59000

The World Bank

Asia Sustainable and
Alternative Energy Program
ASTAE

Timor-Leste

Key Issues in Rural Energy Policy

December 2010

ASTAE

The International Bank for Reconstruction and Development /
The World Bank Group
1818 H Street, NW
Washington, DC 20433, USA

First printing: December 2010
Manufactured in the United States of America.

Contents

Boxes

Figures

Tables

Preface and Acknowledgments

This report responds to a request made by the government of Timor-Leste for assistance in finalizing proposed policies for selected rural energy areas. The team that prepared this report consisted of Frédéric Asseline, Task Team Leader (EASIN); Ernesto Terrado, Renewable Energy Specialist (Consultant); Donald Hertzmark, Energy Economist (Consultant); and R. M. Amarasekara, Rural Energy Specialist (Consultant). The team received guidance from Charles Feinstein, Sustainable Development Leader for Timor-Leste, Papua New Guinea, and the Pacific Islands (EASNS); and Dejan Ostojic, Energy Sector Leader for the East Asia and Pacific Region (EASIN), who reviewed the draft and provided valuable comments. The peer reviewers were Douglas F. Barnes, Rural Energy Specialist (Consultant); and Xiaoping Wang, Senior Energy Specialist (LCSEG).

The team gratefully acknowledges the cooperation of and contributions made by Secretary of State for Energy Policy Avelino Coelho da Silva and his staff.

This study was made possible by the generous support of the Asia Sustainable and Alternative Energy program (ASTAE).

Abbreviations and Acronyms

ADB	Asian Development Bank
CBO	community-based organization
EdTL	Electricidade de Timor-Leste
ERR	economic rate of return
FSD	family-size digester
FX	foreign exchange
GDP	gross domestic product
GNI	gross national income
IAP	indoor air pollution
ICS	improved cooking stove
LPG	liquefied petroleum gas
MAFF	Ministry of Agriculture, Forestry and Fisheries
NER	net energy ratio
O&M	operations and maintenance
PV	photovoltaic
REMP	Rural Electrification Master Plan
SCBS	solar battery charging station
SHS	solar home system

Units of Measure

/d	per day
/y	per year
bbl	barrel
GJ	gigajoule
ha	hectare
kg	kilogram
km	kilometer
kT	kiloton
kw	kilowatt
kwh	kilowatt hour
m^3	cubic meter
m^3/d	cubic meter per day
MJ	megajoule
toe	ton of oil equivalent
W	watt

$ = US$ = United States dollar

Executive Summary

The primary goal of a sound rural energy policy is to promote measures that will enhance the quality of life of people in rural areas by improving their access to modern energy services. The desired approach is one that is environmentally benign and economic from both the country's point of view and for the welfare of individual rural households. A key objective is to ensure that the implementation of the government's rural energy programs provides equitable distribution of benefits.

In Timor-Leste the Secretary of State for Energy Policy is responsible for the design and implementation of the government's rural energy program. National energy policies are approved by the Council of Ministers, and the Secretary of State for Energy Policy takes responsibility for developing legal and regulatory frameworks for all activities related to the use of energy resources. The Secretary of State for Energy Policy plays an essential role in ensuring coordination with other ministries and operators involved in the energy sector in Timor-Leste.

The purpose of this report is to assist the government of Timor-Leste, in particular the office of the Secretary of State for Energy Policy, to develop policies in key areas that would guide planning of the subsequent phase of its ongoing rural energy programs. The selected key areas in the report cover off-grid electrification, household energy, and the development of biofuels from Jatropha crops.

The report does not prioritize policies in the selected rural energy areas, nor does it aim to propose a comprehensive policy framework for rural energy solutions. A national rural energy program is currently being developed by the Secretary of State for Energy Policy; in this context this study proposes practical recommendations derived from lessons learned from international experience in the areas of off-grid electrification, household energy, and the development of biofuels from Jatropha crops.

Off-Grid Electrification

In Timor-Leste, conventional rural electrification through grid extension is being implemented based on a national rural electrification master plan (REMP). While the REMP recognizes the special needs of off-grid communities, it is clear that under current prioritization criteria those communities are unlikely to have access to electricity for at least the next decade. Government policy should be to provide at least basic electricity services to small, dispersed, and poor off-grid communities, through programs implemented during the same timeframe as those directed at concentrated communities living near the main electricity network. The implementation policy should be based on principles of least-cost power planning, and with the objectives of technical and financial sustainability. Where local energy resources are available and potential users are sufficiently numerous and concentrated, those resources could be exploited for decentralized mini-grids. The government is already developing identified oil and gas seeps and hydro resources for this purpose.

The government's off-grid strategy is presently less defined for providing individual households with stand-alone solar photovoltaic (PV) systems. From 2007 to 2010, more than 2,000 PV systems for households and community centers have been provided at no cost to recipients, financed with infrastructure funds provided annually to the *sucos* (villages) by the central government. It is estimated that about 60,000 households nationwide could be provided access to electricity service only with PV. Based on the cost of investments benefiting grid-connected households (average $640 per connection plus subsidized tariff), a substantial upfront cost subsidy for a modest-sized solar home system (for example, 50 watt-peak) may be justified in Timor-Leste on equity grounds. However, it is best in any program to require PV recipients to contribute some part of the system acquisition cost in order to instill a sense of ownership.

Timor-Leste does not yet have an environment that would support an implementation mechanism for a government program in which private PV dealers compete to make sales. The micro-financing system is still undeveloped and the current PV market consists almost entirely of households belonging to the bottom part of the income pyramid. Some type of simplified fee-for-service mechanism executed by the private sector but with a strong government role would appear to be suitable for Timor-Leste, at least for the next 5 to 10 years. Using such a mechanism, competitive bidding for large numbers of installations grouped into several "market packages" could result in unit acquisition costs much lower than they are today in piecemeal, suco-by-suco transactions. A suggested procedure is outlined in the report.

However, as with any model that serves very-low-income households and requires periodic payments to maintain operation, long-term sustainability is more likely only when combined with other programs that raise the incomes of the user community.

Household Energy Policies

As found in a recent World Bank study, there is still abundant biomass supply in most parts of the country, except in the Dili district.[1] Because of this abundance, fuel-wood is, and for some time to come will continue to be, the cheapest cooking fuel in Timor-Leste compared with liquefied petroleum gas (LPG), kerosene, and electricity, even after accounting for different cooking equipment efficiencies.

There is no doubt, however, that the responsible policy for the government to pursue must result in a reduction or eventual curtailment of household fuel-wood use to the extent possible. The rationale for this policy is based on (a) the certainty that the current positive supply-demand balance will change in the future, with population growth and increased pressure on wood supplies as forest lands are converted to agriculture; and (b) the adverse impacts to public health from indoor air pollution (IAP) associated with use of fuel-wood in traditional cook-stoves. A World Bank Country Environmental Analysis for Timor-Leste conducted in 2008 estimated that the mean annual morbidity and mortality cost of health effects from IAP associated with the use of solid fuels is between $5 million and $20 million. The mean estimate is equivalent to about 1.4 percent of Timor-Leste's gross national income, or 3.5 percent of GDP[2] in 2006.

The strategy, therefore, is to pursue programs that combine both demand-side management or interfuel substitution (or both) with programs aimed at improved management of fuel-wood supply. The latter programs are not only good for the country's forests in general, but they also buy time until modern fuels can make significant inroads into the demand picture.

Interfuel Substitution with Modern Fuels

Compared with fuel-wood, modern fuels, including LPG and kerosene, have lower emissions and are more convenient and cleaner to handle. It is almost inevitable that demand for modern fuels, particularly LPG, will increase dramatically in Timor-Leste in the coming years, as economic conditions improve and a middle class emerges and expands. Most developing countries favor this modernization outcome and adopt policies to accelerate the transition from fuel-wood to modern fuels.

It is not recommended that Timor-Leste directly subsidize the price of LPG or kerosene fuel for several reasons: (a) possible diversion of the fuel for noncooking uses, such as transport, can occur (this is likely to be more so with kerosene than LPG); (b) possible smuggling and sale of the fuel outside of the country; (c) difficulties in limiting benefits to low-income households or crafts and professions; and, most important (d) the subsidy burden to the government is likely to become unmanageable in the future. As experience worldwide has shown, it is extremely difficult to withdraw or even reduce subsidies once they become critical to consumer choices for fuel use.

It is often more effective, with fewer undesirable side effects, to subsidize access, not consumption. Subsidizing access calls for programs that subsidize the equipment needed to make the fuel switch (for example, new stove purchases, deposits for LPG cylinders) and facilitating fuel distribution but keeping fuel prices at market levels. The financial exposure of the government for an equipment subsidy program can be determined annually in advance, unlike fuel subsidy programs that are entirely subject to the vagaries of fuel market fluctuations. The government may terminate the equipment subsidy program at almost any time with minimal public inconvenience.

Improved Stoves

Promoting higher efficiency or "improved" cooking stoves (ICS) should not be viewed as encouraging continued use of fuel-wood but as a necessary intermediate approach—the only practical way for the government to reduce fuel-wood consumption on any significant scale while the economy transitions to a future in which modern fuels are more widely available and affordable for most households. The benefits associated with modern fuels, such as lower levels of harmful IAP, higher energy efficiency, and cleaner kitchen environments, are also

1. S. Shum, E. Terrado, K. Openshaw, and V. Tuntivate, "Timor-Leste: Issues and Options in the Household Energy Sector—A Scoping Study," World Bank, 2007.

2. Timor-Leste's GDP is $356 million (current 2006 dollars; World Bank 2007).

obtainable to a certain degree with improved stoves. By their design, improved stoves burn wood more efficiently than traditional ones and thus have lower emissions.

Promoting improved stoves in Timor-Leste is severely hindered by the continuing relative abundance and low cost of fuel-wood supplies in the country, making it hard to motivate households to economize. In addition, Timorese households do not yet have a culture of purchasing stoves. The only way for improved fuel-wood stoves to be disseminated widely in Timor-Leste is to substantially subsidize their cost to users. Fortunately, compared with other programs for reducing fuel-wood consumption, the required subsidies per household are small and could be terminated at any time by the government without immediate drastic welfare impacts on users (they simply revert to traditional stoves). The potential benefits, even if just reducing IAP impacts, far outweigh the cost. An IAP monitoring program should be carried out as part of any ICS program.

The report outlines procedures for a conceptual five-year ICS program targeting 15,000 households in Dili and Baucau. This amounts to about 25 percent of households in the two districts and 8 percent of total households in Timor-Leste. The ICS model would be patterned after the higher efficiency, low-cost, portable "Malawi stove" or similar stoves already tested elsewhere. The cost of the program over five years is estimated to be $300,000 to $350,000, excluding the cost of international consultants needed at the design and preparation stages.

Domestic Biogas Systems

In Timor-Leste, a program has been proposed to provide biogas systems to some 4,600 rural households, which is the estimated number of households owning at least one to two head of cattle. The main purpose is to displace the fuel-wood presently used in these homes with a clean and renewable fuel substitute. In the initial configuration, one small family-size digester (FSD) capable of producing about two cubic meters per day (m^3/d) of biogas would be shared by three households, using waste from a total of four to six head of cattle owned by the families. The investment cost is estimated to range from $500 to $1,000 per FSD, depending on locality-specific prices for construction materials.

Preliminary economic analyses were made of the above configuration and of a case in which only one household uses the FSD and splits the output equally between cooking and lighting. In addition to the fuel benefits, the economic analyses counted the benefits of producing nitrogen fertilizer from the digester sludge. Using as a base case the mid-range values for capital costs and gas quality, the results clearly point to the low economic viability of a program designed mainly to replace fuel-wood. The main reasons are the relatively high investment costs per household and the low opportunity cost of the fuel-wood replaced. The results were somewhat stronger for the single household case mainly because of the higher replacement value of imported kerosene (for lighting). However, this case assumes that the single household owns four to six cattle to supply the waste requirements of the FSD, thus limiting the coverage of the biogas program to a relative handful of households.

Apart from the economics, it is also important for policy making to consider beneficiary issues related to the fact that current recipients of biogas systems are families that are undoubtedly better off than others in the community. In the pilot or demonstration phase, there is little choice but to select such families for biogas installations. However, in subsequent expansion phases of the biogas program, explicit consideration of the distribution of benefits should be factored into whatever financial or subsidy mechanisms are employed. The Ministry of Agriculture, Forestry and Fisheries (MAFF) has an ongoing livestock breeding and distribution program for cattle, buffalo, pigs, goats, sheep, and poultry, and aims to establish large livestock farms. When the livestock program has progressed significantly and more rural families are raising their own animals, it may become possible for the post-pilot phase of the biogas program to have a wider and more varied set of beneficiaries.

In contrast with household-scale biogas digesters, the positive economics of feedlot-scale units has been established for a number of years. There are also ancillary benefits including reducing water pollution and run-off and production of byproducts such as fertilizer and fish farming on commercial scales. Consequently, as larger livestock farms are established, government policy should make feedlot-scale biogas digesters a priority for support.

Meanwhile, the current program to install FSDs has a high capacity-building value and should be continued for that purpose, limited for now to a pilot scale. A key objective should be to monitor actual costs and other operating data from the pilot installations to guide decisions on the subsequent phase.

Alternative Fuels: Biodiesel from Jatropha

The government has initiated a program of cultivation of *Jatropha curcas*, a drought-tolerant vegetable oil crop, to produce biodiesel and replace imported diesel oil for electricity generation or transport. Currently, a few hectares have been planted for a little more than one year by small farmers in various places using marginal lands. The overall concept is for farmers to harvest the Jatropha oil seeds, bring them to the local cooperative for processing, and be paid a fixed price for each kilogram of Jatropha seed. The seeds will be brought to a central place for pressing into oil. The oil will then undergo a transesterification reaction with methanol, using a catalyst. It is envisioned that as many as 200,000 hectares that will be dedicated to Jatropha cultivation in the country.

Reliable and country-specific data are not available on costs, yields, cultivation practices, and other factors needed to assess and evaluate the costs and benefits of the program. The study team used data from similar programs in Thailand and India, reviewed the experience reported in the literature, and made a preliminary analysis of the viability of the program under different diesel-blending scenarios and crude oil prices. The conclusions reached are as follows:

- The land area requirements of the Jatropha program are a significant consideration for a small country like Timor-Leste. At an assumed yield of four tons seed per ha, a B^5 program (blend of 5 percent biodiesel and regular diesel oil) would require about 3.5 percent of the country's cultivated land; a B^{10} program, 7 percent; and a B^{20} program, 14 percent. The 200,000 hectares of Jatropha plantations that have been proposed would be roughly equal to the size of total cultivated land in Timor-Leste today.
- The current Timorese program for Jatropha is predicated on the use of marginal lands. Studies elsewhere have consistently shown that good yields, low unit production costs, and a positive net energy ratio (NER) for the final product are achieved only when Jatropha cultivation is approached in a commercial manner using reasonably fertile land and appropriate inputs, such as fertilizer, irrigation water, and pesticides. To quote the findings of a recent international conference on Jatropha, "Marginal lands will produce marginal yields."
- Based on the overall costs of growing, transporting, and processing Jatropha, a crude oil price at or above \$90 per barrel (bbl) is necessary to cover the costs of the various parties, and requires as well that the price component attributable to processors be capped. In a more typical market setting, still higher crude prices, greater than \$120/bbl, will be needed to provide adequate profitability for both the farmers and the processors. For example, if Jatropha farmers are guaranteed a \$250/ha profit above estimated production costs of \$335/ha, the government will need to provide subsidies in excess of \$2 million/year for a B^5 program at 2010 average oil prices and still more than \$1 million/year at \$110/bbl. Alternatively, if farmers are paid on the net after costs for cultivation and processing, then a "reasonable" level of profit will require oil prices consistently above \$100/bbl, even in favorable production cases. With yields typical of marginal land and corresponding production costs, even oil prices at \$150/bbl will not produce acceptable incomes, net energy ratios, or foreign exchange (FX) savings.
- With FX savings as an objective, the analysis must consider the continued need for imported and oil-based inputs, such as fertilizers and pesticides, and diesel, methanol, and catalysts for processing the Jatropha oil. Based on typical yields, estimates indicate that at current oil prices (\$75 ± \$20/bbl), FX savings are negative (that is, Jatropha is a net FX user), especially in light of the full costs of cultivation, transport, processing, and blending. The potential FX savings become significant only at crude oil prices above \$100/bbl, and the program represents an effective use of FX only if Timor-Leste lacks the ability to supply itself with domestically produced hydrocarbons. Even synthetic crude from natural gas is likely to be less expensive than the estimated costs of Jatropha oil processed for biodiesel blending. The FX calculation includes neither forgone export revenues from displaced crops nor additional food or feed imports resulting from land diverted into use for energy crops. Thus, these FX impact calculations are merely a first approximation and the costs are probably substantially understated.
- While Jatropha cultivation undoubtedly increases rural employment relative to no programs to increase or improve output of agro-forestry crops, it is not clear that the cost is advantageous compared with other means of generating rural employment opportunities in the context of Timor-Leste. Jatropha

cultivation needs to be compared with alternative programs to promote community-based forest management and protection, and with agro-forestry initiatives, for example.

- Finally, the eventual local availability of petroleum products from offshore oil and gas production needs to be considered. This could occur in a time frame of fewer than 10 years, when significant biodiesel production facilities would just be gearing up. At that time, biodiesel substitution would make even less economic sense than it does under current prices for imported fuels. The alternative of exporting biodiesel is possible only if Timor-Leste enjoys a clear comparative advantage over producers in other countries, such as significantly lower production and processing costs and advantageous logistics with respect to potential customers.

1

Context and Background

Timor-Leste, a new country of just 1 million people, is a picture of contrasts. On the one hand, it is generating and accumulating substantial revenues from offshore oil and gas resources developed in partnership with Australia. On the other hand, the country is one of the least developed in the world with much of the population living in poverty. A decade after the period of violence and civil unrest in the late 1990s, slow but significant strides have been made in education, health, agriculture, infrastructure development, and other sectors. Still, the majority of the population lives in rural areas and most do not yet have access to basic services.

