed an overall national average that was weighted heavily to coal- and oil-fired generation.

The prefeasibility study from Indonesia proposed to use a large coal-fired boiler and an extraction/condensing turbine to replace the current heavy fuel oil-fired steam boilers and diesel generators of a large textile factory. There was insufficient boiler and turbine performance data provided in the analysis to verify the process-specific, end-use needs of the proposed cogeneration electrical output of approximately 160–200 MW. Given that the textile plant's fuel is provided at below market rates of $0.21/liter and electricity at $0.053 /kWh, the economic viability of the proposed cogeneration plant may be difficult. However, a large portion of the plant's electrical consumption comes from self-generation, using diesels with a low efficiency of 26%. As a result, the project does show good economic and financial returns. Emission coefficients were based on an overall national average that would be weighted heavily to coal- and oil-fired generation. This project would produce sufficiently large emissions reduction and would be able to sell the carbon credits on the market with relatively low CDM transaction costs. None of these project studies presented sufficient plant operating data to demonstrate the annual performance of the cogeneration systems and their integration with optimized plant operations. Both thermal and electric monthly load profiles and load duration curves derived should have been presented.

Lessons Learned

It is technically viable to implement new or improved cogeneration projects in industrial facilities that have electric and steam requirements of over high hours of use per year. With a cost spread between electricity and fuel of $15 per million British thermal unit (Btu), approximately $350/t BFO and $0.07/kWh electricity, co-generation projects can be financially viable and help the environment.

Barriers and Issues

Availability of suitable local and affordable technologies is not a serious constraint for these nominally high-temperature/pressure industrial grade boilers and heat recovery equipment. Some concern exists with personnel experience in operating these higher-pressure boilers, but even that could be quickly overcome. However, the export of electricity could be a barrier, if that were to be necessary to meet steam requirements. In particular, obtaining a financially acceptable power purchase agreement can be problematic in practice. With proper selection of equipment, the primary financial revenue streams generally result from displacing purchased power and on-site generated steam from old, less-efficient steam generation systems. This can minimize financial risk.

A major concern of the national or local utilities is grid interconnection, since the cogeneration system is embedded in the utility distribution system. Most countries are proceeding with reform/liberalization of the electric power sector that allows or requires purchase of electric power from independent power producers and establishes nondiscriminatory grid-interconnection requirements. In many developing countries, efforts are underway to remove fossil fuel subsidies and let fossil fuel prices be set by the market rather than politically or administratively. It is also unclear in many cases when and how electricity price cross-subsidies will be unwound, with potential risks that are seldom properly considered. However, these energy market reforms often face significant delays and theoretical independent power producer (IPP) prices, and grid-interconnection requirements can be hard to obtain in practice or to a high enough confidence level to get financial deals from banks. Another key issue is the ability of the project to actually realize the benefits of CDM in selling the carbon credits when the level of emissions reduction is typically less that 60,000 t per year. Bundling the CERs through a third party, such as an industrial user's group or industry-wide trade association, may be possible to mitigate this problem.

Next Steps to Wider Implementation

Detailed feasibility studies still need to be done for all of the PREGA industrial cogeneration projects presented. In particular, process energy efficiency needs, in addition to an improved understanding of energy use throughout the operating year, have to be addressed.

District Heating

The Asian Development Bank (ADB) member countries located from the Caucasus through the Central Asian Republics to Mongolia and northern China are in climatic regions that require substantial building space heating for survival. Much of the existing infrastructure of these countries were centrally planned and developed in nonmarket-focused periods when housing, space heating, and hot water were considered necessary communal services to be provided the population. They had little consideration for operating cost or energy efficiency.

In urban areas, central district heating systems were equipped with large central coal- and natural gas-fired boilers that provided pressurized hot water. This pressurized hot water carried the heat circulated throughout the district. The substations located throughout the district had heat exchange systems where the pressurized hot water passed through secondary water circulation loops to provide lower pressure hot water to the buildings. Large central districts had combined heat and power plants that provided heat to the water distribution system and, in some parts of the cities, heating boilers where used in place of heating substations.

