LOW-CARBON AFRICA: ETHIOPIA

POVERTY

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1. COUNTRY CONTEXT

Ethiopia is a country of 86 million people living in an area of 1.1 million square kilometres. It is a very diverse country with eighty-five ethnic groups and complex geography and climate. About two-thirds of the population lives in the highlands, which constitute about a third of the total land mass; the main source of livelihood in the highlands is mixed crop and livestock production. The remaining third of the population lives in the lowlands and practise pastoral (livestock) and agro-pastoral production.

Agriculture is still the main economic activity in Ethiopia; it accounts for 41 per cent of the gross domestic production (GDP) and employs more than twelve million households. Agriculture in Ethiopia is based on small-scale crop and livestock production; the mean land holding by farming households is just under 1ha with mean annual output of 1.5 tons (of mainly cereals). Industry contributes 13 per cent to GDP; the main contributors to industrial output are construction and manufacturing. The service sector, which is composed of distributive and public services, accounts for the remaining 46 per cent of the GDP. The economy has grown rapidly over the past five years (11 per cent/year) and per-capita GDP now stands at US$300. The short-term government plan projects similarly rapid growth for the next five years.

One of the defining characteristics of the energy sector in Ethiopia is its overwhelming dependence on biomass energy. Biomass energy, consisting of wood, charcoal and agricultural residues, provides ninety-two per cent of the total final energy consumed. The main uses for biomass energy are for residential and commercial cooking. Biomass residues are also used in the sugar and tea industries. More recently, liquid bioenergy in the form of ethanol has started to be used as a gasoline (E10) in Addis Ababa. Per capita consumption of bioenergy in Ethiopia is about 1 tonne; annual consumption of biomass energy exceeds 80 million tonnes.

Fossil fuels provide 9.5 per cent of the total final energy supply and are

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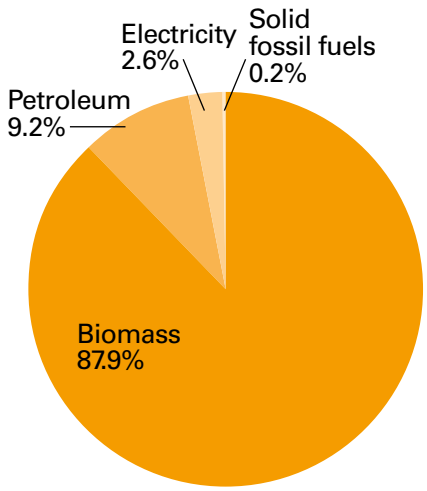
Figure 1. Final energy consumption by fuel



The energy balance in Ethiopia is dominated by biomass energy. Eighty-eight per cent of the final energy supplied in the country comes from biomass fuels (wood, charcoal and agricultural residues). The main use of biomass energy in Ethiopia is for cooking in residential and commercial establishments. Demand for biomass fuels is growing as rapidly as food production (i.e. 6% annually).

consumed in the transport, industry and residential sectors. Ethiopia does not produce fossil fuels and imports all its requirements. The annual import of fossil fuels now stands at 2 million tons. The largest demand for fossil fuels is for transport, where about three-quarters of the total import is used; the remaining amount is consumed in industry and in urban residential cooking. Per capita consumption of petroleum production is just 23kg.

Electricity provides 2.6 per cent of the final energy supply. Total electricity consumption is just over 3,000GWh divided by sector as follows: residential (36 per cent), industrial (37 per cent) and commercial (26 per cent. The electricity supply infrastructure in Ethiopia now consists of 2000MW of installed capacity in eleven hydro and several small thermal plants, 12,150km of transmission and 126,000km of distribution lines and about 2 million customers. Per capita consumption of electricity is only 35kWh per annum.

Biomass energy supply is by user households in rural areas and commercial supply from small-scale suppliers in urban areas. Practically all rural households collect their biomass fuels, and tens of thousands of rural people are engaged in the commercial supply of wood and charcoal to urban areas. Petroleum is imported by a government agency, the Ethiopian Petroleum Enterprise (EPE), and distributed by several domestic and international oil companies. The Ethiopian Electric Power Corporation (EEPCO) is the national power company with the mandate to generate and distribute power throughout Ethiopia; there are a few very small private and cooperative power generators, but their combined capacity is less than 1 per cent of the capacity of EEPCO.

1.1 Energy resources

Indigenous energy resources in Ethiopia consist of renewables including hydro, bioenergy, wind, geothermal, and solar. Ethiopia also has some fossil resources in natural gas and coal. Ethiopia relies heavily on a limited set of renewable energy resources to meet its requirements: principally biomass for thermal energy in the residential and commercial sector and large hydropower for electricity. It has yet to develop its other renewable and non-renewable resources in significant scale.