The Rural Energy Sector

Predominance of Biomass Fuels

Table 1.1 provides an approximate comparison of current consumption of all types of fuels used in Timor-Leste as of 2006. The table shows that the consumption of biomass energy (fuel-wood) exceeds that from all other fuels combined, including hydrocarbons, reflecting the still highly undeveloped and rural nature of the whole economy.

TABLE 1.1 TIMOR-LESTE 2006: USEFUL ENERGY SHARE OF MAJOR FUELS FOR ALL SECTORS

Fuel type	Consumption (tons/year)	Heating value (MJ/kg)	Utilization efficiency[a] (percent)	Useful energy[b] (Ktoe)	Percentage share
Fuel-wood[c]	600,000	15.5	15	33.3	51.9
Diesel[d]	50,000	46.0	40	22.0	34.2
Gasoline[e]	22,000	47.0	30	7.4	11.5
Kerosene[f]	3,000	46.0	35	1.2	1.8
LPG[g]	500	45.0	60	0.3	0.5
Total	**675,500**			**64.13**	**100.0**

Source: Authors' compilation.

Note:

a. Fuel-wood, kerosene, and LPG efficiencies refer to cooking stoves; diesel to power generation; and gasoline to automobile engines.

b. One ton of oil equivalent (toe) = 41.9 gigajoules (GJ).

c. From Shum and others, *op. cit.*

d, e, g. Ministry of Natural Resources and Environment (2006), Dili, Timor-Leste.

f. From ADB Power Planning Study (2003) that estimated 3–4 million liters kerosene used per year. Asian Development Bank and Government of East Timor, "Power Sector Development Plan for East Timor," September 2003, Dili.

TABLE 1.2 SOURCES OF ENERGY USED FOR COOKING

Energy source	Urban (%)	Rural (%)	All areas (%)
Fuel-wood	98.3	98.9	98.7
Agricultural residues	0.5	0.4	0.4
Charcoal	0.5	0.7	0.7
Kerosene	9.2	1.6	3.0
Electricity	1.2	0.7	0.8

Source: Authors.

Note: The totals exceed 100 percent because some households use more than one type of fuel.

The largest consumer of energy is the household sector and the principal fuel used by almost all households is fuel-wood. About 98.7 percent all households use fuel-wood as their main cooking fuel—with agricultural residues, charcoal, kerosene, and electricity constituting the negligible balance (table 1.2).[3] About 80 percent of rural households obtain their fuel-wood by collection while about 60 percent of urban households purchase their fuel-wood. LPG is used by some higher income households in urban Dili, but most usage of LPG is by the commercial sector (hotels, restaurants, and the like).

Despite the overwhelming predominance of biomass fuels, the 2007 World Bank scoping study found that, except for the Dili district, a positive fuel-wood supply-demand balance is still indicated for most of the country.

Limited Access to Electricity Services

Much of the electricity infrastructure was severely damaged during the period of civil unrest in 1999. Today, the national electrification rate is about 20 percent but is estimated to be less than 10 percent for rural areas. The total load demand in the country is less than 50 megawatts (MW). All generation uses diesel systems, including the 19 megawatt Comoro power plant serving the Dili district. In rural areas, 58 isolated grids provide about six hours of service at night. A systematic and comprehensive countrywide rural electrification master plan (REMP) was drawn up by Norplan (initial study in 2004, with an update in 2007). It is the blueprint being followed by the government for rural electrification and is being implemented with assistance from donors. The REMP tasks consist mainly of rehabilitation of existing networks and old diesel plants, grid extensions, and establishment of new decentralized diesel generation. Implementation is under way, with the priority being the connection of district towns to the grid. For communities located in areas considered uneconomic for grid extension, the REMP recognizes the need to exploit local resources where available (mainly oil and gas seeps, and micro-hydro power) for providing electricity through isolated grids. The World Bank has supported the development of a small pilot project to demonstrate the feasibility of local power generation using a gas seep located at Aliambata on the southern coast. Norway has financed a pilot micro-hydro power plant. For smaller, dispersed communities, the REMP has estimated the total number of households in each district whose only possibility of obtaining electricity service is through individual photovoltaic (PV) systems. A consultant company from Portugal was commissioned by the government in 2008 to carry out data collection and an in-depth assessment of the potential for renewable energy applications, including large-scale grid-connected electricity generation. The final report was delivered in May 2010, and it estimated the nationwide hydro-electric generation potential at 252 MW, rising to 352 MW if pumped storage is applied. National wind energy generation capacity was estimated at 72 MW, bringing the total potential for installed renewable energy capacity in Timor-Leste to 451 MW.

Institutional Responsibilities

The planning and implementation of pilot projects for off-grid electrification with renewable energy, such as wind, micro-hydro, and PV, is the responsibility of the office of the Secretary of State for Energy Policy. The Secretariat of State for Energy Policy is also responsible for policies and activities related to the replacement of fuel-wood by alternative fuels (for household energy). Although the intended use of biodiesel is not for rural energy supply but mainly to replace diesel fuel used in power plants, the Secretariat of State for Energy Policy is carrying out the ongoing pilot program to cultivate Jatropha crops.

Key Issues in Rural Energy

For the rural energy sector the key challenges to the government lie in addressing the potentially serious health and environmental problems associated with continued heavy dependence on biomass fuels, and providing improved access to modern fuels, particularly electricity, to all segments of the rural population. The government has initiated several pilot activities in rural areas

3. Shum and others, *op. cit*. A total of 865 households in urban Dili, Baucau, and three selected rural areas in Liquica, Aileu, and Ainaro districts were surveyed.

to address these issues. As it proceeds to an expanded phase of these activities, it wants to ensure that the efforts are rooted in sound policies that are consistent with the country's overall goals of poverty alleviation and economic development.

Basis of Sound Rural Energy Policy

The primary goal of a sound rural energy policy is to promote measures that will enhance the quality of life of people in rural areas by improving their access to modern energy services. In the context of Timor-Leste, part of the policy is promoting the use of renewable energy resources that are indigenous to rural locations and are environmentally benign. Another key part is promoting programs that replace fuel-wood with modern liquid fuels that are cleaner to handle and produce fewer harmful emissions. In all cases, the desired approach is one that is environmentally benign and economic both from the country's point of view and for the welfare of individual rural households. A crucial objective in the implementation process is to ensure that the government's rural energy programs provide equitable distribution of benefits, so that populations in the poorest and remotest areas are accorded the same attention and opportunities as those living close to the electricity grid.

Purpose and Organization of This Report

The government is already implementing several rural energy development programs in pursuit of the abovementioned goals. The objective of this report is to help the government, particularly the Secretary of State for Energy Policy, to develop clear and coherent policies in key areas that would guide planning of the subsequent phase of its ongoing programs, the initiation of new programs, and the prioritization of projects competing for a limited total budget. This requires analyzing the main technical, economic, and social issues related to current programs and plans and identifying various policy and strategy options. If data and needed information are unavailable, the analyses use, as appropriate, information from similar situations in other countries, drawing on extensive experience in World Bank projects worldwide.

The present report focuses on three specific areas that are highly relevant to ongoing and planned programs of the Secretary of State for Energy Policy: (a) improving electricity access for remote, off-grid populations; (b) addressing household energy issues, particularly those arising from the need to curtail fuel-wood consumption; and (c) developing biomass-based fuels, particularly Jatropha, cultivated in rural marginal lands, as a substitute for hydrocarbons.

2

Electricity Access Policies

The official goal of the government is to achieve 80 percent electrification by 2025. Considering the current low electrification rate of about 20 percent and the damaged or substandard condition of the existing infrastructure, the goal is ambitious. Nevertheless, a phased national electrification plan—the Rural Electrification Master Plan (REMP)[4]—was prepared in 2003 and later updated and initiated in 2007. The REMP was based on calculations of present and projected demand, inventory of available generation capacity, and rough estimates of potential generation from local resources. The REMP systematically prioritized districts, subdistricts, and sucos, based on the principle that electrification should follow geographically the areas with the highest economic activity and potential growth. The long-term program would add about 100,000 potential new rural customers at a total cost of about $87 million. The first phase, estimated to cost about $40 million, would add about 50,000 potential new customers. The time frame for the first phase would be five years or more, depending on availability of financing and development of local construction capacity. Electricidade de Timor-Leste (EdTL) has been implementing the tasks defined in the REMP, starting with district-level refurbishments and connections. Issues related to financing, staffing, and other factors have severely limited the capability of EdTL to meet targets. These issues and others related to the conventional, grid-extension part of the government's rural electrification program are being addressed by other assistance activities and are not discussed further in this report.

4. S. Grongstad and B. Stenseth, "Update Rural Electrification Master Plan Report," Norplan, 2007.

Off-Grid Electrification

The REMP recognized that many communities and households located in areas far from the electricity network or across difficult terrain are not expected to be reached by grid-extension programs for at least the next 15 years. These communities are often small, dispersed, and poor. Government policy should be to provide at least basic electricity services to such off-grid communities, through programs implemented in the same time frame as those directed at concentrated communities living near the network. The implementation policy should be based on principles of least-cost power planning, with the objectives of technical and financial sustainability.

For sucos or parts of sucos considered in the off-grid category, access to electricity could be provided through decentralized mini-grids powered by isolated diesel gensets, local energy resources (if available), or by photovoltaic (PV) systems. In general, international experience with diesel-based systems in remote areas has not been favorable. In Timor-Leste, as well, the diesel systems managed by EdTL serving district capitals have been found to be expensive and difficult to operate and maintain, particularly with the low tariffs charged. The problems experienced with large systems are likely to be exacerbated with small, suco-scale diesel systems scattered in relatively remote areas. For new decentralized power systems, it is good policy to put priority on harnessing locally available energy resources, especially environmentally benign renewables, wherever they are available.

Decentralized Mini-Grids

The most likely local energy resources to be exploited in Timor-Leste are already-identified oil and gas seeps and hydro resources.[5] Initial estimates by Norplan indicate that, out of a total 442 unelectrified sucos, about 157 have oil or gas seeps or hydro resources located within 5 kilometers, of which about 125 are hydro and 32 are oil and gas seeps. If screening criteria similar to those for grid-extension projects are applied, about 60 of these sucos could be considered priorities for electrification, of which 34 would be hydro and 20 oil and gas seeps. These numbers are imprecise estimates but provide an idea of the size of the decentralized power needs of the rural electrification program compared with the grid-connected part. The individual scale of power generation from these decentralized resources and the number of connections possible depend on highly site-specific factors. Detailed localized investigations are obviously needed before any decision is made to finance individual investments.

5. In principle, biomass resources, such as animal wastes digested to yield biogas or agricultural residues directly combusted or gasified for power, are also possible but are unlikely to be significant for most parts of Timor-Leste. Small wind power systems could also be used but average wind speeds in Timor-Leste are generally not high. A period of systematic wind measurements at potential project sites will need to be carried out first.

Even when local energy resources are available within 5 kilometers or so of load centers, the least-cost option for the government may be solar PV and not the development of the local resource. This is often the case when (a) the potential users are highly dispersed and thus expensive to connect together, and (b) the most significant use of electricity is only for lighting and small domestic purposes (radio, small TV, and the like). Although the operating costs are low compared with diesel, developing a local energy resource, whether a gas seep or hydro, then building a power plant and constructing a mini- or micro-grid network, normally results in a very high investment cost per user. It is easier to economically justify the project when the total load demand is high, such as when a large productive load, for example, a grain milling machine or cold storage for fish and foodstuff, is envisioned to be built. However, care must be taken when assessing the true likelihood of an economic activity occurring in the community when electricity becomes available. Many past consultant studies, particularly for micro-hydro, have proved overoptimistic in this regard, resulting in projects with significant unutilized power output, high generation costs, and high investment costs per connection. Establishing and sustaining a microenterprise requires some basic entrepreneurial and business skills on the part of the local residents who will manage the enterprise, even when the establishment costs are fully borne by the

TABLE 2.1 DISTRIBUTION OF POTENTIAL PV CUSTOMERS BY DISTRICT

District	Number of grid customers	Cost per grid customer ($)	Number of potential PV customers	PV installed in 2008	PV installed in 2009
Aileu	2,160	784	3,240		
Ainaro	4,040	719	3,557		
Lautem	5,574	847	5,427		58
Manufahi	3,490	603	5,111		
Manatuto	4,670	628	2,893		94
Viqueque	4,775	263	5,990	240	772
Covalima	6,620	640	4,905	40	10
Baucau	7,320	415	8,649		6
Liquica	1,690	1,116	1,739		
Ermera	5,825	645	7,735	96	585
Bobonaro	8,125	772	7,627	97	145
Oecussi	8,365	692	2,189		
Total	**62,654**		**59,062**	**473**	**1,670**

Source: REMP (Norplan 2007).

project. In most cases, these skills do not exist in remote communities of Timor-Leste.

Solar Home Systems

Norplan estimates that about 60,000 households nationwide cannot be electrified by grid extension or by local mini-grids in the foreseeable future and considers such households to be appropriate for stand-alone solar PV systems. The breakdown of potential PV customers ranges from about 1,740 in Liquica to about 7,600 in Bobonaro. In 2008 and 2009, more than 2,000 PV systems for households and community centers were provided by the government of Timor-Leste to sucos in Viqueque, Ermera, Bobonaro, and a few other districts (table 2.1).

To date, the PV installations have been fully subsidized by infrastructure funds provided annually to the sucos by the central government. Suco leaders submit applications for PV installations in their communities. The Secretariat of State for Energy Policy reviews the applications and recommends approval. When approved, the suco leaders negotiate directly with private PV companies to install the systems. Recipient households do not contribute to the purchase cost but are expected to operate and maintain their own systems. The Secretariat of State for Energy Policy considers the ongoing effort to be a pilot and hopes to learn from the experience before embarking on a full-scale program for electrification with PV.

Costs

Most households in remote sucos require electricity mainly for lighting, and for small domestic power applications such as radios, small TVs, and the like. These applications could be adequately met by individual PV systems. Moving from kerosene lamps to PV-powered electric bulbs results, for the household, in a marked improvement in the quality of lighting and a reduction in indoor air pollution; for the country, it results in significant reductions in greenhouse gas emissions. However, even considering current household expenditures for kerosene and candles for lighting and dry cells for small appliances, the cost of shifting to PV can exceed the ability and willingness to pay.

PV systems for households range in capacity from about 10 watts for a portable solar lantern to 100 watts or more for a large solar home system (SHS).[6] The price can range from about $100 for the lantern system to about $1,500 for the 100-watt SHS. For Timor-Leste, an SHS of about 50 watts, capable of powering two to three lamps for three to four hours a night, would be sufficient for the needs of most remote households and could be made the basis for program planning. This size has gradually emerged in past Bank projects (for example, in Sri Lanka and China) as sufficient for the majority of households and most popular in price-performance ratio. The average international retail price, including installation, of a 50-watt SHS is about $700–$800 today. This price could be lowered significantly if the units were purchased in large volumes and if installation of many systems in a remote area could be made in one trip by the provider.

Subsidy issues

The high upfront cost of SHS precludes its acquisition by almost all households if not subsidized. In most past and ongoing PV projects financed by the World Bank, user subsidies average about 50 percent of the upfront cost, with the actual level depending on the size of the system, the business model employed by the project, and the general policy of the government with regard to electrification of off-grid areas. In countries with high electrification rates, very small unserved populations, and robust sources of subsidy funds (for example, Mexico and Argentina) a much higher level of subsidy has been applied and sustained. Aside from the objective of financial sustainability of the program, however, a key purpose of requiring PV recipients to contribute part of the system acquisition cost is to instill a sense of ownership. A wealth of evidence from past projects has shown that PV dissemination mechanisms in which systems are just given away or fully subsidized fail within a short period.

In Timor-Leste, a policy for providing a relatively high level of subsidy for PV users may be justified on social equity grounds (households in remote areas deserve attention similar to that received by households living near the grid) and the small total number of households that need to be provided individual systems (manageable total cost to the government). In Phase 1 of the REMP involving up to 63,000 potential customers, the average investment cost per grid connection is estimated to be about $650, of which about $10 is paid by a majority of the customers as a connection fee. In addition to the investment cost subsidy, households are charged a tariff of only $0.12 per kilowatt hour or $2.40 per month for a household consuming about 20 kilowatt-hours. The tariff is well below EdTL's cost of generation and distribution—about $0.27–$0.35 per kilowatt-hours.

The above suggests that providing an upfront grant for PV of about $640 per household while charging a monthly

6. An SHS comprises a solar PV panel, a battery, regulator, and lamps. The battery could be an ordinary car battery, which lasts about two years or less, or a deep-cycle battery that could last for four to seven years. The lamps are typically 10-watt compact fluorescent lamps but, recently, lower wattage light-emitting-diode lamps have been increasingly used.

maintenance fee of about $3 (for battery replacement and similar needs) would be roughly equivalent to the situation of grid-connected rural households. The government may decide under some circumstances to pay the full upfront cost of a PV installation but, to ensure sustainability, leave the full cost of operation and maintenance (replacement of battery, lamps, and so on) as the user's responsibility, to the extent possible. The appropriate level of capital cost subsidy for Timor-Leste will depend on the actual PV system costs at the start of implementation of a full-scale program based on the mechanism discussed below, the estimated total budget requirements, and the source of funding decided upon by the government. Although other factors obviously need to be considered, these policy considerations should be the basis for designing an implementation mechanism or model for the next phase of the government's PV program.

Implementation options

Although several variations and combinations exist, the implementation mechanisms or business models for PV dissemination that have been used in most countries generally fall into two basic categories: (a) dealer model (also called direct sales or open market), and (b) fee-for-service model (energy service company or concession system). In the dealer model, the consumer purchases the system either with cash or financing, and owns it. Beyond warranty service, the consumer assumes responsibility for all operational and replacement costs. In the fee-for-service model, the consumer is simply provided electricity service. The company, which retains ownership of the equipment, is responsible for maintenance and providing replacement parts over the life of the service contract.

Timor-Leste does not yet have an environment that would support implementation of a dealer model: there are few or no companies that could be provided incentives to compete in selling PV; the micro-financing system is still undeveloped; and most important, the current PV market consists mainly of households belonging to the bottom part of the income pyramid. Some type of fee-for-service mechanism executed by the private sector but with a strong role for the government would appear to be more suitable, at least for the next 5 to 10 years. A suggested mechanism and implementation procedure for an SHS program are outlined in annex 1.