Most of the buildings in these countries used bricks or cast concrete, usually without insulation. Windows and doors tended to fit poorly, allowing high infiltration of outside air, resulting in additional high heat losses. Further losses were introduced by the lack of room heat output controls, so local room overheating could only be addressed by opening windows to let the excess heat out, resulting again in high heat losses.

When these countries changed to market-driven economies, the existing building stock, heat production, and water heat carrier distribution systems offered huge opportunities to profitably improve energy efficiency, reduce energy consumption, and reduce CO_2 emissions. In each of these three components, there was the opportunity to reduce energy losses by roughly 20%, potentially resulting in a 50% overall primary energy use reduction from space heating and hot water services. However, there is a lot of catching up to do because of a generally deferred maintenance of buildings in former Soviet republics in the early to mid-1990's.

Broad commonality in the design and construction of buildings and district heating systems gave rise to an equally broad replication process for implementing district heating technologies and energy service business operating approaches. Many key policy reforms—to clarify heating/hot water system ownership and operations, certification and performance standards for metering and heating equipment, more cost-reflective tariffs for heat supply, and a modern regulatory structure for the operation of emerging new private heat sector energy service companies—are underway.

Four specific district-heating project opportunities were studied under PREGA with one project each in the PRC and Kazakhstan, and two projects in Mongolia. The pre-feasibility study undertaken in Kazakhstan looked into a combined heat and power plant with a 100-megawatt electrical (MWe) gas turbine-combined cycle cogeneration system that will use associated gas, and an 83-MW installed capacity gas turbine, with a 17-MW steam turbine that will produce 55 Gcal/hour of heat for the district heating system. This configuration will have an overall fuel utilization efficiency of approximately 80%. By utilizing the recoverable heat from the gas turbine, the efficiency of the heat production system will significantly improve compared to using a heating-only boiler. With the cost of heat at $0.10/Gcal and electricity at a weighted average of $0.004/kWh, the project will require low-cost associated gas to be cost-effective. The estimated CO2 to be displaced by the project was approximately 275,000 t per year.

Replacing district-heating systems with individual heating systems is another way to improve the heat supply. This was the approach taken by the PRC report, closing five local coal-fired heating-only boilers. The individual apartment gas-fired heaters used in the project were intrinsically more efficient than coal-fired boilers because heat carrier distribution losses were eliminated and both heat and hot water supply can be controlled by the end-user. Major savings were made during the summer when relative heat losses are particularly high in central heating systems. Additionally, gas metering provided a strong incentive to apartment owners to be more energy efficient and to employ technical improvements. The study did not show a positive return on investment or net present value. The combination of fuel-switching and efficiency improvement did yield an estimated displacement of 3,816 t of CO_2 annually.

The two studies undertaken in Mongolia were a pre-feasibility study on the rehabilitation of heating-only boilers and a technical study on improving the performance of the main Thermal Electric Station #4 in Ulaanbaatar City. Rehabilitation of the heating-only boiler houses would entail replacing low-efficiency (40–50%) boilers with new, high-efficiency (75%) ones. However, the high-efficiency boilers are still in the development stage. The technical study, on the other hand, identified a number of opportunities for improved instrumentation and controls as well as upgraded auxiliary equipment for the Thermal Electric Station. In both reports, additional work that will define the complete project development plan, economic and financial analyses, and emissions analysis is still necessary.

Lessons Learned

It is technically and financially viable to implement new decentralized or improved district-heating projects. District heat and hot water systems are a major energy consumer; thus, the overall system of heat production, heat distribution, and end-use offers a wide variety of opportunities for both demand side, supply side, and heat-distribution energy-efficiency improvements. With heat and electricity tariffs generally becoming more cost-based, there is now a growing potential for economic and financial viability of projects at all component levels of the heat and hot water supply system, including the option to completely decentralize the system.