Energy supplies in Ethiopia are mainly from renewable sources. However, the level of use for renewables is disparate, with a very high level of use for bioenergy and limited use of others. Bioenergy uses in Ethiopia are generally not sustainable: according to a recent study, in more than two-thirds of districts bioenergy uses surpass sustainable yields. Bioenergy contributes to greenhouse gas emissions, due to deforestation and non-renewable use of biomass, in addition to other local environmental problems it creates. There is significant potential to diversify bioenergy sources into liquid biofuels and energy recovery from urban domestic and industrial waste.

Hydropower is the most economically viable power generation resource for Ethiopia, but only five per cent of the available potential is now utilized. The government has now made considerable commitment to accelerate the development of hydropower resources with the view to increase output to 40GW (or about a quarter of the total potential available) by 2015 to 2020. Hydropower plants in Ethiopia are large and getting larger; projects now under construction include two hydropower plans with capacities

Table 1. Indigenous energy resources of Ethiopia

Resource	Unit	Exploitable potential	Developed
Hydropower	TWh	159	7.6
Small hydropower	TWh	16	Negligible
Wind	Area with wind speed above 7m/s (km^2)	33,771	0
Solar	$kWh/m^2.d$	5.5	Negligible
Geothermal	TWh	22	0
Biomass	Yield in million tonnes/year	96	58
Natural gas	Trillion cubic feet	2.7	0
Coal	Tonne	70	0

Source: Ministry of Mines and Energy, 2007; World Energy Council, 2007

of 1800MW and 5200MW. There are fewer than fifty pico and micro hydropower plants in Ethiopia, with combined generating capacity below 10MW.

Wind energy has been promoted for water-pumping applications in rural Ethiopia for the past forty years. However, it has never been widely adopted. Wind-power generation is now considered a viable supplement to hydropower on the national grid and two wind farms are now under development in the north and central parts of Ethiopia, with combined capacity of about 170MW. There are plans to develop six more wind farms, with total capacity of 700MW. The power-generation potential from areas with the highest wind energy density (those exceeding 7m/s at 50m above ground level) is 170GW.

Current uses of solar energy are for off-grid rural applications in homes, rural telecoms and in the social sectors (water pumping, health services, schools). Solar energy is also becoming an important alternative to water heating in the major cities. The current total installed photovoltaic power in Ethiopia is about 3.5MW, three-quarters installed in telecom stations (mostly in mobile towers but also in other stations). Solar water-heating installations are in a thousand or so units in Addis Ababa and the major cities.

Ethiopia has geothermal power potential estimated to range from 700 to 5000MW. One small geothermal plant (7MW) was developed in the mid-1990s but has ceased production after a few years. The current power system expansion plan indicates that a 70MW geothermal plant will come online by 2015.

1.2 Short-term plans for the energy sector

Demand for energy is growing rapidly in Ethiopia. Electricity consumption on the national grid has grown at more than 12 per cent annually,[1] petroleum consumption at 11 per cent and biomass at 6 per cent. Access to sustainable and improved energy services are, however, still very low: per capita electricity consumption is only 35kWh and per-capita consumption of petroleum fuels is 23kg. These figures compare unfavourably even to Sub-Saharan Africa levels.

The government now sees energy as an important development input and is increasing capacity, infrastructure and access. The major plans for the next five years include:

- Addition of 9673W of power generation capacity (8737MW hydro, 866MW wind).
- Providing basic electricity access to 100 per cent of the population (access defined as providing access to distribution infrastructure for all towns and villages).
- Dissemination of 14,000 domestic biogas plants.
- Dissemination of 3 million solar home systems.
- Producing and using 1.8 billion litres of liquid biofuels.
- Promote demand side management for electricity in all sectors.

Other development plans that will have significant impact on the energy sector include:

- Introduction of electric freight rail. This program is expected to reduce freight transport by road by as much as 50 per cent.
- Introduction of urban passenger rail. The plan foresees moving about 7 per cent of the total urban passenger traffic onto mass transit electric rail (to be implemented in Addis Ababa).
- Increased mining activity, particularly for potash in the north, will increase the demand for freight transport significantly.

1.3 Main issues in the energy sector

The main challenge for the energy sector in Ethiopia is to increase access to sustainable energy for basic services and for growth. Energy access indicators for Ethiopia are very low; they are lower than the Sub-Saharan average (in areas such as rural electrification level and per capita modern energy use). The four key issues for the sector are:

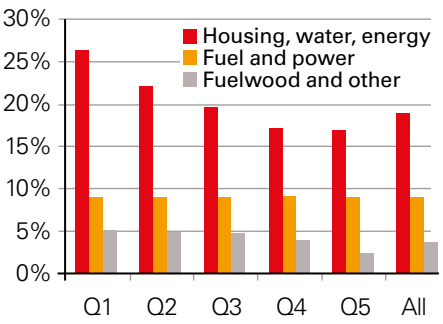
Increasing access to sustainable energy

The majority of people do not have sufficient and sustainable energy to provide for their basic needs such as cooking, lighting, and information; they also lack energy for productive activities to improve their economic status. Households spend quite a substantial proportion of their income, time and effort to acquire energy to meet their basic needs; women in particular are heavily burdened with fuel collection and meal preparation, which impacts their health and limits their opportunity for full participation in social and economic life.