The approach would group several communities into a package for competitive bidding, improving on the current practice of letting the sucos negotiate prices of installations individually with vendors, thus potentially reducing the total cost to the government. However, given the low implementation capacity of government staff, technical assistance should be provided at the start to provide sufficient training to staff on the optimal grouping of prospective communities, preparation of bidding documents, and conduct of the bidding process. The mechanism outlined in annex 1 follows the typical concession model but should be implemented in a highly simplified version, given constraints on local capacity. It can be thought of as a simple extension of the winning supplier's responsibility to provide and install the equipment, then later to operate and maintain the equipment in groups at the sites for an extended period.

The suggested mechanism results in a minimal monthly payment by each household to the service provider that

BOX 2.1 EXPERIENCE WITH SOLAR BATTERY CHARGING STATIONS IN NICARAGUA

In indigenous communities of Nicaragua's remote Atlantic Zone, seven SBCSs, each with a 2-kilowatt capacity, were installed in 2006. Each SBCS served some 50 households, and each family was provided a battery and lighting kit. The Nicaraguan government bore the capital cost of the stations and initial battery expenses. Beneficiary communities were trained to operate, financially manage, and maintain the stations. Each family paid a monthly fee of $5 to cover weekly battery charging and contribute to a fund for buying replacement batteries.

The original concept was to allow families to charge their batteries only when they had available cash (much like the retail buying of cooking oil or fuel-wood), but the concept proved unworkable in practice. To sustain the station business, however, each user family had to commit to regular monthly payments, which became a major stumbling block for this off-grid approach. Although community organizations managed SBCS operations well, the users—mainly poor subsistence farmers—eventually could not afford the monthly fees.

The Off-Grid Rural Electrification Project (PERZA) is addressing this problem by working to raise farmers' incomes. For example, the project has developed a customized micro–business services program that assists in the bulk transport and marketing of crops and livestock and advises on agricultural matters. It has also arranged for noncash payment for battery charging.

should be roughly equivalent to the amount the household normally pays for traditional systems, for example, kerosene lamps, dry cells, candles, and so on. Even with this small monthly responsibility, experience worldwide has shown that at some point many families become unable to pay. This is to be expected from any socially oriented energy provision program that serves the lowest income communities. The only way to increase the chances of sustainability of such energy provision programs is to combine them with other agricultural or rural development projects that actively try to raise incomes in the target communities.

Solar Battery Charging Stations

A solar battery charging station (SBCS) is an option that could be considered for electrification of remote households through PV. A typical SBCS would consist of an array of PV panels totaling about 2 kilowatts of capacity and a special controller that enables the charging of up to eight batteries simultaneously.[7] The station could serve about 50 families, providing each with service equivalent to that of an individual 40-watt-peak SHS. The family would bring the battery for charging to the central station once a week. Normally, each family pays a fixed monthly fee to cover the salary of the operator (a trained local resident) and to amortize the cost of the next replacement battery.

7. Project Appraisal Document, Nicaragua Off-Grid Rural Electrification (PERZA) Project, World Bank, 2003.

In countries where PV programs are based on the demand-driven dealer model for SHS, the market served consists only of those in the middle and top portions of the income pyramid. In such countries, SBCS is often used as a way to address the needs of the poorest off-grid households, with the government paying for the full capital cost of the stations, initial batteries, and lighting kits. A 2-kilowatt SBCS would cost about $20,000.

In principle, SBCS is also a fee-for-service PV business model. But compared with the SHS model previously discussed, no solar panel is located at the user's house, and the user must manually carry the battery to the station weekly for charging. One advantage of SBCS is a small economy of scale in capital costs achieved when compared with acquiring several SHSs of the same total capacity. A second advantage is that the mechanism does not rely on an external service provider. However, the resident local operator is often not capable of addressing any significant technical problems and still needs some external support. A requirement or disadvantage is that client families must be situated relatively close to the station; otherwise, carrying the heavy battery back and forth to the station becomes impractical. Where off-grid situations can be found in Timor-Leste with sufficiently concentrated but small numbers of poor households, the SBCS option may be worth considering. Again, as with any model that serves very-low-income households and requires periodic payments to maintain operation, long-term sustainability is more likely when combined with other programs that raise the income of the user community. (See box 2.1.)

3

Household Energy Policies

This chapter addresses the use and replacement of fuel-wood for cooking through (a) substitution of modern fuels, (b) an intermediate step of improved cooking stoves that still use fuel-wood, and (c) domestic biogas systems.

Fuel-Wood: Key Issues

Development of a sound policy for fuel-wood use and its potential replacement by modern fuels must take into account a number of factors. Almost 99 percent of all households in urban and rural areas in Timor-Leste use only fuel-wood for cooking, making this domestic use of biomass energy responsible for about half of all delivered energy from all fuel types (including petroleum fuels) used in all sectors.[8] This reflects the still-abundant biomass supply in most parts of the country, except in the Dili district.[9] As a result of this abundance, fuel-wood is, and will be for some time to come, the cheapest cooking fuel in Timor-Leste compared with liquefied petroleum gas (LPG), kerosene, and electricity, even after accounting for different cooking equipment efficiencies.

There is no doubt, however, that the responsible policy for the government to pursue must be the curtailment of fuel-wood use to the greatest extent possible. From the supply viewpoint, two main factors drive the need for such a policy. First, the heavy use of fuel-wood by households in very inefficient traditional stoves wastes tremendous amounts of the country's biomass resources. Second, population growth is certain to erode the current overall positive supply-demand balance for fuel-wood, as a consequence of increased total wood consumption coupled with decreased area of forest lands resulting from conversion to agriculture.

Another important reason for the government to curtail the use of fuel-wood relates to the public health impacts of its use. Strong correlations have been found in many low-income countries between exposure to indoor air pollution (IAP) from the use of solid fuels (smoke from traditional cook-stoves burning biomass) and acute respiratory infections, such as tuberculosis and pneumonia. For Timor-Leste, a World Bank Country Environmental Analysis conducted in 2008[10] estimated that the annual morbidity and mortality cost of health effects from IAP associated with the use of solid fuels is between \$5 million and \$20 million (see table 3.1). The mean estimate is equivalent to about 1.4 percent of Timor-Leste's GNI, or 3.5 percent of its 2006 GDP.[11]

The rationale for a policy curtailing fuel-wood use is clear but the issue is what realistically can be achieved in Timor-Leste and at what cost. It may not be possible to

8. The use of biomass fuels in rural industries is insignificant in Timor-Leste.

9. Shum and others, *op. cit.*

10. J. Bojo and F. Ruiz Nunez, "Timor-Leste Country Environmental Analysis," World Bank, 2009.

11. Timor-Leste's GDP is \$356 million (current 2006 dollars; World Bank, 2007).

TABLE 3.1 TOTAL HEALTH COSTS FROM SOLID FUELS USE IN TIMOR-LESTE ($ PER YEAR)

		Lower bound	Central	Upper bound
ARI, Children < 5	Morbidity	277,283	1,651,832	3,495,129
	Mortality	3,900,059	4,953,133	6,006,206
Total ARI		**4,177,342**	**6,604,965**	**9,501,336**
COPD, Adults ≥ 30	Morbidity	270,782	379,379	489,066
	Mortality	533,901	5,457,434	10,380,966
Total COPD		**804,684**	**5,836,813**	**10,870,031**
TOTAL		**4,982,025**	**12,441,777**	**20,371,367**
% of GNI		**0.58**	**1.44**	**2.35**

Source: J. Bojo and F. Ruiz Nunez, "Timor-Leste County Environmental Analysis," World Bank, 2009.

Note: ARI = Acute Respiratory Infection; COPD = Chronic Obstructive Pulmonary Disease.

significantly change the pattern of fuel-wood consumption using substitution or demand-side management programs for at least the next decade. However, the surplus supply situation also suggests that it may be possible to buy time for the transition to other fuels with sustainable forest management programs that could enable continued use of fuel-wood for some time, until modern fuels could make significant inroads into the demand picture.

The strategy, therefore, is to pursue programs that combine both demand-side management or interfuel substitution programs with programs for improved management of fuel-wood supply.

The latter does not necessarily entail launching separate efforts for managing supply of fuel-wood species but could be part of Ministry of Agriculture, Forestry and Fisheries (MAFF) programs for management of forest resources, in general.

This report discusses issues and options for three different approaches: (a) substitution of LPG and kerosene for fuel-wood, (b) promotion of higher efficiency cooking stoves, and (c) promotion of domestic-scale biogas systems.

BOX 3.1 BIOMASS BRIQUETTES AS A SUBSTITUTE FOR FUEL-WOOD

Biomass briquettes could be made from a variety of agricultural residues available in Timor-Leste, such as rice husks and coffee shells. The process is relatively simple, requiring only a mechanical or hydraulic press to compress the residues into a dense solid fuel that could be used in stoves. Programs for densification of biomass residues have been successful in regions that have severe fuel-wood shortages, such as parts of northern Vietnam and China. In such areas, many people have even resorted to using agricultural residues, such as rice straw, directly in stoves in their unprocessed or loose form.

The problem with promoting biomass briquettes in Timor-Leste is not with the technology or availability of raw materials for densification but simply the fact that the fuel of choice, wood, is still widely available for collection in almost all parts of the country. Even if biomass briquettes are sold in markets at a price much less than fuel-wood, it is highly unlikely to result in any significant shift by households to this alternative. It is appropriate for technical agencies and nongovernmental organizations (NGOs) in Timor-Leste to familiarize themselves with densification technologies and to conduct pilot activities, as is being done today. Such efforts, however, are more in the nature of preparing for a future of reduced fuel-wood supplies rather than expecting any possibility of having briquettes compete with fuel-wood now.

Interfuel Substitution with Modern Fuels

Compared with fuel-wood, LPG and kerosene[12] are more convenient and cleaner to handle. LPG is the cleanest, with the lowest amounts of pollutants emitted per kilogram burned, thus best for reducing indoor air pollution.[13] With both kerosene and LPG now sold at market prices,[14] however, those fuels are more costly per unit of delivered energy for households, even after accounting for the significant efficiency differentials between wood stoves and kerosene or LPG stoves. According to the Bank's 2007 scoping study, in which consumers purchased wood, primarily in urban areas,[15] the average cost of delivered energy was about $43 per gigajoule (GJ) for fuel-wood versus $48/GJ for electricity and $77/GJ and $81/GJ for kerosene and LPG, respectively. In addition to the direct cost of fuel, which is greater for refined hydrocarbon fuels, there is also the question of the cost of the equipment to use that fuel. Kerosene and LPG both introduce significant costs of shifting, including the purchase of new stoves or burners and the purchase of or cash deposits for storage cylinders for LPG.

There are four main options for promoting the increased adoption of modern fuels:

1. Subsidize the price of fuel (LPG and kerosene);
2. Subsidize the new equipment (stoves, cylinders);
3. Provide vouchers to low-income customers only for fuel purchases; or
4. Provide vouchers to low-income customers only for equipment purchases.

Either of the two fuel subsidization options can be combined with either of the two equipment subsidization options, leading to a significant menu of policy choices. These choices result in significant differentials (see figure 3.1) in the effects on beneficiaries, the cost to individuals and the government, and the likely efficacy of the subvention.

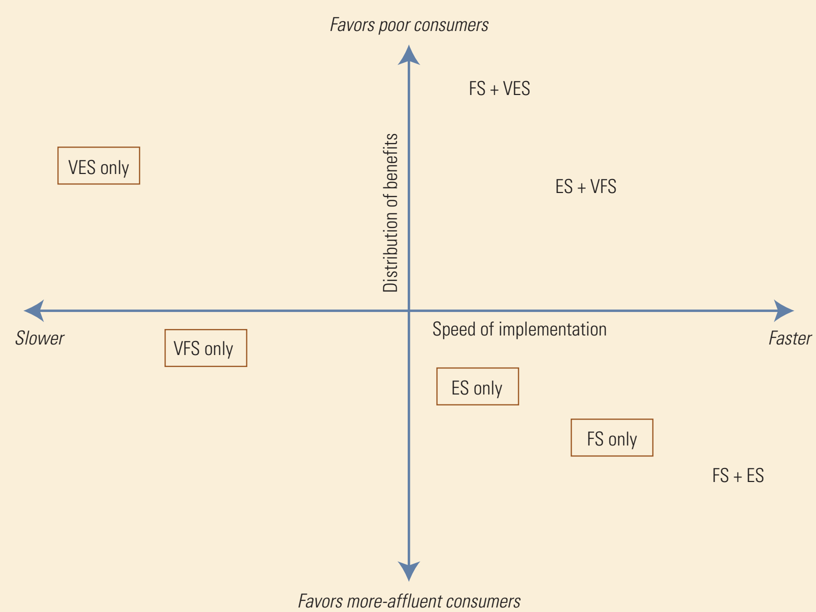
12. Modern cooking fuels usually include LPG, kerosene, and electricity. In Timor-Leste, even in more-affluent homes, electricity is used only in rice cookers. In most Asian countries, the growth of the middle class has resulted in rapid growth in the use of LPG.

13. Kerosene actually has about the same level of pollution as fuel-wood, but because of its higher energy density and the higher efficiency of stoves that use kerosene, the amount of pollutants emitted for cooking the same meal is much lower.

14. Before independence Timor-Leste was part of a national pricing scheme in Indonesia that provided significant subsidies to kerosene users.

15. In rural areas 80 percent of wood supplies are collected by the household.

FIGURE 3.1 IMPACTS AND EFFICACY OF PROGRAMS TO PROMOTE MODERN COOKING FUELS



Source: Authors.

Note: FS = fuel subsidy; ES = equipment subsidy; VFS = voucher system for subsidized fuel; and VES = voucher system for subsidized equipment.

Programs That Subsidize Fuel, or Equipment, or Both Without Income Tests

Programs that subsidize both fuel and equipment with no questions asked (identified as 1 and 2 in the list above), would obviously be the most effective and the fastest to implement. Of the two options, subsidizing the fuel offers continuing value to consumers and has been shown in other countries to result in significant and rapid switching from fuel-wood within a short time frame. It tends to be more effective because the process is convenient and the costs are hidden from consumers. Such programs establish expectations on the parts of consumers of a low—and stable—price for fuel.

The main disadvantage is that many of the beneficiaries of such unrestricted subsidies are often people who do not need them. For example, in some countries (Indonesia, for instance) subsidized kerosene has been diverted for use as engine fuel, thereby benefiting car drivers, owners of small electricity generators, and industry.[16] Subsidies without restrictions could create incentives for smuggling the fuel or equipment out of the country to be sold (or re-imported) at international prices.

16. This is less of a problem with LPG because LPG requires a more complex engine conversion process to enable its use in lieu of gasoline.

Programs That Subsidize Fuel, or Equipment, or Both with Income Tests

Programs that use income testing are identified as 3 and 4 in the list above. Voucher programs take a long time to establish. The government will need to have accurate census and income tax information to ensure that only the targeted income groups receive the vouchers. Even if implemented properly, such programs will generally be less effective than a no-questions-asked subsidy program. The voucher options show up on the left side of figure 3.1. Voucher programs tend to be less successful in promoting quick adoption of modern fuels because (a) they carry high administrative costs; (b) unlike a direct price subsidy, the financial costs of the program are apparent through the printing of the vouchers, thereby reducing the appetite of the government to expand it; and (c) the system is conducive to corruption—the emergence of a secondary market in vouchers is almost inevitable.

Combination Programs of Direct and Voucher Subsidies

To better target the subsidies, some countries have attempted various combinations of approaches. Combining voucher programs with direct subsidies for equipment and fuel will tend to increase the administrative complexity and costs, possibly slowing the pace of adoption of

BOX 3.2 LPG SUBSIDIES IN INDIA: GROWTH OF DEMAND AND FINANCIAL LIABILITIES

LPG was introduced in India as a domestic fuel in the 1960s. The demand for LPG grew from less than 200,000 tons in 1970–71 to about 5 million tons (MT) in 2000. The average growth rate in demand has been about 12 percent annually. In the 1990s, LPG demand was estimated to grow to 7.5 to 9.0 MT by 2001–02 and 10.0 to 12.0 MT by 2006–07. The projected supply was only about 4 to 5 MT in 2001–02, leaving a gap of about 3 MT.

The expected increase in demand is partly due to the expansion of the Indian middle class, which sees subsidized LPG as improving their lives.

The introduction of differential subsidies and taxes on various products led to a misallocation of both private and public expenditures for selected petroleum products, leading to a burgeoning demand for the subsidized ones, supplied increasingly through imports. The large subsidy on LPG combined with that on kerosene and the historical subsidy burden contributed by diesel, together with infrequent adjustments to pooled prices and a mismanagement of the pool account, built up a deficit of $4.42 billion (184.4 billion rupees) by 1997–98, $6.5 billion in 1998–99, and almost $14 billion in 2000.

In April 2002, the government announced that subsidies for all petroleum-based products would be phased out except for LPG and kerosene, which, the government pledged, would see their subsidies phased out within a three- to five-year period. LPG and kerosene are used as domestic cooking fuels by a large portion of the population. The issue, however, was not resolved and left to a later government.

Source: Center for Energy Economics, "LPG Subsidies in India," The University of Texas at Austin, Texas, 2005.

LPG or kerosene to less than what either voucher program alone might accomplish.

Better Practice: Subsidize Equipment, Not Fuel

In rural electrification programs, the guiding principle for sustainability (although not always observed) has been to subsidize only the construction of the system but not the purchase of electricity by consumers. The basic policy is to subsidize access, not consumption. In the household energy sector, the analogous policy—an alternative that has worked well in some countries—is to subsidize the equipment needed to make the switch to modern fuels but to keep fuel prices at market levels. This enables poor households to surmount the barrier of high first costs but avoids recurring and increasing costs to the government.

Although, as discussed above, the pace of switching by households will be significantly slower than in a program that subsidizes the fuel price, it prevents the problem of the government committing to a subsidy scheme in which costs are certain to grow very rapidly in the coming years, as economic conditions improve and a middle class emerges and expands in Timor-Leste. The fiscal impact of the fuel subsidy requirement may become unmanageable. At that point, as experienced in many countries, it becomes extremely difficult if not impossible for the government to significantly reduce or remove the fuel subsidies because users would suddenly be faced with greatly increased costs of a convenient fuel to which they have become accustomed (see box 3.2).