Barriers and Issues

The primary barrier identified in the studies is the link of district heating systems to municipal or state governments with weak incentives and means to maximize efficiencies. The World Bank, United Nations Development Programme/GEF, and United States Agency for International Development are funding numerous heat and hot water supply projects throughout the northern Asian countries to address a number of key regulatory and operational issues, which include:

- Strengthening the role of condominiums in organizing and managing the heat and hot water supply services at the building level;
- Supporting the restructuring process and building the capacity of the existing district-heating companies to improve the efficiency of their operations;
- Supporting the emerging new service providers for condominiums and structuring financing for the investments needed; and
- Documenting and disseminating the results, experiences, and lessons learned.

Another key issue is the ability of a project to actually realize the benefits of CDM in selling the carbon credits when the level of emissions reduction is typically less than 60,000 t per year. Bundling the credits through a third party, such as an industrial user's group or industry-wide trade association, may be possible to mitigate this problem.

Next Steps to Wider Implementation

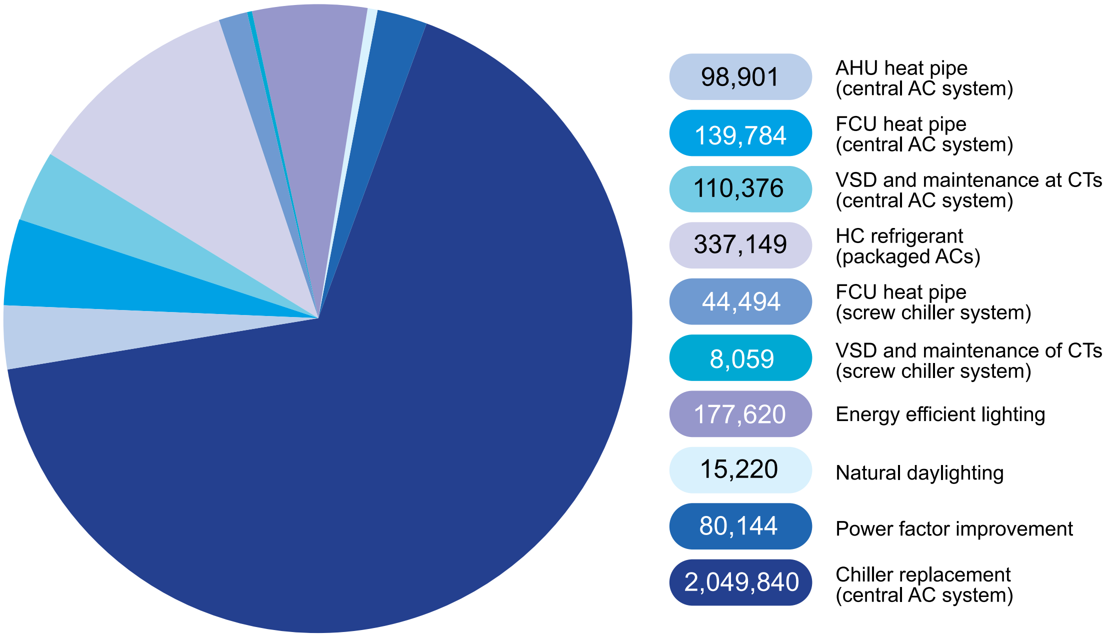
A more detailed feasibility study for all the PREGA district-heating projects presented is necessary. The PRC fuel-switching project appears to have been completed at the time of the PREGA study, although replication of the project is widely possible. Policy, regulatory, privatization, certification, standards, and heat sector energy-service operational experience is required to make available technological applications fully viable.

Energy Efficiency in Buildings

Buildings represent an attractive opportunity for reducing energy consumption through efficiency improvements. Most buildings do not incorporate efficient design or equipment standards and are managed or used sub-optimally as far as energy consumption is concerned. They have very long lifetimes that can lock in accumulated energy savings (or waste), but they can be readily retrofitted or modified in a piecemeal, cost-effective manner. The sizeable population of all types of building stock across cities can result in significant savings. Commercial buildings, in particular, represent feasible candidates for targeted demand-side management on account of their typically higher energy intensity and financial capacity for such investments.

The PREGA study on energy efficiency in buildings focused on the evaluation of heating, ventilation, and air-conditioning (HVAC) improvements in a cardiac care hospital in Jakarta, Indonesia. Hospitals are particularly good candidates for energy efficiency improvements because they operate around the clock, have fairly stable load profiles and occupancy patterns, and have demanding and generally high-energy air-conditioning requirements. Therefore, it is easier to design and predict potential energy saving solutions for them. A more comprehensive evaluation could also result in additional potential savings through improved building insulation, fenestration, lighting and electrical upgrades, and systems and usage management.

Figure 1. Potential Buildling EE Power Savings (kWh/year)



AC = air conditioning, AHU = air handling unit, CT = cooling tower, EE = energy efficiency, FCU = fan coil unit, HC = hydrocarbon, kWh = kilowatt hour, VSD = variable speed drive.

The selected building was a multi-component, centrally air-conditioned, 168-bed hospital complex in Jakarta, Indonesia. The hospital uses approximately 60% of its total energy on air-conditioning. It is supplied by grid electricity and backed up by a diesel generator for essential loads and an uninterruptible power supply (UPS) for critical loads. Two diesel-fueled boilers provide steam and hot water through alternate operation. The average monthly electricity consumption of the hospital is 603,800 kWh, with a corresponding cost of $ 21,700. About 12,000 liters of diesel are consumed every month, mainly by the boilers.

The building energy audit largely excluded building envelope design, construction, and materials; lighting and electrical systems; insulation; occupancy and usage schedules, and, therefore, never fully evaluated their corresponding energy-saving potentials. The costing and financial analysis of the recommended energy efficiency investments was also neglected, and the diesel generator and UPS were not considered as these are used only intermittently. Thus, this study did not provide a replicable template for a comprehensive commercial building energy efficiency improvement, even if the limited focus might have been financially justifiable. The study suggested improvements on the following components of the HVAC system:

- Replacing the chillers with new, higher efficiency units;
- Retrofitting the air handling and fan coil units in the central AC system and the fan coil units in the screw chiller system with improved controls and heat pipes to suit local humidity conditions and reduce latent cooling loads;
- Installing variable speed drives in the secondary chilled water pumps and cooling tower fans, and improving the management of the cooling towers of both the central and screw systems; and
- Replacing synthetic CFCs/HFCs/HCFCs in the packaged ACs with more efficient hydrocarbon refrigerant.

Potential annual energy savings resulting from these measures are shown in Figure 1, which also includes additional benefits from power factor improvements, day lighting, and use of higher efficiency lighting compact fluorescent lamps (CFLs) and electronic ballasts). However, the basis for the three latter options was not provided, and improvements to the screw chiller system were found to be financially unfeasible. Waste-heat recovery in the boilers can additionally save 35,000 liters, or 24%, of diesel fuel annually.

The financial analysis was limited only to HVAC improvements, wherein the major investment cost will be for the chiller replacement at $0.57 million. The total GHG savings due to the project were estimated at 1,590 t of CO_2/year. The project's FIRR at 12% discount rate, with and without CER revenue, is 35% and 33%, respectively, making it highly feasible.

Lessons Learned

The study reaffirmed the potential for large energy savings from building energy efficiency improvements in developing countries, such as Indonesia. A key driver for this will be the ability of building managers or their advisors to properly assess and recommend such solutions tailored to each individual case, using professional expertise in energy auditing and building surveys, equipment and design upgrades, and energy savings and cost analyses. Access to such expertise—in addition to lowering barriers to domestic marketing of efficient equipment and development of national energy codes and standards—can greatly help initiate and facilitate a domestic buildings energy efficiency (EE) market in developing countries. The study, even though limited to HVAC improvements, served this key function, and given the large potential energy savings possible, it was surprising that it was the only one of its kind in the PREGA project portfolio. This lack of country-driven focus on energy efficiency was also widely found across PREGA and is not confined to the building sector alone.