In contrast, the financial exposure of the government for an equipment subsidy program can be determined annually, in advance. The government may stop the equipment subsidy program at almost any time with minimal public inconvenience. The only negative effect would be a reduction in the number of new households switching to modern fuels. Those who are already using LPG or kerosene would be unaffected.

It is not possible to quantify the costs and benefits of these different options at present. However, the financial parameters of an equipment subsidy program can be established. Suppose, for example, that the costs of supplying a household with an LPG stove and an LPG cylinder deposit is \$100.[17] In that case the cost of converting, say, 15,000 households annually would amount to \$1.5 million per year, about the same cost as would be incurred by the government to support Jatropha growers for a small scale (B^5) biomass liquid fuel program.

There would be no other government costs, and if the program were terminated after five years, overall costs would be capped at \$7.5 million, and about 75,000 households, representing a significant proportion of the population, would have access to modern fuels. This represents a modest public cost for potentially effecting a significant change in the fuel mix.

Likely Continued Use of Fuel-Wood Stoves

Even with full-scale switching to modern fuels, including electricity, for cooking, experience in many countries indicates that fuel-wood stoves would continue to be used in a significant proportion of households. Fuel-wood stoves are often needed to supplement the LPG or kerosene supply when these fuels run out or when cooking costs need to be trimmed. In other cases, it is simply a cultural preference and households desire the flexibility of using multiple types of fuel. Nevertheless, it is expected that both the volume of demand for fuel-wood overall, especially in urban areas, and the rate of growth of wood demand, would tend to moderate as a modern-fuels program is fully implemented.

Improved Cooking Stoves as an Intermediate Approach

Promoting higher efficiency or "improved" cooking stoves (ICS) that still burn fuel-wood obviously does not have the same impact on fuel-wood use or IAP reduction as promoting full interfuel substitution with modern fuels. It should not be viewed as encouraging continued use of fuel-wood but as a necessary intermediate approach—the only practical way for the government to reduce fuel-wood consumption on any significant scale while the economy transitions to a future in which modern fuels are widely available and most households can afford them. The benefits associated with modern fuels, such as lower levels of harmful IAP, higher energy efficiency,

17. It is assumed for the sake of this discussion that consumers who are receiving the equipment for free will prefer LPG to kerosene from a food flavor standpoint. This has certainly been the experience elsewhere when the two fuels have been sold without subsidies. However, if lighting is a consideration, then support for kerosene equipment would be relevant. Also, if there is domestic production of natural gas, a small separation plant could be built for the local market, something that is virtually unthinkable for crude oil or kerosene.

and cleaner kitchen environments, are also obtainable to a certain degree with improved stoves. By their design, improved stoves burn wood more efficiently than traditional ones and thus have lower emissions.[18]

Initiating an Improved Stoves Program: Subsidy Issues

Ideally, improved biomass stoves programs should be based on sustainable commercial practices, that is, users buy the stoves at full cost, producers and marketers make a profit and are able to produce and market more stoves, and so on. Subsidies provided to the stoves program would be solely in the form of technical assistance, training, and promotion. Stoves programs in some countries have been implemented under this ideal principle; most other programs, however, could only be carried out by providing subsidies that reduced the final cost to the users, at least to the amount that they normally would have paid for their traditional, inefficient stoves. Governments justify the subsidies on environmental (curbing deforestation) or public health (reducing IAP) grounds. In all cases, however, these successful large-scale programs were implemented in environments and cultures in which users were accustomed to purchasing their biomass stoves, and replacing them when they break by purchasing another one in the market.

In Timor-Leste, however, virtually no households purchase their fuel-wood stoves and, except for brief periods when some specially funded programs require it, no one produces stoves to be marketed.[19] In addition, introducing improved stoves commercially is severely hindered by the continued relative abundance and low cost of fuel-wood in Timor-Leste, making it hard to motivate households to economize. The only way for improved fuel-wood stoves to be disseminated widely in Timor-Leste is to subsidize their costs to users substantially. The questions for policy makers are whether the benefits outweigh the costs of subsidies, whether the size of the subsidies required is manageable, and whether there are less costly alternatives.[20]

Fortunately, the cost to implement an ICS program is small compared with the cost of other types of interventions such as subsidizing LPG and kerosene for domestic cooking. For example, a five-year improved fuel-wood stoves program targeting 15,000 households, or about 25 percent of households in the Dili and Baucau districts, could be carried out at a cost of less than $350,000.[21] This amount is insignificant compared with even a fraction of the annual cost of health effects from IAP associated with the use of solid fuels, as shown in table 3.1.[22] A 100 percent subsidy to users in such a program could, in theory, be more than justified, but is not recommended. The improved stoves should be marketed at a price that is low enough to be affordable and attractive to buyers, but high enough that the stoves are not perceived as a giveaway of no value. For the conceptual program outlined in annex 2, a retail price of about $2 for a higher efficiency portable clay stove that costs about $7 to produce and market could be considered.

Given various implementation constraints, launching a much larger ICS program is not possible. The initial five-year, 15,000 "urban" stoves program outlined in annex 2 would first focus on the Dili and Baucau urban and peri-urban markets, where most families buy rather than collect their fuel-wood and hence may be more easily motivated to switch to ICS.[23] Depending on the results, the program could be expanded to an additional 20,000 units in the next 5 to 10 years, with expanded geographic coverage. Initiating a program of even modest scale as early as possible is good policy because it enables the necessary long-term market structure to be put in place slowly, and potential consumers can begin to absorb information about the various benefits provided by improved stoves.

After the initial five-year program, when the public has become more familiar with improved stoves and their benefits, the retail prices of the stoves will be raised by $1 per year so that at the 10th year all subsidies are removed. Demand is expected to drop after prices are raised but is expected to stabilize at a certain level even after full removal of retail subsidies. Unlike subsidizing LPG or kerosene fuel, which is not recommended in this report, the total subsidy requirement for the proposed improved stoves program over 10 years is a manageable amount and could be stopped at any time by the government without drastic welfare impacts on users.[24]

18. World Bank, "India: Household Energy, Indoor Air Pollution, and Health," ESMAP, World Bank, Washington, DC, 2002.

19. Shum and others, *op. cit.*

20. In the immediate term, because of the current overall fuel-wood surplus situation, benefits related to curbing deforestation impacts would be small and localized.

21. Based on stoves cost only. Associated program costs should be added.

22. Obviously, the full health impact costs of IAP cannot be avoided by an improved fuel-wood stoves program because it only reduces, not replaces, wood use.

23. The initial five-year program will also include some 200 demonstration "rural" stoves, which are massive and must be constructed in place because of rural households' different cooking patterns. However, it is expected that demand for the portable urban stove exists in rural areas as well, so they will be actively promoted later in these areas. See fuller discussion in annex 2.

24. Unlike the case of withdrawing LPG and kerosene subsidies

Monitoring Indoor Air Pollution

As part of the ICS program, a study should be carried out to evaluate the influence of stove type on kitchen air pollution levels and women's exposure to particulate matter from wood smoke. IAP levels and exposure levels would be measured in selected homes before and after introduction of the improved stoves. The design of the measurement regime, its execution, and interpretation of the data require specialized skills and equipment. It is recommended that the study be carried out by international experts in this field. The results could indicate to what extent the improved stoves are actually reducing IAP impacts.

Domestic Biogas Systems

The production of biogas by anaerobic digestion of animal wastes has been practiced in various parts of the world for many years, notably in China, India, and other South Asian countries. Biogas can be used as fuel for cooking and lighting, and fertilizer can be produced as a byproduct from the sludge. In Timor-Leste, a program has been proposed to provide biogas systems to some 4,600 rural households, which is the estimated number of households that own at least one to two head of cattle. The main purpose of the program is to replace the fuel-wood presently used in these homes with a clean and renewable fuel substitute.[25]

The technical feasibility of a biogas program is not in question. The key issues are economic and distributional. Given the limited financial resources of the government, and mindful of other programs to provide modern energy to rural areas, can such a program, with an initial cost of at least $3 million, contribute more to the country's energy supplies than some other use for that same money? And will these funds go to those who can best use the resources for household betterment and improved standards of living?

after years of providing them and after the market has grown enormously, withdrawing subsidies after several years from an improved stoves program would have much lower negative impacts on household welfare. When the subsidies are withdrawn, households are likely to simply revert to using traditional or self-made stoves. They may notice a cooking cost increase from increased fuel-wood use but the amount would not be significant in absolute terms because of generally low wood prices. This may even prod them to continue buying ICSs at unsubsidized prices.

25. In addition to cooking, it is possible to use biogas for lighting, via a mantle lamp, though this use will obviously reduce the gas available for cooking. About 1 cubic meter of biogas could provide light from a mantle lamp equivalent to a 60 watt bulb for about seven hours.

Under the proposed program, one small family-size digester (FSD) capable of producing about 2 cubic meters per day (m^3/d) of biogas would be shared by three households, using wastes from a total of four to six head of cattle owned by the families. The FSD would be of Chinese fixed dome design with a volume of about 10 m^3. Based on international experience, approximately 1 m^3 of biogas is required for the daily cooking needs of a family of four. The average size of a Timorese family is almost twice this number and, in principle, a single family could use all of the output of the 2 m^3/d digester. However, the capital cost of this small digester is significant compared with rural incomes and very few families in Timor-Leste own enough cattle to supply the amount of waste required daily.

Costs and Benefits

To guide policy making in this area, an idea of the costs and benefits of different options for using family-sized biogas systems needs to be obtained. As yet, however, no operational and cost data from the biogas installations in Timor-Leste are available, so it is difficult to make a detailed quantitative assessment. Nevertheless, some estimates can be made using information collected from the team's field mission and from international benchmarks.

The cases analyzed in this report consider the use of the FSD in two ways:

- The FSD replaces only fuel-wood for three households, and
- The FSD replaces fuel-wood and kerosene (for lighting) in one household.

In addition to fuel benefits, the economic analysis counts the benefits of producing nitrogen fertilizer from the digester sludge. The FSD will theoretically produce the equivalent of 30–45 kilograms/year of urea fertilizer. However, much of this fertilizer benefit is already gained by farmers who spread manure on their fields. Hence, the incremental benefit from this byproduct is relatively small. The initial cost to construct the FSD is assumed to range from $500 to $1,000, depending on locality-specific prices for construction materials.[26]

The methane fraction in biogas varies from 30 percent to 70 percent and the lower heating value of the 2 m^3 gas output will range from 28 to 51 megajoules per day. The amount of fuel-wood replaced depends on the quality of the biogas and the heating value of the fuel-wood,

26. Information obtained from the local UNDP office.

TABLE 3.2 HEATING REPLACEMENT VALUE OF BIOGAS

	Fuel-wood (15% conversion)		Biogas (60% conversion)	
	MJ consumed	MJ usefully consumed	MJ supplied	MJ usefully consumed
Daily	348	52	50	30
Annually	126,870	19,030	18,320	10,990

Source: David Ludington, "Calculating the Heating Value of Biogas," Ithaca, NY, not dated; and mission estimates. Household consumption figures from Shum and others, *op. cit.*

Note: The World Bank and most other experts generally use 15 percent as the conversion efficiency of a simple wood fire.

assumed here as about 15.5 MJ/kg. If about 50 megajoules of biogas per day is generated by the FSD, then the project is capable of replacing about 58 percent of the net wood energy used by the three households (table 3.2).[27] With the FSD shared by three households, the families will still need to supplement their fuel needs for cooking with fuel-wood or other alternatives.

The economic cost of fuel-wood replaced by biogas is assumed to be the opportunity cost of fuel-wood collection by families in rural areas, where about four to six hours per week are spent gathering an average of about 55 kilograms of wood. Based on a GDP per capita of about $440, the opportunity cost of fuel-wood for a rural household would be about $12–$19 per ton.

Results of Analyses

The details of the economic analyses of the two cases are shown in annex 3. Using as a base case the mid-range values of capital cost and gas quality, the economic rate of return (ERR) of Case 1 is nearly zero and the net benefits per household are equal to negative $468.[28] Less than 50 percent of wood energy consumption would be replaced. A best case scenario, with an ERR of 32 percent, is produced by the most positive assumption for each of the key parameters: gas quality, initial cost, and the opportunity cost of the wood that is replaced. In this highly unlikely case the highest possible gas quality and lowest capital cost was assumed for the FSD, and the opportunity cost of wood was assumed at twice the current opportunity cost of wood, that is, about $25–$40/ton.

In Case 2, where only one household uses the FSD and splits the output equally between cooking and lighting, the base case yields a positive ERR of about 8 percent but still a negative net present value of about $123 per household. Almost 67 percent of wood energy consumption is replaced. The somewhat stronger economic results for Case 2 are mainly due to the higher replacement value of imported kerosene. However, this case assumes that the single household owns four to six head of cattle to supply the waste requirements of the FSD and thus further limits the coverage of the biogas program.

Moreover, the use of biogas for lighting with mantle lamps is considered by experts to be an inefficient use for the fuel and should be resorted to only if electricity is unavailable. A mantle lamp equivalent to a 60-watt electric light bulb requires 0.11–0.15 m^3 of biogas per hour.

Sustainability Issues

The preliminary analysis has shown that investments in FSD systems generally produce poor or negative economic returns. Benefits to household health, especially among women and children, resulting from IAP reduction were not included in the analysis. To realize the health benefits, the reduction in wood use through partial or full substitution with biogas in cooking must be sustained over a reasonably long period. In this regard, FSD systems have generally fared poorly. Individual FSD systems have a poor track record for long-term performance, many being abandoned because of technical problems after only a brief time of operation.[29] This is especially true for systems for which users provided no significant contribution to the investment costs. Although typical technical problems (clogging, air in gas pipe, insufficient gas pressure, too much carbon dioxide in gas, and the like) are

27. Based on 7.5 kilograms of fuel-wood consumed per household per day, at 15.5 MJ/kg.

28. The base case for biogas also uses a highly optimistic assumption of a 15–20 year economic life for the FSD. In practice, such lifetimes have been achieved in very few countries and five years or less is a more normal FSD lifetime. Needless to say, the returns in even the most optimistic cases will be negative with such a short lifetime.

29. The track record is better in China, India, and other South Asian countries where very-large-scale programs have been implemented for decades, and a culture of livestock raising and waste recycling exists.

often manageable, the tendency is simply to abandon the biogas system and shift to alternative cooking fuels, such as fuel-wood, if these alternatives are still easily or cheaply obtainable. The need for continuous operating and maintenance (O&M) assistance from the government to individual recipients of biogas systems and the cost of such assistance cannot be underestimated.

Worldwide, biogas systems that have operated sustainably over the long term are generally larger-scale, multipurpose installations in livestock farms. They are built not simply to replace other fuels for cooking but also to replace kerosene for lighting, produce higher quality fertilizers, generate electricity for decentralized use or export to the grid, provide process heat, nourish a fish farm, and so on. The improved overall economic return is due to economies of scale, higher value of the outputs of the varied applications, and the likelihood of operating continuously for 15–20 years as a result of better O&M procedures.

Conversely, experience with communal kitchens, whether fueled by biogas or other energy forms, has generally not been positive for a variety of social reasons. Although economies of scale may also be gained by establishing larger-scale biogas systems for communal cooking, the communal systems are not likely to be sustainable over the long term, thus failing to deliver potentially large IAP reduction benefits.

Conclusions

The specific figures cited are less important than the overall results that clearly point to the low economic viability of a biogas program designed mainly to replace fuel-wood, today. The current overall fuel-wood situation in Timor-Leste does not yet present a significant supply problem to households in rural areas and results in a low opportunity cost of fuel-wood. This, of course, does not suggest that the supply situation will continue unchanged; efforts to prepare for a future deficit situation and higher fuel-wood costs are justified.

The current program to install household biogas digesters has a high capacity-building value and should be continued for that purpose but on a limited pilot scale. The main objectives of the pilot program would be to train installers and technicians, to demonstrate the technology to the public, and most important, to systematically collect cost and operational data that could be used to make realistic policy decisions for the next steps. Meanwhile, as indicated by the analysis, the only way to improve the economics is to find digester designs and configurations that reduce capital costs significantly, require less operational intervention, and generate benefits other than just fuel-wood replacement.

Apart from the economics, it is also important for policy making to consider beneficiary issues. Presently, only a

BOX 3.3 COMMERCIAL-SCALE BIOGAS PROJECTS: POTENTIAL CONTRIBUTIONS TO POWER SUPPLY

The Ermera district project integrates a 98-head (of cattle) feedlot, fish farming, fertilizer production, and a 15-kilowatt generator. Using the standard energy values for the expected gas output from this project, the village of 150 can be supplied with 15 kilowatts for approximately seven hours per day (29 percent load factor and 30 percent conversion efficiency).

With initial total investment costs of about $250,000, and allocating 30 percent of the total costs to the electricity generation component, a the project earns an ERR of about 10 percent at an assumed value for electricity of 35¢/kilowatt hour. Thus, at a cost that is competitive with small PV or diesel gensets, this integrated system can supply reliable electricity for both daytime and evening hours. Such a project, while not capable of contributing to the grid, can nevertheless provide a decentralized electricity supply for villages near large livestock farms.

Larger biogas systems, based on commercial scale feedlots of 500–1,500 head of cattle, can support power plants capable of distribution grid integration (70 percent load factor), at sizes ranging from 36 kilowatts for the 500-head feedlot to 110 kilowatts for a 1,500-head feedlot.

a. A 15-kilowatt generator of the type used at Ermera costs approximately $25,000–$30,000 for machinery, installation, controls, and distribution wiring.

handful of rural families own sufficient livestock to supply the required amount of wastes for a biogas digester; these families are most likely to be better off than those who do not own any livestock. Subsidizing the construction of biogas digesters for only these few families may raise criticism that the program benefits the relatively better-off (less-poor) segment of the rural population. In some countries, this social issue has proved to be a major barrier to finding continued political support for household-scale biogas programs. In the pilot or demonstration phase, there is no choice but to use relatively more well-off rural families because they are the only ones who have enough livestock. The beneficiary issue becomes relevant in the subsequent or expansion phase of the biogas program, at which time it should be factored into the subsidy mechanism finally adopted.

The Ministry of Agriculture, Forestry and Fisheries (MAFF) has an ongoing livestock breeding and distribution program for cattle, buffalo, pigs, goats, sheep, and poultry, and aims to establish large livestock farms. When the livestock program has progressed significantly and more rural families are raising their own animals, it may become possible for the post-pilot phase of the biogas program to have a wider and more varied set of beneficiaries. Meanwhile, poor rural families without livestock could still be provided some basic energy assistance through other government programs that are less costly to implement as measured by investment cost per household, for example, improved cooking stoves, solar lanterns, and others.

As larger livestock farms are established, government policy should make development of domestic biogas systems a priority for support because the economics are very likely to be more attractive at large digester sizes. Unlike a cooking-only application, large-scale systems could be used to provide other important services, such as power generation, process heating (for example, meat processing), and fish farming, that benefit the overall economy.

The Ermera project (see box 3.3) could provide valuable experience in this area. The government should take advantage of the Ermera project to systematically evaluate actual costs and benefits, so that the economics of similar subsequent integrated installations could be improved.

4

Alternative Fuels: Biodiesel from Jatropha

The government of Timor-Leste has initiated a program of cultivation of *Jatropha curcas* (Jatropha), a drought-tolerant vegetable oil crop, to produce biodiesel and replace imported diesel for electricity generation. Currently, a few hectares (ha) have been planted for a little more than one year by small farmers in various places using marginal lands. The overall concept is for farmers to harvest the Jatropha oil seeds, bring them to the local cooperative for processing, and be paid a fixed price for each kilogram of Jatropha seed.[30] The seeds will be brought to a central location for pressing into oil. The oil will then undergo a transesterification reaction with methanol, using a catalyst. The product—biodiesel—has very similar properties to petroleum-based diesel. Ultimately, it is envisioned that as many as 200,000 ha will be dedicated to Jatropha cultivation in the country.

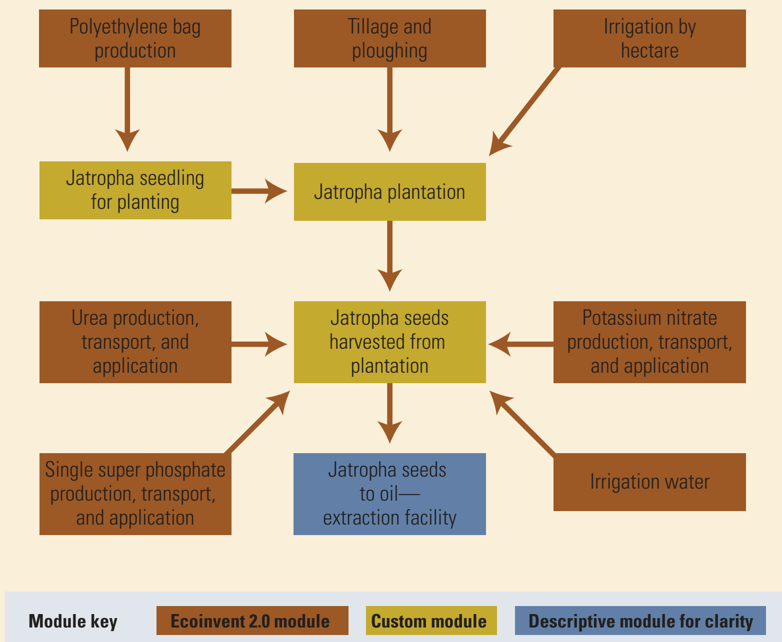
To address the issues raised in both the current proposals and in examination of Jatropha cultivation in India and elsewhere, the following issues and concerns must be examined:

- Land use. Can Jatropha be cultivated on marginal lands? If so, is the question of the opportunity cost of land resolved or mitigated?
- Energy balance. What is the energy balance for the biodiesel fuel cycle, including blending into petroleum middle distillates? Is a positive net energy ratio (NER) sufficient cause to continue the program? Conversely, is a negative NER sufficient reason to terminate the program?
- Cost. Can biodiesel be supplied at or below the cost of imported diesel? If not, is the program worth continuing based on potential benefits gained through local employment opportunities? What types of subsidies might be used to supply Jatropha at a cost that is competitive with that of petroleum fuels? Are such subsidies justified by employment creation or other benefits?
- Need for a pilot phase. What critical data and information should be collected during the pilot phase to be able to fully support a decision to scale-up or terminate?
- Foreign exchange saving and fuel security. Given the substantial oil revenues (about $60 million to $75 million per month) the country is earning, as well as current and potential sources of diesel fuel supply, to what extent does the strategy of locally producing a diesel substitute actually benefit the country in foreign exchange (FX) savings and fuel security?

At the present time Jatropha is not cultivated commercially in Timor-Leste. However, Norges Vel has proposed a pilot program that could scale to full commercial size for the cultivation, processing, and end use of Jatropha-based biodiesel. The question of Jatropha cultivation has also been considered by the local office of the Food and Agriculture Organization.

30. A price of $0.25/kg has been suggested as sufficient to provide farmers with "adequate" incentives to undertake cultivation of Jatropha. However, most bioenergy schemes involve a percentage split of the final price between growers and processors. That issue is addressed further on in this section.

FIGURE 4.1 MODELING SCHEMATIC FOR COMMERCIAL JATROPHA CULTIVATION



Source: Michael Whitaker and Garvin Heath, "Life Cycle Assessment of the Use of Jatropha Biodiesel in Indian Locomotives," NREL/TP-6A2-44428, March 2009, p. 24.

Estimates of the costs of growing Jatropha, expected yields under different cultivation regimes, conversion to biodiesel, and land use needs for various program alternatives in this report are derived primarily from studies of Jatropha cultivation in India and elsewhere.[31] The analytical schema for modeling Jatropha cultivation in the India study is shown in figure 4.1.

Land Use

As a general rule, land with higher quality soil, more rainfall, and greater use of necessary pesticides and fertilizers will yield more crops of any kind than the same natural conditions with fewer human and chemical inputs. The same general rule applies to Jatropha. A number of crop studies consulted for this report[32] indicate that Jatropha responds similarly to many other crops with respect to the use of fertilizer and irrigation. Because the crop has been cultivated commercially for only a few years, the type of hybridization and selective breeding that produces a uniform crop and seedpod has not yet occurred. Nor is there a cultivar that has entirely predictable responses to fertilizer and irrigation use.[33]

The literature on Jatropha indicates the following:

- At the present time no studies exist that use standardized density, soil chemistry, fertilizer, and irrigation plots with consequent yield figures such as do exist for many other agricultural crops.[34] Much of the evidence on growing Jatropha remains anecdotal.
- Though Jatropha is drought tolerant (that is, it can stay alive for two to three extremely dry years), it will not produce seedpods during such years, and subsequent production is reduced as well.
- Jatropha responds to fertilizer and should be weeded regularly.[35]

31. Michael Whitaker and Garvin Heath, "Life Cycle Assessment of the Use of Jatropha Biodiesel in Indian Locomotives," NREL/TP-6A2-44428, 2009.
32. Pere Ariza-Montobbio, "Impact of *Jatropha curcas* Plantations for Biodiesel on Livelihood and Food Sovereignty in South India," Institute of Environmental Science and Technology, University Autonomous of Barcelona (UAB), 2008. Roy Beckford, "Fundamentals of Producing *Jatropha curcas*," University of Florida, November 2008.

33. Ariza-Montobbio, *op. cit.*, p. 6.
34. Whitaker and Heath, *op. cit.*, p. 4.
35. Whitaker and Heath, *op. cit.*, pp. 4, 16, 20, 25.

- Jatropha requires natural annual rainfall in excess of 900 millimeters and total annual rainfall plus irrigation in excess of 2,300 millimeters to produce seed and oil continuously throughout a 15–20 year life.
- Jatropha will not tolerate more than two days of flood conditions,[36] a significant issue as it relates to where to locate the Jatropha crops.
- The plant is subject to a number of well-known plant pests, including aphids, weevils, and various boring insects.
- There are not yet any longitudinal studies indicating the longer-term impacts of growing Jatropha on either prime or marginal agricultural lands.

Jatropha has been promoted on the grounds that it can be a "no-cost" supplement to farm incomes, with an added FX benefit for the country with regard to fuel supplies. In particular, it is thought by some that Jatropha can be grown in areas adjacent to existing croplands, intercropped with other crops, or grown on soils or slopes that are not suitable for conventional cropping.

Timor-Leste has about 1,231 square kilometers of arable land, 8.2 percent of a 15,007 square-kilometer total land area. Cultivated land in the country, including permanent crops, totals 1,917 square kilometers, or 12.77 percent of the country's total land area. The area for permanent crops,[37] 4.5 percent of the country's land area, is low relative to other countries in the region—more than 15 percent of the total land area of both Malaysia and the Philippines is devoted to permanent crops. The figure for Indonesia is 7 percent.[38]

In looking at the availability of "unused" or unproductive agricultural land for planting Jatropha, it is useful to consider the land-use requirements of a program that might make a meaningful contribution to the country's energy supplies. Current consumption of middle distillate liquid fuels in Timor-Leste is 2,300 barrels per day (bbl/d), equivalent to 133 million liters per year (123 kT/y). Studies of Jatropha in other countries used standard biodiesel blends of 5 percent, 10 percent, and 20 percent (B^5, B^{10}, and B^{20}, respectively) for their analyses.

A B^5 program in Timor-Leste would use about 6,667 ha of land, roughly 3.5 percent of the country's cultivated land (arable plus permanent crops) at an assumed yield of four tons of seed per ha, a "normal" figure for a field receiving fertilizer and other cultivation in India. Expansion of the program to B^{10} or B^{20} will require 13,333 ha and 26,667 ha, or 7 percent and 13.9 percent, respectively, of cultivated land.

Experience elsewhere indicates that use of otherwise unproductive land will not produce any salable amount of seed for oil extraction in the absence of other inputs, including fertilizer, pesticides, cultivation, and irrigation. Under such conditions Jatropha will compete with other permanent crops, including nuts, fruits, and fuel-wood, for marginal lands that surround farm fields. In other words, wherever Jatropha can be grown to yield a commercial volume of seeds it is likely that there are other tree and shrub crops competing for the same land. Low- or no-input plantings of Jatropha on truly marginal lands are not likely to produce commercially salable seed quantities. If production of seeds is low in density, amount, and quality, then the transport costs for moving small amounts to a distant processing center will be high, reducing the net income to the farmer for the sale of the Jatropha seeds.

Energy Balance

Two recent studies addressed the energy balance of Jatropha cultivation, one for India and another study that used conditions in Thailand.[39] Energy balance was generally found to be positive under conditions of high plant density, adequate rainfall and irrigation, good seed yields, and little efficiency decrement for the biodiesel mixtures in the power plant.[40]

The Thailand study found that the net energy ratio (NER) for biodiesel production was generally greater than 1 (that is, energy value of the oil in a form that can be readily mixed into diesel as a proportion of the total nonsolar energy used to cultivate, transport, and process the Jatropha seeds). NER > 1 indicates a net energy contribution from the proposed cultivation; NER < 1 indicates that Jatropha cultivation, transport, and processing consume more energy than is contained in the oil. Under "normal" conditions, that is, assuming reasonable soil quality, rainfall and irrigation, fertilizer and pesticide inputs, and time spent cultivating the crop, the NER could be as high as 2.7 and averaged 1.42. This means that the energy value of the output oil was on average 40 percent higher than

36. Beckford, *op. cit.,* found that root rot was significant following two days sitting in flooded conditions.

37. Permanent crops are considered multiyear agricultural, viticultural, or horticultural activities and include fruit trees, nuts, vineyards, and perennial flowers. This figure excludes trees used for timber or paper products.

38. Arable land is considerably larger as a percentage of total land area in both Indonesia and the Philippines (CIA, The World Factbook, June 2010).

39. Whitaker and Heath, *op. cit.*; Kritana Prueksakorn and Shabbir H. Gheewala, "Full Chain Energy Analysis of Biodiesel from *Jatropha curcas* L. in Thailand," *Environmental Science and Technology*, 2008, 42 (9): 3388–93.

40. Whitaker and Heath, *op. cit.,* p. 47.

the energy value of the inputs and as much as 170 percent greater in some cases (the system configuration used for this analysis is shown in figure 4.2). However, under conditions of low yields, low shrub density, and poor conversion to a diesel-compatible oil, the NER could drop as low as 0.53, meaning that the energy value of the output oil was only about half as great as the energy value of the nonsolar inputs.

It may be reasonable to conclude from these studies that the NER can be positive as long as there is some effort to grow the crop on agricultural land and put some money and time into the cultivation. Grown as a true marginal crop on marginal lands, the NER is likely to be negative and strongly so.

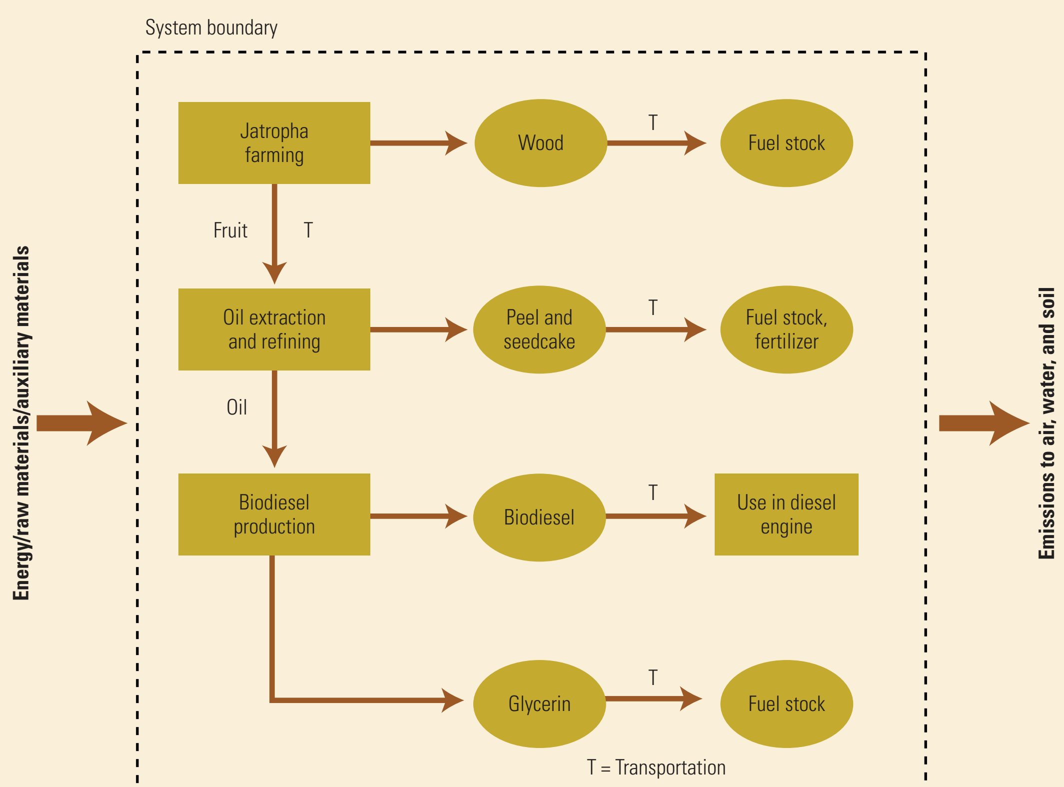
A source of renewable energy should be, on balance, a net energy contributor unless there are secondary considerations, including soil conditioning, wind breaks, and the like that provide a compelling economic case for the investment. A project with NER < 1 is unlikely to be eligible for Clean Development Mechanism or other carbon offset payments.[41]

For the conditions that were examined in Thailand and India, Jatropha can be a net energy contributor as long as it is cultivated in a serious manner. This means, among other things, good soil, sufficient water, continual weeding, and use of fertilizer and pesticides at appropriate times. As a purely marginal activity on low-quality, dry lands Jatropha is not likely to show a feasible NER.

Growing conditions sufficient to produce Jatropha oil on a feasible NER basis (NER > 1) should be examined from the standpoints of economics, rural incomes, and energy supply considerations. Conditions under which Jatropha shows a net energy deficit (NER < 1) are unlikely to provide much in the way of income or energy supply benefits either.

41. The notation specifying the positive net energy condition can be found as Equation 15 in the UNFCC document at this location: http://cdm.unfccc.int/UserManagement/FileStorage/IXDFJ1ZGIPXAWCCC2FKG605E4CFW0C.

FIGURE 4.2 NET ENERGY ANALYSIS OF JATROPHA CULTIVATION IN THAILAND



Source: Kritana Prueksakorn and Shabbir H. Gheewala, "Full Chain Energy Analysis of Biodiesel from *Jatropha curcas* L. in Thailand," *Environmental Science and Technology*, 2008, 42 (9): 3388–93.

Cost of Supplying Jatropha Oil

The only information available on Jatropha cultivation that is specific to conditions in Timor-Leste is the Norges Vel conceptual paper. However, the paper contains little that can be used to assess the economic feasibility of Jatropha cultivation and processing, much less its opportunity cost with respect to other agricultural activities. To make a preliminary economic analysis, this report uses yield and cost data from other studies, primarily the studies cited earlier.[42] Using a series of prices paid to farmers for Jatropha seed relative to different prices for imported fuels,[43] a pattern emerges with regard to economic cost and feasibility of Jatropha cultivation at different crude oil prices.

The economic analysis used the following parameters:

- yield of Jatropha seeds per hectare (tons),
- yield of oil per kilogram of seed,
- cost per hectare of Jatropha cultivation,
- crude oil price,
- processing cost, and
- split between growers and processors of oil.

Variations of these parameters will provide a range of results. In the current circumstances, and in the absence of country-specific information, the values in table 4.1 were assumed for a base case.

The economic analysis assumes that purposeful cultivation activity of Jatropha takes place. As the net energy analysis and land use discussions have indicated, without inputs and on inappropriate land the cultivation of Jatropha is not likely to be a net energy producer and will be inferior to other uses of marginal lands, possibly including fuel-wood.

42. Whitaker and Heath, *op. cit.*; Prueksakorn and Gheewala, *op. cit.*
43. The price split with processors was discussed previously.