Barriers and Issues

Barriers to energy efficiency investments in buildings typically relate to ownership, technical, and financial issues. Capital expenditure in building systems and infrastructure adds to the property's asset value, which benefits the owner or developer. However, energy savings that would pay for such investments accrue to the occupant or tenant. Unless they are the same, this dichotomy makes it difficult to convince either of the two to undertake investments involving any significant outlays or payback periods. Technical constraints include low levels of awareness, unavailability of modern energy saving equipment and retrofit materials, and absence of local building energy codes and equipment performance standards. Energy prices, particularly electricity tariff subsidies, high initial costs, and the incremental nature of achievable savings can also mitigate against convincing building management to seriously consider major improvements.

In the case of hospitals, such as in the study, the primary determinants will be financial rather than technical, given that the potential savings can be as high as 30% of existing energy costs. However, this may also make it difficult for the project to qualify for CDM credits as the investment would remain economically and financially viable even without such support, unless lower return upgrades (such as to the screw chiller system and other building features) were also included. Another way to address this will be to bundle several similar projects under an umbrella commercial building energy efficiency project, which could collectively promise more significant CO_2 reductions.

Next Steps to Wider Implementation

Areas for further action include enlarging the coverage of such projects to other commercial and residential building categories; undertaking building stock surveys and representative energy use evaluations; developing national building energy codes and compliance guidelines, as well as efficiency standards and certification data for construction materials and equipment; assessing effective financing and fiscal incentives for EE investments; and improving awareness about potential energy efficiency measures and benefits among architects, developers, builders, owners, and occupants on a countrywide basis. This will be highly cost-effective, but will be more complex and will take longer to deliver.

Transport

The transport sector accounts for approximately one quarter of CO_2 emissions globally, and this sector is still growing. A PREGA prefeasibility study on this sector in Nepal looked into transport energy use and the underlying factors leading to transport energy, GHG, and local pollution growth trends. It illustrated how renewable energy can provide clean and emission-free transportation solutions.

Safa Tempo

The rapidly growing transportsector in Nepal relies nearly completely on imported fossil fuels and is the primary cause of escalating levels of air pollution in its cities, accounting for 31% of the total national CO_2 emissions. The number of vehicles registered in Kathmandu alone in the last 10 years has increased by 211%. This increase in registered vehicles is accompanied by a corresponding increase in local air pollution, adverse health impacts, congestion, noise pollution, and traffic accidents. The quest for efficient means and financial mechanisms to switch to cleaner transportation fuels indicates that CDM has the potential to increase funding for transportation projects, enhance local planning and project evaluation capacity, and expand technology transfer opportunities.

The PREGA study focused on electric vehicles (EVs), such as trolley buses, railway, and battery-operated Safa Tempo vehicles, which can reduce Nepal's increasing transport emissions. The study showed that although CDM revenue is small, it can play an important part in improving the financial viability of clean transportation projects.

The pre-feasibility study suggested replacing some diesel vehicles in the Kathmandu Valley with trolley buses. This could reduce 129,000 t of CO_2 during the project lifetime (2005–2025). Financing is seen to be variable (Table 3), depending on whether trolley buses are imported or locally assembled. The same variability applies on carbon emissions reduction and whether the credits will be paid upfront or upon delivery (Table 3). For the project to take off, a grant requirement of $2.06 million for imported trolley buses and $0.84 million for locally assembled ones is necessary to attain a 14% financial return.

Table 3. Financing Variability for Trolley Buses

	Investment Cost	Emission Reductions	
		Upfront Payment	Pay-on-Delivery
Imported Trolley Buses	$ 15 million	$ 16/tCO_2e	$ 57/tCO_2e
Locally Assembled Trolley Buses	$ 13 million	$ 6.50/tCO_2e	$ 23/tCO_2e

tCO_2e = ton of carbon dioxide equivalent.

The project was seen to have clear net benefits to society as a whole. However, it will require additional income through carbon financing in order to be financially feasible. Looking at the experiences of trolley bus operation in Kathmandu, the project needs to have strong management and private-sector involvement for it to succeed.

Higher operating costs and other constraints have impeded further expansion of EVs, making them unable to compete with cheaper diesel microbuses plying the same routes. The Safa Tempo Project Idea Note, developed under PREGA for the Electric Vehicle Association of Nepal, seeks to promote the operation of an additional 1,000 Safa Tempos (to the existing 600 units) as a viable business opportunity and to catalyze substantial GHG emissions reduction over a 5-year period. Each Tempo will reduce about 12 t of CO_2 per year, following the current small-scale methodology for baseline emissions calculation. The additional revenue generated from GHG reduction will give Tempo operators the vital edge to compete with diesel microbuses. Although the project's potential carbon credit value is very low to attract commercial buyers, it would be appealing to a voluntary carbon market. However, the project should highlight how the battery disposal issue will be handled to further clarify its overall environmental benefits and impacts.

A prefeasibility study also looked into the development of an electric railway along Nepal's 1,027-km main East–West highway. This project will utilize Nepal's hydropower resources to substitute for some of the passenger and freight road transport that use imported fossil fuels. The project will positively impact on the national economy by displacing a significant amount of imported fuel—about 30 million liters of diesel per year. The total capital costinvestment requirement for this project will be $ 2.1 billion, a large-scale project when compared to Nepal's gross national income of $5.8 billion in 2001. The project is estimated to abate about 9.4 million t of CO_2 over the 21-year crediting period, but this will make little difference with an initial FIRR estimate of only 7%. If CDM revenues would be available, it would only add 1–2% to FIRR.

It would seem highly desirable to develop suitable CDM methodologies and make CDM an explicit element in project development. If not, claiming CDM additionality at a later stage could compromise its CDM eligibility. It is very unlikely that the trains will run at the precise times to use the spilled energy from hydropower plants, so a dedicated 18-MW hydro plant would seem realistic in order to supply electricity to the railway. However, a reliable supply of electricity at rated voltage, especially from run-of-river hydro plants, would be of great concern for the smooth operation of the trains. Furthermore, it would seem sensible to review all route options, including feeder lines, into Kathmandu and other urban centers, as well as connections to existing or planned rail networks to the PRC and India .

Lessons Learned

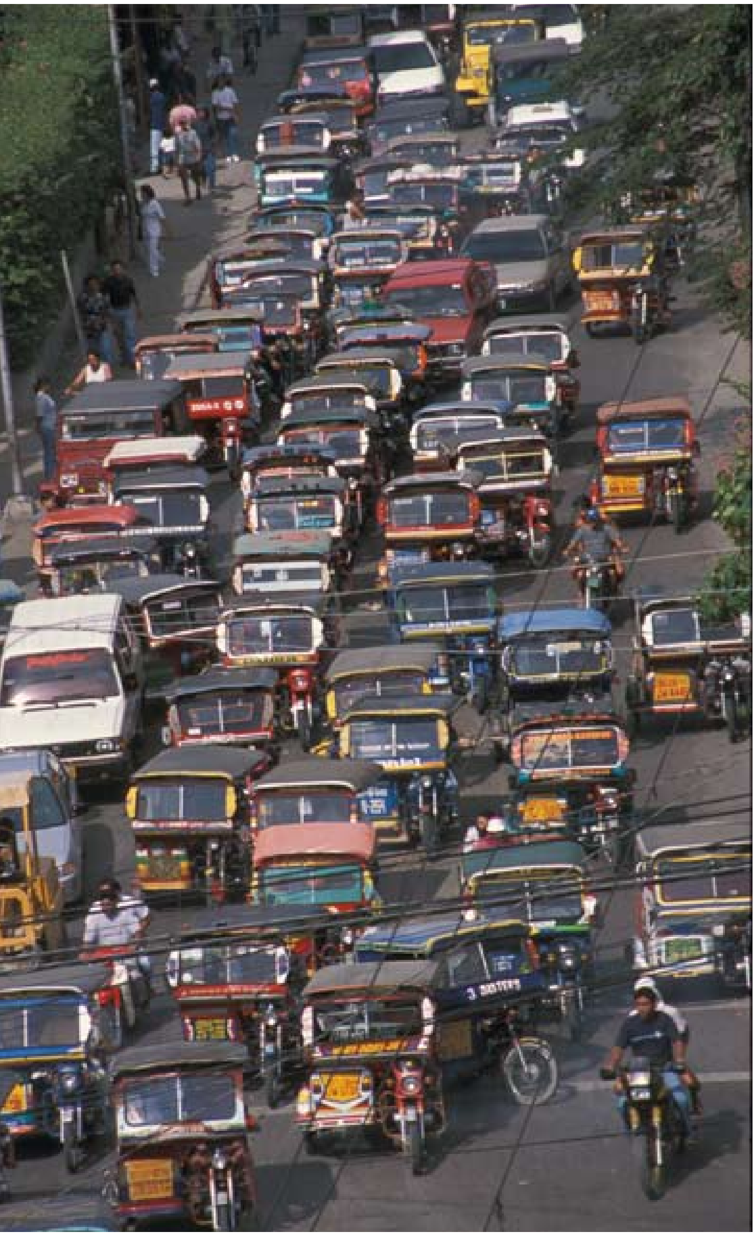
The proposed projects showed that policy-based and sectoral approaches have major impacts on clean transport options, and that privately owned and managed transport systems are more sustainable than public transportation systems.