For example, at a (farmer's break-even) seed price of 8.3¢/kilogram, the raw material cost of 1 liter of oil will be 33.2¢. With minimal processing cost of 26¢/liter, the minimal break-even price for refined diesel-compatible oil is 57¢/liter, equivalent to diesel oil at $90/bbl. This result is shown graphically in figure 4.3. If farmers are guaranteed 15¢/kilogram for seed, the minimal break-even price rises to about 65¢/kilogram, consistent with diesel oil at $110 to $120/bbl on a consistent basis.

Under conditions of active cultivation (use of fertilizer, pesticide, weeding, irrigation, and so forth) profitable returns to the farmer will require crude oil prices in excess of $90/bbl. Even with an increasing proportion of the oil price returned to growers as crude prices rise, farm profits from Jatropha planting are very modest until crude prices reach $120/bbl.[44] At no time does the price (actually the netback value) for Jatropha approach the 25¢/kilogram level discussed by the Food and Agriculture Organization representative in Dili. Such a price, were it realized, would generate grower profits in excess of $500/ha, but would also require a fuel price equivalent to almost $200/bbl as a break-even price for the processor.

44. Grower-processor splits of the type displayed in figure 4.3 are typical of a fully market-oriented grower-processor relationship, one in which the processor would be responsible for blending with diesel or selling to a refined products jobber. Note also that even with 15¢/kilogram for the crop, net farm income at $100/bbl for oil is just $250/ha, hardly a dispositive case for Jatropha cultivation on normal croplands when other food or feed alternatives are likely to provide higher net income.

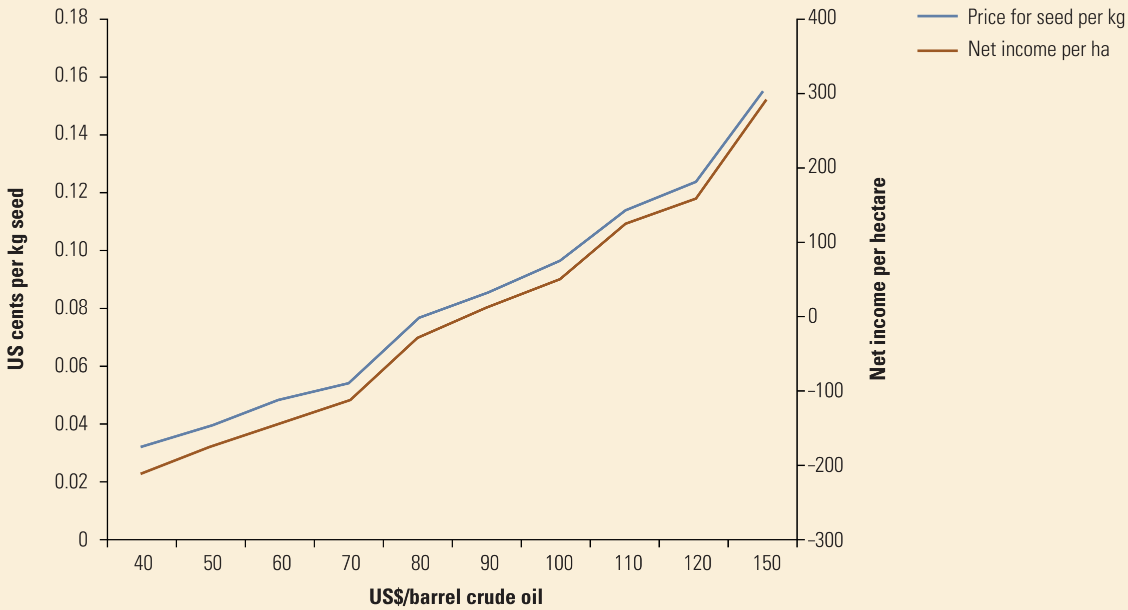
TABLE 4.1 PARAMETERS FOR ECONOMIC ANALYSIS OF JATROPHA CULTIVATION IN TIMOR-LESTE

Yield of Jatropha seeds per hectare (tons)	4
Yield of oil (liters) per kilogram of seed	0.25
Cost per hectare of Jatropha cultivation	$333
Crude oil price	market
Split between growers and processors of oil	50:50, rising to 65:35 at higher crude prices
Processing cost (per liter raw oil, diesel-powered expeller including equipment, profit, fuel, labor)	$0.17
Additional processing (transesterification per liter)	$0.09

Sources: Whitaker and Heath, *op. cit.*, pages 26–27. Authors' assumption for split between growers and processors. Processing cost data from Reinhard Henning, "Jatropha as a Tool to Combat Climate Change and for Poverty Reduction," UNCTAD (unofficial), 2006, p. 13. Cost of expelling process uses oil price of $75/bbl.

Note: Processing includes transport to mill and subsequent transport of transesterified oil to blending plant.

FIGURE 4.3 JATROPHA ECONOMICS WITH MARKET-DETERMINED SPLIT FOR GROWERS AND PROCESSORS



Source: Authors.

Subsidies for Jatropha Oil Growers

With grower profits unlikely at current and expected future crude prices, one way to induce growers to switch to Jatropha is to guarantee a seed price sufficient to generate a reasonable profit, say, $250/ha. The cost of providing such a price floor at varying levels of output (B^5, B^{10}, B^{20}) and with the same variation in crude prices used in figure 4.3, was examined.

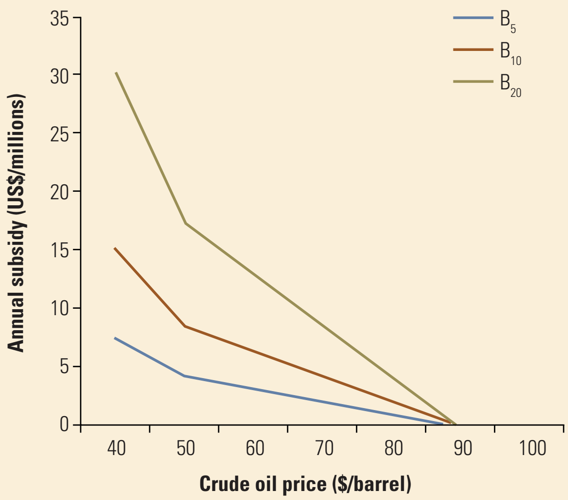
The big change in assumptions in this case vis-à-vis the case that resulted in figure 4.3 is that rather than share the profits from Jatropha sales through a market-determined grower-processor split, it is assumed that farmers will form a cooperative to own the processing facilities, thereby effectively capping the costs associated with expelling oil and refining it up to blendable biodiesel quality.[45] Even under such conditions, the costs of processing will vary directly with the price of oil. Both diesel (about 1 liter required for each 15 liters of oil expelled) and methanol (about 0.4 liter required per liter produced) have variable prices.

45. Investment costs for such a plant are likely to be well beyond what small farmers in the country can afford, with initial investment needs likely in excess of $20,000 for a small mill capable of servicing the output of 50 hectares.

If farmers are to cultivate Jatropha profitably and if processors are to breakeven on their costs, a minimum price of $110 to $120/bbl will be needed to support Jatropha cultivation and use in Timor-Leste. At least $90/bbl is required just for break even with no profits for processors and net farm income of less than $200/ha. Figure 4.4 shows what the government might be expected to spend subsidizing Jatropha cultivation and processing in a cooperative ownership situation for the oil processing. The figure indicates that guaranteeing a price to farmers of at least 15¢/kilogram will require significant subsidies until the price of oil is a bit above $90/barrel.

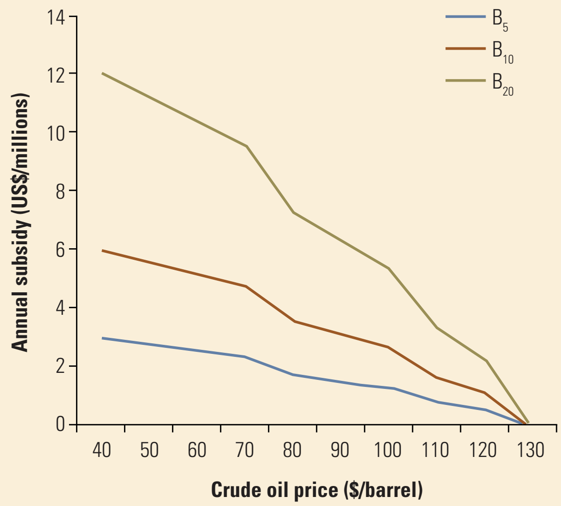
To have a meaningful impact on the energy sector, the government of Timor-Leste will need to look at Jatropha programs that are capable of providing a uniform fuel type throughout the country, thus one of the programs—B^5 through B^{20}—for biodiesel. Figure 4.4 shows the costs per year for providing growers with a profit of $250/ha by guaranteeing a purchase price for the seed. A B^5 program can be instituted at an annual subsidy of about $2 million for the current range (US$40–US$100/bbl) of oil product prices. The B^{10} and B^{20} programs are more expensive and scale up arithmetically. As figure 4.4 indicates the subsidies are very small at crude prices of about $90/bbl and disappear entirely before crude prices reach $100/bbl, as long as the cost of processing is capped.

FIGURE 4.4 GOVERNMENT SUBSIDIES FOR GROWERS UNDER COOPERATIVE OWNERSHIP OF PROCESSING (THAT IS, COST CAP ON PROCESSING)



Source: Authors.

FIGURE 4.5 GOVERNMENT SUBSIDIES FOR JATROPHA GROWERS UNDER TYPICAL MARKET ARRANGEMENTS



Source: Authors.

Note: In this case growers and processors split 50:50 (grower: processor) for oil prices below $90/bbl and 65:35 for higher prices.

Under market arrangements more typical of bioenergy crops, the targeted break-even price for growers would likely not be reached until crude prices hit $125/bbl or more (see figure 4.5). Such a break-even price for growers is based on price splits suggested for Jatropha cultivation and processing by parties in Timor-Leste and in India.

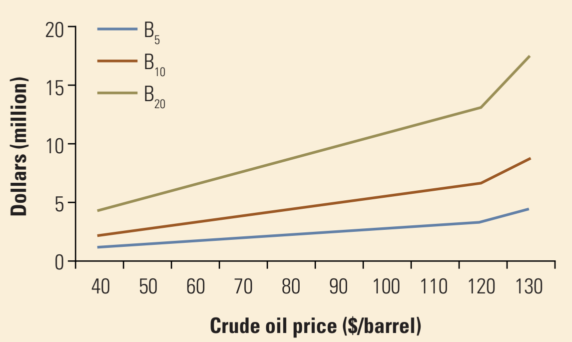
No present value analysis has been performed for this economic assessment because the data are insufficient to determine initial investment needs, land costs, investments in trucks and other equipment, and infrastructure improvements that must be made for the project. Such information could be produced in the course of a pilot-scale project as suggested at the end of this subsection.

Impacts on Foreign Exchange

Most of the inputs for growing Jatropha, including fertilizer, pesticides, and tools, will be imported, as will be the equipment and chemicals for processing. The FX costs of each of the biodiesel programs will be dependent on the amount of fuel produced and the cost of imported inputs. These input costs are expected to vary in a generally proportionate manner with crude oil prices because most of the inputs are derived either directly or indirectly from crude oil.

The FX savings consist largely of the middle distillate fuel that is not purchased as a result of the Jatropha program because there are FX costs for diesel used to run the expeller, methanol for transesterification, and machinery for processing. Costs of transport of the fuel and seeds are not included in this calculation. Figure 4.6 shows the

FIGURE 4.6 FX IMPACTS OF JATROPHA-BASED BIODIESEL



Source: Authors.

Note: These calculations do not include the FX that is forgone when export crops are displaced by Jatropha cultivation or when food crops that currently compete with imported foods are displaced by Jatropha. Such impacts, requiring more extensive local analysis and data, are likely to further disadvantage the arguments favoring Jatropha.

net FX costs or benefits from the B^5–B^{20} biodiesel programs as a function of oil prices.

At low oil prices, the FX costs of importing inputs for cultivation and processing are low relative to purchasing diesel abroad, at about \$1 million to \$1.6 million annually for a B^5 program when oil prices are in the \$50–\$60/bbl range. However, at crude prices above \$80/bbl, there are noticeable FX savings, ranging from about \$2 million per year to just under \$3 million per year when crude prices range from \$80–\$110/bbl for a B^5 program. Substantial FX savings accrue once the oil price rises above \$120/bbl and for the larger-scale programs.

The costs of imported inputs will remain a significant drain on larger programs, for example, inputs would cost roughly \$14 million annually for a B^{20} program at current (2010) crude oil prices. This expenditure of FX to produce 27 million liters per year of refined Jatropha oil suitable for blending would save the importation of \$12.5 million in equivalent diesel fuel, for a net FX cost to the government of \$1.5 million annually.

The results in this section do not change in an economic sense if the diesel is domestic or foreign in origin. However, from the standpoint of financial analysis a well-managed Jatropha cultivation program has the potential to save FX and provide measurable net benefits to farmers only if the price of oil consistently exceeds \$100 to \$120/bbl.

Impacts on Farm Incomes and Employment

At this time it is impossible to gauge the impact of a Jatropha program on farm incomes in Timor-Leste using domestically generated data. As has been demonstrated above, it is possible for Jatropha cultivation to be either a net energy drain or a contributor. However, using the NER > 1 standard for all feasible programs, a positive increment to farm incomes will occur if oil prices rise well above current levels (and remain there) or if the government guarantees payments to farmers and growers that will compare in cost with importation of the same volume of middle distillate fuel.

Conclusions

Available country-specific data are insufficient to make firm conclusions about the economic viability of a future investment program for Jatropha in Timor-Leste. However, based on agronomic work and other evaluations of Jatropha projects in India, Florida, and Thailand, some tentative findings can be advanced for Timor-Leste:

- The putative benefits of Jatropha cultivation on FX, net energy, and farm incomes are highly dependent on crude oil prices. At the present time a major investment in Jatropha cultivation and processing does not appear to be prudent unless oil prices achieve a plateau at or above \$100–\$120/bbl.
    - At oil prices near current levels (\$75/bbl ± \$20/bbl) there could be measurable FX savings on energy products only provided the cultivation of Jatropha is approached seriously and not treated merely as a sideline crop for farmers.
    - Farm incomes will require subsidies exceeding \$2 million/year for the B^5 program at current oil prices and above \$1 million/year at \$80/bbl for crude. Larger-scale programs would be proportionately more costly.
- Agronomic studies have consistently indicated that cultivation of Jatropha on marginal lands without much attention or input from the grower can result in a commercially viable crop, or in one that is capable of supplying net energy, rural income enhancement, and FX savings to the country. To achieve the maximum benefits of Jatropha cultivation, it will be necessary to devote reasonably good land, cultivation time, fertilizers, pesticides, and irrigation water.

It is not possible at this time to calculate a rate of return for the local Jatropha projects. Fundamental data regarding investment and cultivation costs do not yet exist for Timor-Leste. However, it is clear that achieving a positive rate of return would require opportunity costs for diesel that are well above current or projected crude oil prices. Indeed, at prices sufficient to make Jatropha a positive contributor to the country's economy, the production of synthetic crude oil from the country's offshore gas would probably be a better investment (box 4.1).

Recommended Activities

Certain basic information is needed for an intelligent assessment of the potential for Jatropha cultivation in Timor-Leste to be made. It is suggested that ongoing pilot projects on Jatropha cultivation and processing be closely monitored to obtain actual field information that includes the following:

- yields of seed per hectare in relation to tree density, soil type, rainfall and irrigation, and fertilizer;
- cultivation labor requirements (weeding, pruning, bed maintenance, and so forth) in relation to yields;
- susceptibility of Jatropha to pests common to Timor-Leste and appropriate and effective control methods;

BOX 4.1 JATROPHA-BASED FUELS IN THE CONTEXT OF OVERALL NATIONAL ENERGY AND AGRICULTURAL POLICIES

As a significant producer of hydrocarbon fuels, and with new hydrocarbon development in the near term highly prospective, the devotion of substantial national resources to hydrocarbon substitutes needs careful examination. Subsidies to farmers to raise energy crops such as Jatropha compare in scale to the cost of simply purchasing middle distillate fuels.

Ultimately, the arrival in the country of natural gas or gas condensates from offshore production is likely to make that source the fuel of choice for electricity generation. Such supplies could start within five to eight years, before Jatropha plantations pay back these investments just from sales to domestic energy markets.

Once Timor-Leste begins receiving gas or condensate from offshore production, continued profitable operation of Jatropha plantations and processing plants would require export of the seeds or processed oil to some other country. Then the commercial viability of Jatropha vis-à-vis other cropping alternatives would become a simple question of dollars and cents. Will Jatropha cultivation and export prove more profitable for farmers than use of the same land for other export-oriented crops?

Such a question cannot be answered with much precision today, but it is crucial to land use and energy policies. The key to successful continuation of Jatropha cultivation would be commercial-scale planting with all output exported, possibly supported by carbon credits or similar mechanisms. Studies of Jatropha do not support the idea that the crop can contribute much, if at all, to farm incomes or energy supplies without serious effort at the farm or plantation level on productive, not marginal, land.

Once domestically supplied hydrocarbons become widely available, it would not be prudent policy to continue a domestic biodiesel program that carried cash and other opportunity costs for the country's economy.

- yields of oil per kilogram of seed in relation to cultivation issues (first three bullets);
- costs of establishment, cultivation, and stand maintenance of Jatropha shrubs;
- costs of establishment and operation of processing plants, and investigation of scale economies, if any, at each stage of operations;
- optimal blending methods for B^5–B^{20} programs, assessment of power plant output decrements, if any, from biodiesel use; and
- comparisons of Jatropha impacts on rural incomes with the impacts of other possible export crops using similar agricultural resources and inputs—land, water, fertilizer, pesticides, and labor.

It should take about three to five years for the current pilot programs to generate data needed to make decisions on the next phase. It is recommended that no further expansion of the current programs be made until such data are available.

5

Conclusions and Recommendations

The primary goal of a sound rural energy policy is to promote measures that will enhance the quality of life of people in rural areas by improving their access to modern energy services. The strategies to pursue are those that are sustainable, environmentally benign, and economic from both the country's point of view and the welfare of individual rural households. A key objective in implementation is to ensure that the government's rural energy programs provide equitable distribution of benefits, to the extent possible.

Improving Access to Electricity

- Government policy should be to provide, at a minimum, basic electricity services to off-grid communities, through programs implemented in the same time frame as those directed at concentrated communities living near the network. The implementation policy should be based on principles of least-cost power planning, and with the objectives of technical and financial sustainability.
- For new decentralized power systems, it is good policy to put priority on harnessing locally available energy resources, especially environmentally benign renewables, wherever they are available.
- Even when local energy resources are available within 5 kilometers or so of load centers, however, the least-cost option may be solar photovoltaic (PV) and not the development of the resource. This is often the case when the potential users are highly dispersed and thus expensive to connect together, and the most significant use of electricity is only for lighting and small domestic purposes.
- Aside from the objective of financial sustainability, a key purpose of requiring PV recipients to contribute part of the system acquisition cost is to instill a sense of ownership. A wealth of evidence from past projects has shown that PV dissemination mechanisms in which systems are just given away or fully subsidized fail within a short period.
- The government may decide under some circumstances to pay for the full upfront cost of a PV installation but, to ensure sustainability, leave responsibility for the full cost of operation and maintenance (replacement of battery, lamps, and so forth) to the user, to the extent possible.
- In the context of Timor-Leste, a fee-for-service mechanism executed by the private sector but with a strong role for the government would appear to be more suitable for a PV dissemination program for off-grid areas. However, as with any model that serves very-low-income households and requires periodic payments by users to maintain operation, long-term sustainability is more likely when combined with other agricultural or rural development programs that raise the income of the target communities.

Household Energy

- Despite the still abundant biomass supply in most parts of the country, the responsible policy for the government to pursue must be the maximum curtailment of fuel-wood use by households.
- The rationale for this policy includes (a) the certainty that the current positive supply-demand balance will change in the future, with population growth and increased pressure on forest land conversion to agriculture; and (b) the adverse impacts to public health from indoor air pollution (IAP) associated with use of fuel-wood in traditional cook-stoves.

- The strategy is to pursue programs that combine demand-side management or interfuel substitution programs (or both) with programs for improved management of fuel-wood supply.

Interfuel Substitution

- It is not a recommended policy to directly subsidize the price of liquified petroleum gas (LPG) or kerosene fuel for three reasons: (a) diversion of the fuel for other uses, such as transport, can occur (more likely for kerosene than LPG); (b) the immediate beneficiaries of the subsidy would be households already using modern fuels or having higher incomes; and (c) most important, the future subsidy burden to the government is likely to become unmanageable.
- Inevitably demand for modern fuels, particularly LPG, will increase dramatically in the coming years, as economic conditions improve and a middle class emerges and expands in Timor-Leste. The burden to the government of a fuel subsidy could become huge and unmanageable. As experience worldwide has shown, it is extremely difficult to withdraw or even reduce the subsidies at that point.
- It is often more effective to subsidize access, not consumption. This means subsidizing equipment needed to make the fuel switch (for example, new stoves purchase, LPG cylinder deposits) and facilitating fuel distribution but keeping fuel prices at market levels. The financial exposure of the government for an equipment subsidy program can be determined annually in advance. The government may terminate the equipment subsidy program at almost any time with minimal public inconvenience.
- The simplest way to provide subsidies must be adopted. Experience elsewhere has shown that a voucher or means-testing system for applying subsidies often carries high administrative costs and tends to be more complex to implement than a direct price subsidy mechanism.

Improved Cooking Stoves

- The promotion of improved cooking stoves (ICS) should not be viewed as encouraging continued use of fuel-wood but as a necessary intermediate approach—the only practical way for the government to reduce fuel-wood consumption significantly while the economy transitions to a future in which cleaner modern fuels are widely available and most households can afford them.
- The promotion of improved stoves in Timor-Leste is severely hindered by the continued relative abundance and low cost of fuel-wood in the country, making it hard to motivate households to economize. In addition, Timorese households do not yet have a culture of purchasing stoves.
- The only way for improved fuel-wood stoves to be disseminated widely in Timor-Leste is to substantially subsidize their cost to users. Fortunately, compared with other programs for fuel-wood reduction, the required subsidies per household are small and could be terminated at any time by the government without drastic welfare impacts on users.
- The potential benefits, even for just reducing IAP impacts, far outweigh the costs. As part of an ICS program, an IAP monitoring program should be carried out.

Domestic Biogas

- Economic analysis of domestic biogas systems currently being installed clearly point to the presently low economic viability of a program designed mainly to replace fuel-wood resulting from the relatively high investment costs per household and the low opportunity cost of fuel-wood replaced.
- The current program to install household biogas digesters has a high capacity-building value and should be continued for that purpose but on a limited pilot scale.
- Apart from the economics, it is also important for policy making to consider beneficiary issues related to the fact that current recipients of biogas systems are families that are undoubtedly better off than others in the community. It is clear that there is little alternative in the pilot or demonstration phase, but in the subsequent or expansion phase of the biogas program beneficiary considerations should be factored into the subsidy mechanism.
- Compared with alternative rural energy programs, the coverage of the biogas program and its total potential fuel-wood replacement benefits are severely limited by the small number of rural families that own enough livestock to provide the daily waste requirements of a digester.
- When the Ministry of Agriculture, Farming and Fisheries' livestock breeding and distribution program has progressed significantly and more rural families are raising their own animals, it may become possible for the biogas program to have a wider and economically more varied set of beneficiaries.
- As larger livestock farms are established, government policy should make the biogas program a priority for support given that the economics are very likely to be more attractive at large digester sizes and benefits other than fuel-wood replacement can be achieved.

Biodiesel from Jatropha

- The program being implemented in Timor-Leste to produce a biomass-based substitute for diesel oil has as its objectives fuel security, increased reliance on domestic resources, and foreign exchange (FX) savings. These objectives make sense only if biofuels can be produced locally with few imported inputs and at reasonable costs in comparison with the price of imported diesel fuel.
- The land-area requirements of the Jatropha program are a significant consideration for a small country like Timor-Leste. At an assumed yield of 4 tons seed per hectare, a B^5 program (blend of 5 percent biodiesel and regular diesel oil) would require about 3.5 percent of the country's cultivated land; a B^{10} program, 7 percent; and a B^{20} program, 14 percent. Up to 200,000 hectares of Jatropha plantations have been proposed. This is roughly equal to the amount of total cultivated land in Timor-Leste today.
- The current Timor-Leste program for Jatropha is predicated on the use of marginal lands. Studies elsewhere have consistently shown that good yields, low unit production costs, and a positive net energy ratio (NER) for the product are achieved only when Jatropha cultivation is approached in a commercial manner and with appropriate inputs, such as fertilizer, irrigation, and pesticides. To quote the findings of a recent international conference on Jatropha, "Marginal lands will produce marginal yields."
- Based on the overall costs of growing, transporting, and processing Jatropha, a crude oil price at or above $90/bbl is necessary to cover the costs of the various parties, and requires as well that the price component attributable to processors be capped. In a more typical market setting, still higher crude prices, above $120/bbl, would be needed to provide adequate profitability for both the farmers and the processors. For example, if Jatropha farmers are guaranteed a $250/ha profit above estimated production costs of $335/ha, the government will need to provide subsidies in excess of $2 million annually for a B^5 program at current oil prices and above $1 million/year at $110 per barrel.
- FX savings as an objective must take into account the continued need for imported and oil-based inputs, such as fertilizers and pesticides and methanol for the Jatropha oil processing. Based on typical yields, estimates indicate that at current oil prices (about $75 ± $20/bbl), FX savings are negative (that is, Jatropha is a net FX user), especially in light of the full costs of cultivation, transport, processing, and blending. The potential foreign currency savings become significant only at crude oil prices above $100/bbl, and represent an effective use of FX only if Timor-Leste lacks the ability to supply itself with domestically produced hydrocarbons. Even synthetic crude from natural gas is likely to be less expensive than the estimated costs of Jatropha oil processed for biodiesel blending.
- While Jatropha cultivation undoubtedly increases rural employment, it is not clear that the cost is advantageous compared with other means of generating rural employment opportunities in Timor-Leste, such as programs to promote community-based forest management and protection and agro-forestry initiatives.
- Finally, the eventual local availability of petroleum products from offshore oil and gas production needs to be considered, which could occur in fewer than 10 years, just when significant biodiesel production facilities would be gearing up. At that time, biodiesel substitution would make even less economic sense than it does under current prices for imported fuels. The alternative of exporting biodiesel is possible only if Timor-Leste enjoys a clear comparative advantage over producers in other countries, such as significantly lower production and processing costs and advantageous logistics with respect to potential customers.

ANNEX 1

Designing a Sustainable Solar Home Systems Program for Timor-Leste

Program Phasing

The task of providing photovoltaic (PV) power to identified communities and households in a more systematic and sustainable manner should be approached in phases, with the first phase possibly covering about 15,000 homes (about a fourth of total potential PV customers) in five years. The cost of this phase would be about $1.5 million to $2.0 million. The program would include, as is being done now, installation of PV systems for public facilities (schools, clinics, community centers, and the like). The idea is to select qualified private sector service providers through competitive bidding who would install the systems in the designated communities and maintain them for a contract period of five years. Although it is clear that at this time providing PV systems to households must be heavily subsidized, competitive bidding for large numbers of installations grouped into several "market packages" would result in unit acquisition costs much lower than they are today in piecemeal, suco-by-suco transactions with providers.[46] Based on the experience acquired in the first phase, the business model, subsidy levels, and other implementation details would be modified as needed in the second phase, which could aim for an additional 20,000 off-grid households in years 6–10.

46. The idea is to implement a highly simplified version of the "sustainable solar market packages" approach practiced in the Philippines and elsewhere. The lots in Timor-Leste will be small but, with the right publicity, could probably attract companies from neighboring Indonesia and Australia.

Payment Scheme

As a matter of policy, beneficiaries should be required to contribute to the capital cost of their specific PV installations. The purpose is not merely to save the government some money but, as earlier stressed, to instill a sense of ownership. For communities receiving PV equipment for public facilities, the contribution may be in kind, such as organizing a local means for routine maintenance of the equipment or to maximize the community's use of the equipment. Individual households that receive PV must be required to pay a portion of the upfront cost and agree to pay a monthly maintenance fee to the service provider. The capital cost contribution could be in the range of 5–10 percent of actual costs. The monthly fee should be sufficient to cover the O&M costs (replacements and the like) for each user in the market package for the duration of the service contract, as estimated by the company in its bid.[47] Based on international experience, this is generally in the vicinity of $5–$7 per month.

Preparing Market Packages

The government's first step is to group planned installations for public facilities and individual homes in unserved communities into several market packages of sufficient size to be commercially attractive to the private sector. Public facilities usually require much larger PV systems and their inclusion increases the financial attractiveness

47. One criterion for a winning bid will be the monthly O&M fee the provider expects to charge customers.

of the package. The grouping criteria relate mainly to the physical location of the potential users: the areas must be reasonably close enough to each other so that as many systems as possible can be installed and later serviced periodically by the provider with a minimum number of technicians and trips to the site. It may be necessary to group together homes that belong to several communities or portions of other communities into one package to meet the scale criteria, and to try and include in each package some baseload public facilities.

International Competitive Bidding

To maximize private sector interest, the packages should be put up for competitive bidding simultaneously in a multilot single tender, with the bidder having the option to bid on one, some, or all of the packages. The bid documents will specify the experience required, the minimum technical requirements for equipment, and the desired outputs for each package. Assuming all conditions and eligibility requirements are met, the companies that quote the lowest cost will win the package or set of packages they bid on.

The bidding would be open to all interested parties, domestic or international, and the invitation to bid would be publicized widely. Because of the relatively small size of the business and the geographical location of the country, international interest may be limited to neighbors in the region, specifically Australia and Indonesia. Nevertheless, many qualified PV companies exist in these countries and it may be useful for the government to conduct a roadshow in those countries to maximize participation. The success of the program will hinge on whether a sufficient number of qualified service providers could be attracted to participate in the bidding process. Donor agencies currently active in Timor-Leste may be asked to help publicize the project and the bid opportunity to private companies in their respective countries.

Service Contract Terms

The winning company will execute a contract with the government to provide PV service to the subject area over a period of five years.[48] The company will install PV systems for public facilities, if part of the package, and solar home systems of no less than 50-watt-peak capacity to designated households in the service area. Before the installation phase, the company will submit equipment prototypes for inspection and acceptance by the government, train local technicians, and conduct site visits to meet with local officials and residents to promote the project and provide basic information about the systems to be installed. Specific maintenance obligations will be defined in the contract, for example, responding to a customer's call about malfunctioning equipment and fixing it within 15 days, and the like. However, the company will have flexibility in deciding how to organize its maintenance response system, for example, one or two local persons may be trained and paid to respond to relatively minor maintenance problems and the company might send a technician from headquarters for major cases. In any case, the contract will require the provider to send a qualified technician to inspect the installations at least once every year. Finally, the provider will be required to organize a battery recycling system in its service area to ensure proper collection and eventual disposal of all dead batteries.

Payments by the government will be tied to agreed milestones, for example, 15 percent of total contract amount against pre-installation requirements, such as acceptance of prototypes; 70 percent against installations (paid on a quarterly basis); and 10 percent against required annual maintenance visits. The government may also withhold 5 percent of the total amount until the end of the contract, to ensure all obligations have been met. These are suggested figures and milestones only and should be modified for specific contracts, as needed.

Options at End of Service Contract

At the end of the contract period, the government has three possible options: (a) leave users on their own, (b) get a new service contractor through bidding, or (c) persuade the existing provider to continue for another term. The first option is feasible because it is expected that during the implementation of the first phase, the local PV industry would have gradually developed. At the end of five years, it is likely that a few more local companies would be selling PV equipment and accessories in the country, and more technicians would be available. Furthermore, solar home system users in the service areas would already be familiar with their systems and would only require sources of replacement parts, such as batteries and lamps. The only government action needed would be to organize and train community leaders to

48. At least one replacement of deep-cycle batteries is expected for most of the users.

handle the new situation, and connect them with private technicians and sources of replacement parts. The second option is only possible if the government provides an upfront financial incentive to persuade prospective new service providers, because it is unlikely that users' monthly payments alone would be sufficient enticement.

In the third option, the current service provider would be persuaded to remain for another five-year contract by the same upfront grant described in the second option. Keeping the same contractor would be an easier, less costly option to the government than conducting a new bidding process.

Outline of a Program for Dissemination of Improved Fuel-Wood Cooking Stoves

The purpose of the program described below is to stimulate actions by relevant units of the government to design a program for dissemination of improved fuel-wood stoves.[49] The proposed program is based on observations made by the author during a visit to Timor-Leste in July 2009, discussions with local authorities and non-governmental organizations (NGOs) at that time, and on the findings of the 2007 World Bank report on household energy issues and options.[50] The suggested implementation procedures draw from the author's experience with improved stoves programs in Sri Lanka and other countries. The details provided must be viewed as guidelines and ideas rather than fixed prescriptions. A high degree of flexibility, based on their own knowledge of local conditions, must be exercised by government designers when formulating details of the final program.

Immediate Objectives

The concrete, quantifiable objectives might be as follows:

- To produce and disseminate 15,000 portable improved fuel-wood cooking stoves in Dili and Baucau within a period of five years. This amounts to about 25 percent of households in the two districts and 8 percent of total households in Timor-Leste.
- To construct on-site 200 "heavy mass" improved fuel-wood cooking stoves for use in selected rural homes.
- To develop an institutional mechanism for dissemination.
- To strengthen the production capability of local potters and artisans to enable realization of the above outputs.
- To measure and compare indoor air pollution levels in 25 homes before and after adoption of improved stoves.
- To construct 10 demonstration improved kitchens in urban and rural areas.

Target Area and Market Size

The urban and peri-urban areas of Dili and Baucau are recommended as target areas for the pilot project. More than 60 percent of households in these areas purchase their fuel-wood, compared with only about 20 percent in rural areas, suggesting that the urban households may be more receptive to ideas for economizing on fuel-wood consumption. Within the two districts, the specific distribution sites should be selected on the basis of local fuel-wood deficiency, market price of fuel-wood, and household density. Another reason for choosing the two districts is that they are close to an existing pottery center in Manatuto district.

49. This annex was written by R. M. Amarasekara, President ARECOP.
50. Shum and others, *op. cit.*

Implementation Phasing

The project will consist of a preparation phase and a dissemination phase. The preparation phase, with a duration of eight months, will require initial assistance from international experts, particularly in developing stove designs, improving production infrastructure, and capacity-building of project staff. The international assistance may consist of an energy and stove expert and a technician experienced in stove construction, clay technology, indoor air pollution monitoring, and kitchen improvement activities. Their services will be provided intermittently within the first year after initiating the project. The outputs of this phase will be two proven stove models for the urban and rural areas (discussed below), and the infrastructure needed to produce about 200 units a month, with capability to be increased gradually according to demand. The second phase would be devoted to marketing and dissemination activities.

Development of New Stove Models to Suit User Needs in Timor-Leste

Developing a stove design suitable for local conditions is complicated and needs considerable amounts of patience and time. The stove not only has to be energy efficient but has to meet other consumer aspirations and socioeconomic requirements to achieve social acceptance and widespread dissemination. The design, if it is to be produced locally, has to take into account the production skills and infrastructure available to undertake production of stoves. It is recommended that the assistance of international stove experts be obtained at this stage.

Two stove models are proposed to be developed for Timor-Leste: (a) a single-pot portable clay stove to be produced in Bili Bala, Manatuto, for the urban market; and (b) a two-pot heavy mass stove, made of brick, cement, or mud, for rural kitchens to be made on-site by trained artisans.

The purpose of the small rural stoves component is to test the demand for this type of stove in rural areas, where cooking patterns may be different. It is highly possible that the portable "urban" stove will be preferred by more rural families than the more expensive, larger stove. The second five-year phase of the program will thus include dissemination of portable stoves in areas beyond Dili and Baucau.

A large number of efficient stoves have been devised in many developing countries. The models used in those countries probably cannot be directly introduced into Timor-Leste without some modification. In the context of socioeconomic standards in Timor-Leste, the following considerations, in addition to user preferences, have to be taken into account in developing suitable models:

- Considering the general poverty level, the stove has to be cheap.
- Considering the lack of artisan skills and the primitive technology currently used, the stove design has to be simple so that its construction is not complicated.
- The stove should use locally available raw materials and skills.