Given the high cost associated with transportation projects, CDM revenue will not, by itself, raise transportation projects above financial feasibility threshold. Therefore, other funding sources will be necessary at the start of the project, and private-sector participation will be valuable during project implementation.

The Safa Tempo project will impact on transportation emissions reduction only if grouped in a large scale.

Barriers and Issues

The main barrier to clean transportation is financial viability. Given the high upfront investment necessary to initiate clean transportation projects, grants and subsidies will be necessary, and CDM revenues paid upfront will be very valuable to project developers.



Awareness, capacity-building, technology improvements, better traffic management, and supportive government policies are crucial in the promotion of clean transportation projects, but human behavior is as equally important to make the projects successful.

Next Steps to Wider Implementation

- Formulate favorable government plans and policies to favor clean transportation
- Use CDM revenue to leverage other funding sources
- Facilitate private-sector involvement in the transportation sector
- Integrate GHG reduction potential with other cobenefits (e.g., congestion, local air quality, health) when promoting cleaner transportation
- Simplify methodological requirements for transportation projects and manage uncertainties for accounting leakage by developing more robust data collection systems

Improved Cook Stoves

Cook stoves using woodfuel, agricultural wastes, and dried animal dung are the most common combustion devices and the dominant means of cooking in the world, with more than 2.4 billion users. However, traditional cook stoves are extremely energy-inefficient and polluting, resulting in 1.6 million deaths per year—mostly of women and children in rural areas—from indoor air pollution; excessive fuel use that exacerbates poverty due to high expenditure on fuel purchase or long hours of gathering fuel; deforestation and desertification; and significant GHG emissions from unsustainable biomass, dung, and coal use.

Improved cook stoves (ICS) are a well-proven, simple, and affordable technology available in most developing counties. ICS can be made locally by trained self-employed workers from local materials, and can provide a stable business through replacement grates and chimneys. However, despite extensive and successful promotion programs in most developing countries, widespread use of and sustainable business from ICS have not been successful once donor and grant funding support for the projects ended.

There is a very promising potential for CDM revenues in the cooking sector. GHG savings from domestic ICS are estimated at 1–2 t or more of CO_2 equivalent per stove per year, and delivery programs in the millions of tons per country are possible. In fact, larger savings per stove is possible for many local commercial cooking establishments that use traditional cook stoves in many developing countries. This could also save on firewood purchases and reduce cooking smoke for customers.

Conventional (top) and improved (bottom) cook stoves

Potential GHG reductions will be based on the percentage of fuelwood use, availability and type of agricultural residues, dried dung, and coal, cooking habits, and size, type, efficiency, and ongoing maintenance of the ICS. The key advantage of CDM is its emphasis on sound project design, and continued CDM revenue streams could ensure ICS effectiveness through emissions reduction. These elements are often weak or missing in donor- and grant-funded projects. Therefore, CDM has the potential to transform ICS projects from donor- or grant-dependent projects to self-sustaining projects with continued effectiveness.