Possible Urban Stove

For an urban stove suitable for commercial marketing, using or adapting a configuration similar to the portable clay stove developed for Africa by ITDG and being propagated in Malawi by the GTZ-funded Integrated Food Security Programme is suggested (figure A2.1). The stove is reported to be capable of 40 percent fuel-wood savings. The steps in constructing the stove are described on the Household Energy Network (HEDON) Web site (http://www.hedon.info/PortableClayStoveConstruction).

Prototypes of the stove should be constructed and subjected in the lab to basic tests for thermal efficiency, including water boiling and controlled cooking. To establish social acceptance, the stoves should be further tested in 15 to 20 households before large-scale dissemination.

The Stove Project Implementation Organization (SPIO)

FIGURE A2.1 THE MALAWI STOVE: A PORTABLE URBAN STOVE

Source: http://www.hedon.info/PortableClayStove Construction.

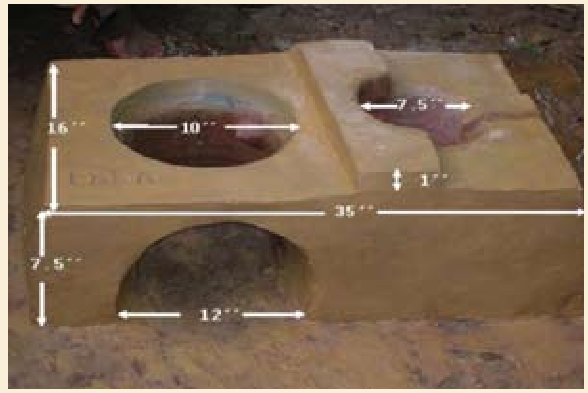
project staff have to be trained on how to conduct these lab tests. Sophisticated tools and equipment are not required. The tests can be carried out in a room with good ventilation. The basic equipment needed includes

- scale of at least 6 kilograms capacity and 1 gram accuracy,
- heat-resistant pad to protect the scale,
- heat-resistant gloves,
- digital thermometer with 0.1 degree accuracy,
- timer,
- aluminum pots of 3 and 5 liter capacity,
- small spatula, tongs to handle charcoal,
- metal trays,
- digital moisture-measuring meter, and
- digital thermocouple to measure up to 1,300 degrees C with probes may be required to monitor kiln performance.

Rural Stove

For the rural stove built on-site, the program may start with the two-pot heavy mass stove presently used in Sri Lanka and shown in figure A2.2. The stove has a thermal efficiency of 22 percent and recorded fuel-wood savings of 30–40 percent. The heavy mass stove must be built on-site by an artisan and obviously cannot be marketed like the Malawi portable stove.

FIGURE A2.2 A MASSIVE RURAL STOVE BUILT ON-SITE



Source: http://www.hedon.info.

The totally different design is needed because urban cooking and rural cooking have different characteristics. Urban cooking is mostly short-time cooking with a small cooking load. In contrast, rural stoves are kept burning for longer periods and the cooking load is larger because agricultural and livestock activities require that cattle food and the like be prepared. Accordingly, the rural stove needs to be heavy mass while the urban stove is light and uninsulated. The proposed rural stove is a two-pot stove that has to be insulated using bricks and mud or cement. The cost will vary according to the material used. If mud is used, the stove will be cheaper. In any case, it is clear that the massive rural stove will cost more to build than the portable urban stove. Users selected for the initial stoves would probably be households with many members, households with livestock, and small rural food vendors.

A short period of field testing of prototypes should be conducted before the regular installation program. One factor to determine is whether the volume of the combustion chamber is sufficient for Timor-Leste's rural families, which are large, requiring greater cooking loads. A grate may also be added to improve combustion, if necessary, depending on user responses in the field-testing process. The pot seats may also require changes depending on the size and shape of the pots used.[51]

Under the proposed program, about 200 rural stoves would be built on-site. Including a heavy mass stove component in the program will enable local artisans to be exposed to and trained in this particular improved stove technology, assist them with identifying initial clients, and potentially start them on the way to a long-term business activity in their localities. After the project, the trained artisans are expected to find their own markets and possibly develop other heavy mass designs using various materials to suit local user needs.

Production Strategy

Urban Stove

A total of 15,000 urban stoves is proposed to be produced over a period of five years, with the local production capacity reaching about 500 stoves a month in the fifth year of the program. To achieve this production rate the existing pottery production center in Bili Bala, Manatuto, could be used. Bili Bala's major output now is handicraft items, but it has some experience in producing clay stoves for burning coffee hull briquettes (for which there seems to be no consistent market). The current capacity of the center is severely limited by the small

51. The UNDP has reportedly installed about 40 heavy mass rural stoves under a recent project. However, at the time of writing, the report for the UNDP project was still unavailable.

number of skilled workers and the small kiln capacity. The ex-factory prices of stoves and handicraft items are very expensive compared with prices of similar items in neighboring countries. The introduction of improved production techniques could potentially reduce costs considerably. If used as a stove production center for the project, the factory will need technical and financial assistance. The available infrastructure is sufficient to meet the production targets and does not require any major improvements other than moulds, drying boards, and the like. However, a new kiln design must be introduced to replace the current method of firing using a primitive bonfire. New drying techniques will also need to be introduced. Clay supply appears to be of no concern because plenty of clay fields are available in close proximity to the center. Staff training will be necessary to improve productivity. Two potters should be trained for about two months. The training will include clay preparation, throwing, drying, firing, and use of moulds.

An advantage to using the Bili Bala factory is the existence of a traditional pottery village about 2 kilometers away. These potters could be tapped for production of improved stoves. They presently produce pottery items such as pots and handicraft items using very primitive methods. With support to upgrade their skills and infrastructure, such as training in improvement of clay mixing and throwing, and introducing kilns to fire stoves to replace the primitive bonfire methods, productivity could be significantly increased. At the fifth year of the proposed program, production capacity for urban stoves from all sources should be about 500 units per month. About 300 units could be produced at the Bili Bala factory while 200 units could be produced by the potters from the village. Stove production will begin at the Bili Bala center because certain skills and infrastructure are already available, then will be expanded to the village potters.

It is estimated that the materials for the Malawi urban stove would cost about $1 per unit. The stoves would be sold ex-factory for $3 per unit, ensuring a reasonable profit margin for the producer. At a volume of 300 stoves per month, the total sales will be $900 per month and the profit $600 per month before labor costs. Producers will be provided with a 50 percent advance to help cover the raw materials, transport, and labor costs for a month of production. The estimated amount, $150, can be used as a rolling fund. At the initial stages of production, producers will be guaranteed that all stoves will be purchased by the SPIO.

Rural Stove

The rural stove would be made of brick, cement, or mud depending on the availability and cost of raw materials. A three-day training course will be conducted for selected artisans, covering both technical and social factors related to stove installation. Training will also be provided to stove users on how to cook with and maintain the new stove. Selection of the users and artisan trainees will be done by the respective community-based organizations (CBOs) after completion of awareness programs. Users would be expected to provide the materials for the stove and unskilled labor to assist the artisan. The construction of the stove is estimated to take one full day and the stove will take at least one week to dry before any cooking can be done on it. The artisan is expected to monitor the stove's performance in the initial days of cooking. With proper maintenance by the user, the lifetime of the heavy mass stove is about four years.

The total cost of constructing the stove is estimated to be about $25, of which about $6 will be paid to the installer for services rendered. The balance will be mainly the cost of materials, which the user is expected to provide.

Organizational Arrangements

In many countries where stove programs have been successful, NGOs and similar organizations have taken the leading role. It is recommended that a suitable nongovernmental entity be selected for this purpose in Timor-Leste. First, it is proposed to form a national steering committee consisting of a few representatives of relevant government agencies (for example, MAFF, Ministry of Health, Secretariat of State for Energy Policy, and others), NGOs, and women's groups. The steering committee would then select the organization to implement the improved stoves program, the SPIO. The selected organization does not need to be an existing NGO with experience in improved stoves work. It could be any NGO or any organization already carrying out activities with strong community participation, in fields related to poverty alleviation, health, gender empowerment, or energy. The SPIO staff will initially be trained by the international experts, and will be responsible for the management, financial administration, coordination, progress reporting, and overall execution of the project.

The steering committee would monitor implementation progress, help promote public awareness at the broader level, and help with the flow of funding. While direct involvement of the government in implementation would be limited, its commitment and interest are essential to the success of the program.

The SPIO will select or organize six or more CBOs to promote, sell, or install the improved stoves at the suco or village level in the selected districts. To create demand for stoves, the CBOs will be trained and provided funds and promotional materials by the SPIO to conduct local awareness programs. Each CBO would aim to sell in its assigned area about 500 urban stoves and install about 40 rural stoves a year beginning with the second year of the program. A small profit would be made by the CBOs for every stove sold or installed. The SPIO will supply stoves monthly to the CBOs. The SPIO will also select retail stores or shops where stoves could be sold.

Marketing and Dissemination Strategy

Urban Stove

As discussed in the main report, the urban improved stoves would be disseminated with a significantly subsidized retail price.

The stoves will be marketed through two different routes:

- selling stoves through CBOs and women's groups and
- selling stoves in public markets and hardware shops.

Involvement of CBOs is necessary to provide improved stoves to users who are relatively more isolated or far from commercial markets. Initially, because of the lack of a well-developed market economy and the absence of marketing channels, the SPIO has to play the role of distributing agent. Later, as the market develops, this role can be gradually transferred to private sector distributors.

The portable urban stoves would be bought ex-factory for $3 per unit by the SPIO. The SPIO would distribute the stoves to the retailers—the shops and the CBOs—at a price of $1 each. The retailers will be required to price the stoves at $2, thus making a profit of $1 per stove.[52]

Rural Stove

The purpose of the rural stoves component at this stage would be simply to demonstrate the technology and train a core of installers. The effectiveness of the demonstration stoves and user acceptance will need to be assessed before designing a financing mechanism for wider dissemination.

Demonstration Improved Kitchens

In any effort to reduce indoor air pollution and related health impacts, provision of improved stoves is only one component of the solution. Improved ventilation and air circulation, orderly storage and processing of food, and other simple but ergonomic improvements should also be promoted. The program should finance the construction of 5–10 demonstration kitchens incorporating these features to serve as models. The model kitchens could be used as sites for cooking demonstrations and other promotional activities. Elsewhere, the demonstration of improved kitchen environments effectively promoted not only improved stoves but also improved kitchen behavior in women.

Budget Requirements

It is estimated that the proposed five-year program would cost between $300,000 and $350,000 excluding the cost of international consultants needed at the design and preparation stage.

52. Considering prevailing costs in neighboring countries, it is estimated that in an unsubsidized program, the selling price of the stove would need to be about $7 or a margin of about $4 from factory to retail store to cover all distribution costs and profit margins by the middleman (no longer a funded SPIO) and the retailer.

ANNEX 3

Economic Analysis of Domestic Biogas Systems

In Timor-Leste, a program has been proposed to provide biogas systems to some 4,600 rural households, which is the estimated number of households owning at least one to two head of cattle. The main purpose is to displace the fuel-wood presently used in these homes with a clean and renewable fuel substitute. In the initial configuration, one small family-size digester (FSD) capable of producing about 2 cubic meters per day (m^3/d) of biogas would be shared by three households, using waste from a total of four to six head of cattle owned by the families.

In this annex preliminary economic analyses were made of the above configuration and of a case in which only one household uses the FSD and splits the output equally between cooking and lighting. In addition to the fuel benefits, the economic analyses counted the benefits of producing nitrogen fertilizer from the digester sludge. Using as a base case the mid-range values for capital costs and gas quality, the results clearly point to the low economic viability of a program designed mainly to replace fuel-wood.

Case 1: Cooking Only, Three Households per Digester

If three households use one biogas digester for cooking only, the economic rate of return (ERR) is negative, at −0.23 percent; that is, if the initial cost = $750, annual operations and maintenance (O&M) = $40,[53] annual (net) fertilizer benefit = $10, and annual value of replaced fuel-wood = $52 (for 3.65 tons). Digester output of average-quality gas would be sufficient to supply each household with about 45 percent of its cooking needs. Full results for several ranges of the key parameters—gas quality, digester cost, fuel-wood price—are shown in table A3.1.

For a cooking-only program to be attractive from a country economic point of view, three conditions are necessary:

- costs for the digester must be at the bottom end of the published range, or about $500;
- gas quality must be high so as to replace as much fuel-wood as possible; and
- most important, fuel-wood prices need to reflect a growing scarcity resulting from population growth, increased GDP, and consequent deforestation.

Under such conditions, biogas can replace almost 60 percent of fuel-wood consumption for a typical rural household, generate an ERR of 33 percent, and generate roughly $323 in net annual benefits for each household that participates. It may turn out that economic benefits based entirely on an optimistic set of assumptions would induce individuals to make such investments.

However, under the base case set of assumptions (a) less than 50 percent of cooking needs are supplied by biogas; (b) the ERR is negative at −0.23 percent; and (c) negative net benefits in excess of $150 per participating household are generated. Such a set of assumptions and outcomes would not prove sufficient to induce investment from private individuals and would call into question a publicly financed program.

53. O&M expenditures are calculated at 2 percent of investment costs plus $25/year for labor, based on UN Biogas Manual, page 96. (Food and Agriculture Organization of the United Nations, "Biogas Technology: A Training Manual for Extension," Nepal, September 1996.)

TABLE A3.1 CASE 1: THREE HOUSEHOLDS PER DIGESTER, COOKING-ONLY SCENARIOS (2 m³/d OUTPUT)

Outcome under given parameters	Case			
	Base	Best	Worst	Base (with low-cost digester)
Costs (present value $)	1,141	848	1,316	848
Benefits (present value $)	673	1,816	375	673
Net benefits (present value $)	(468)	968	(941)	(175)
ERR (%)	(0.23)	32.31	(23.38)	4.97
Key parameter values				
Digester cost ($)	750	500	1,000	500
Gas quality (MJ/m³)	19.36	25.10	14.34	19.36
Wood price ($/ton)	18.90	43.00	12.61	18.90
Biogas as % of household cooking energy	44.57	57.77	33.01	44.57

Source: Mission estimates and UN data.
Note: Includes fertilizer benefit; gas stove efficiency = 60 percent; fuel-wood efficiency = 15 percent.

Case 2: Cooking and Lighting for One Household

Replacing hydrocarbon fuels used for lighting, and focusing on households that can support the proposed digester size by themselves for both cooking and lighting (households with four to six head of cattle), the economic calculations are decidedly more positive. Table A3.2 shows the results of four economic cases of single-household cooking and lighting end uses for biogas.

The base case uses current fuel-wood and oil prices to estimate benefits of substitution. With average gas quality and a digester cost of $750 per unit, the net benefits are negative at a 10 percent discount rate. However, if the digester can be installed for $500, net benefits are

TABLE A3.2 CASE 2: ONE HOUSEHOLD PER DIGESTER, COOKING AND LIGHTING SCENARIOS (2 m³/d OUTPUT)

Outcome under given parameters	Case			
	Base	Best	Worst	Base (with low-cost digester)
Costs (present value $)	1,312	955	1,526	955
Benefits (present value $)	1,189	2,814	624	1,189
Net benefits (present value $)	(123)	1,859	(902)	233
ERR (%)	8.02	43.59	(7.56)	14.74
Key parameter values				
Digester cost ($)	750	500	1,000	500
Gas quality (MJ/m³)	19.36	25.10	14.34	19.36
Wood price ($/ton)	18.92	43.00	12.61	18.92
Biogas as % of household cooking energy	66.89	86.71	49.55	66.89
Kerosene price ($/ton)	600	800	450	600

Source: Mission estimates and UN data.
Note: Includes fertilizer benefit; gas stove efficiency = 60 percent; fuel-wood efficiency = 15 percent.
Implied crude oil prices are $600/t <=> $72/bbl, $450/t <=> $55/bbl, and $850/t <=> $97/bbl.

BOX A3.1 THE OPPORTUNITY COST OF FUEL-WOOD IN RURAL TIMOR-LESTE

The price of fuel-wood in urban areas of Timor-Leste has been estimated at 10¢/kg ($100/ton) based on the 2007 World Bank Scoping Study (Shum and others 2007). This price comprises (a) the costs of gathering wood for sale to urban markets, (b) the cost of transporting the wood to those markets, and (c) a retail markup for the urban wood vendor.

In rural areas, where biogas plants would be built, only the gathering cost is relevant, and it is lower than the gathering costs for urban markets. The team estimated the cost of supplying wood in rural areas using an hourly wage based on the country's current GDP/capita of about $440. The Bank Scoping Study estimated that rural households spend about six hours per week gathering an average of 55.37 kg of wood.

Based on these figures, the opportunity cost of fuel-wood for a rural household is about 1.892¢/kg or $18.92/ton. A best-case estimate of the opportunity cost of wood, four hours/week of labor, results in an economic cost of $12.61/ton. In a few years, with continued economic growth (GDP rising to $750/capita) and increased deforestation (eight hours/week for gathering) the economic cost of fuel-wood in the countryside could rise to as much as $43/ton, just under half the current urban market price.

positive and the ERR is 14.7 percent. Such a result might be possible if there were a mass-production capability for digesters, thereby bringing the unit cost down.

Improved gas quality, higher benefit estimates resulting from rising oil prices and deforestation, and low installation cost will generate strongly positive returns. With fuel-wood at $43/ton, oil at $100/bbl, and good gas quality, the household can earn a rate of return of 44 percent, with a net present value of almost twice the initial cost (excluding livestock). The worst-case results are similar to the base case for the cooking-only scenario—a negative rate of return (–7.6 percent) and a negative net present worth of more than $900. Unlike the cooking-only alternative, a program to provide both energy and light could be done for a tolerable loss under a plausible set of circumstances. Inducing households to invest their own funds might require simply a subsidy of $250–$300 per digester unit, resulting in a rate of return close to 15 percent for the household (a financial rate of return for the household, not the economic rate of return for Timor-Leste as a whole).

The World Bank

The World Bank Group
Asia Sustainable and
Alternative Energy Program
1818 H Street, NW
Washington, DC 20433 USA

www.worldbank.org/astae