Promotional campaigns are required to effectively create a demand for efficient stove technologies among the public. Developing technical and entrepreneurial skills among local stove constructors, microcredit mechanisms, and culturally and gender-appropriate marketing will be critical in removing the key barriers to enhanced ICS deployment and their sustainable and effective use.

Two PREGA studies on the potential role of CDM in ICS dissemination were conducted in Bangladesh and Nepal. The Bangladesh prefeasibility study looked into the widespread dissemination of three million ICS over a 10-year period and assessed CDM-financing feasibility for the project. The initial project investment cost was estimated at $0.63 million. The negative FIRR, however, indicated that the project will require additional support during implementation. Two million tons of CO_2 are estimated to be reduced once all the stoves are installed and in use, increasing FIRR to 12%. This is an ex cellent example of how CDM can ensure feasibility of socially beneficial projects, which would otherwise not be possible. However, the project will need well-formulated strategies coupled with effective implementation modality and strong quality control mechanism in order to meet the ambitious target of 300,000 new stoves installed per year and their continued use for 10 years.

The prefeasibility study in Nepal looked into improving the currently implemented ICS Program. The new project will disseminate an additional 250,000 stoves in the mid-hills of Nepal over the next 5 years. The carbon revenue generated from the savings of about 1 t of CO_2 per stove per year (about 150,000 t of CO_2/year upon installation of all stoves) could be utilized to create further demand through increased awareness of ICS benefits. The program will support necessary capacity development at the local level and undertake regular monitoring and evaluation of installed stoves to ensure quality. The carbon revenue will contribute toward the $4 million total project cost. The revenues from CDM—roughly $5 per stove per year—could pay for all or part of the ongoing and future ICS promotion programs. Some grant support from donors in addition to the households' participation will also be necessary.

Both projects will have to face the challenge of monitoring the use and performance of these stoves in order to comply with CDM requirements. However, it was not made clear how these projects will address this vital issue in practice.

Lessons Learned

There is a need for a participatory approach involving government, semigovernment, nongovernment, and private organizations, as well as the end-users, in the program design and implementation of ICS promotional campaigns. Social acceptability—in terms of perceived benefits, performance improvements, convenience, and ease of use over existing conventional options—is important for effective ICS promotion. The role of enterprise is key to a sustainable ICS program beyond the project period and market development and transformation will require financial support in the early stages of project implementation. The CDM could accelerate market development, either through actions that address market barriers or by providing targeted subsidies, or a combination of the two.

Barriers and Issues

The main barriers to and issues of the widespread dissemination of efficient stoves are the following:

- Awareness, accessibility, and serviceability of ICS in the lowest and least educated rural population segments;
- High cost of quality assurance for stoves;
- Need to promote and implement more stoves to enhance the project's CDM viability, since carbon credits from each stove are very small;
- A critical need for suitable microcredit mechanisms for ICS and sustainable local ICS construction and servicing businesses; and
- Monitoring actual effectiveness of ICS, especially during the CDM crediting period.

Next Steps to Wider Implementation

There is a need to pilot-test improved cook stoves to evaluate consumer response, actual performance, and scaling-up mechanisms. Awareness raising and capacity building among the cooking community are likewise necessary to promote the benefits and advantages of ICS. To take advantage of the potential income from ICS, technicians and field workers have to be trained in the demonstration, dissemination, and servicing of ICS.

Health, poverty reduction, forest conservation, and GHG emissions reduction could act as drivers for ICS promotion, and the CDM potential could ensure both device quality and improved user practices.

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Promotion of Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement Project

The Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA) project is one of ADB's regional initiatives that provide assistance to its developing member countries (DMCs) in mitigating and adapting to the impacts of climate change. PREGA aims to promote investments in renewable energy, energy efficiency, and greenhouse gas abatement technologies that will increase access to energy services by the poor, realize other strategic sustainable development objectives, and help reduce greenhouse gas emissions.

Co-financed by the Dutch Cooperation Fund for the Promotion of Renewable Energy and Energy Efficiency and ADB, PREGA is implemented in 15 DMCs.

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