Providing adequate energy for growth

The Ethiopian economy is growing rapidly from a low base; energy demand for manufacturing, transport, and agriculture are

Figure 2. Energy spending by expenditure quintile



Households in Ethiopia spend 9% of their income on energy. Firewood and other cooking fuels account for 40% of this expenditure. While the share of energy expenditure is the same for all income classes, the share of expenditure on fuelwood and other cooking fuels is greater for low-income households compared to better-off households.

Source: CSA, 2007

increasing faster than the economy. Energy for these sectors must be adequately provided to maintain economic growth. Electricity consumption on the national grid has grown by 12 per cent annually in the recent past. The power utility estimates, however, that this rate of growth is addressing only about half of the actual demand (i.e. the unmet demand for electricity is growing at 12 per cent also).

Ensuring sustainability of energy supply and use

Sixty to eighty million tons of biomass fuels are consumed annually in Ethiopia. This puts enormous pressure on forest resources and contributes to deforestation and forest degradation, which in turn contributes to soil and water quality degradation. Non-sustainable management of forest resources also result in the emission of greenhouse gases.

Ensuring energy security both at the household and national levels

Ethiopia is a poor, land-locked country which imports its entire petroleum fuel requirement; its exposure to petroleum supply risks is high. The country relies on a few large hydropower plants for electricity, which renders the power sector vulnerable to climate variability. Excessive dependence on biomass energy adds to the vulnerability of households to climate change. Ensuring energy security is critical for providing essential energy services as well as to provide energy for growth. The key action to address this will be increasing supply diversity and rapid up-take of energy efficiency in all sectors.

1.4 Energy and climate resilience and adaptation

Climate change has had severe impacts on life and livelihoods in Ethiopia. Droughts and, to a lesser extent, floods have been frequent and have exposed millions to hunger and displacement. Agriculture and the more than 12 million households that depend on it for their livelihood have been severely impacted. Climate change is affecting hydropower production from Ethiopia's hydro-dominated power system; this impact is transmitted to the other sectors of the economy, manufacturing and services, rendering these sectors as vulnerable to climate change as agriculture. Losses of land productivity in agriculture and forestry are reducing access to biomass energy, which provides for the basic needs of the population.

The energy and climate change link has the following three dimensions: (a) vulnerability of energy supply to climate change, (b) greenhouse gas emissions from the energy sector, and (c) access to energy to enhance adaptive capacity.

The energy system in Ethiopia is vulnerable to climate change because the major sources of energy supply, bioenergy and hydropower, both depend directly on the climate. Diversity of supply is the key to addressing these problems; Ethiopia has a variety of renewable resources that it can use to this end.

The energy sector's contribution to greenhouse gas emission in Ethiopia is about 15 per cent.[2] Emissions are mainly from fossil fuel use in the transport, industrial and residential sectors. Emissions are expected to rise sharply in the next twenty years because of rapid economic growth, particularly in the manufacturing and transport sectors. These emissions can be reduced drastically through energy efficiency and substitution of indigenous renewables for fossil fuels.

One of the more important means of increasing adaptive capacity and is to increase productive capacity employment diversity, and to improve basic services for the population. Improving access to energy for irrigation; agricultural output preservation and processing; manufacturing and social services will contribute to this goal.

1.5 Low carbon development strategies

The Ethiopian government has stated its intention to follow a green development path in its current five-year development plan called the Growth and Transformation Plan (GTP, 2011-2015). It is now drafting a Climate Resilient Green Economy (CRGE) strategy, the first draft of which is now out for public discussion. The strategy foresees cutting greenhouse gas emission from Ethiopia by more than half in 2030. It also foresees diversifying energy supplies and uses to increase climate resilience in the energy sector. Some of the major actions proposed for the energy sector in the draft strategy include energy efficiency for biomass fuels and, in transport, substitution of fossil fuels with renewable electricity. For example, using electric freight rail to replace petroleum fuel based road freight transport.

Low carbon development (LCD) actions, in addition to being sustainable, are also in many cases more economic compared to conventional alternatives. The major actions anticipated for Ethiopia, including renewable electricity for transport and energy efficiency, cost less than their conventional alternatives on a lifecycle basis. Some of these measures also have considerable local environmental benefits in reducing air pollution (indoor and outdoor), and in re-establishing the balance between resource supplies and uses.

The major barriers for low-carbon technologies include the relatively high investment requirement, low institutional readiness, and human and material capability for implementation. An LCD leapfrog fund can address these barriers and contribute towards the rapid uptake of low carbon technologies in Ethiopia.

2. CASE STUDIES

2.1 The National Biogas Program of Ethiopia

Background:
The National Biogas Program of Ethiopia (NBPE) is part of an Africa-wide program for large-scale deployment of domestic biogas. It is implemented in four regional states of Ethiopia which account for 85 per cent of the total population.[3] The NBPE is implemented by a national coordinating office and four regional project offices. The program is supported by the Netherlands development organization SNV, who also supported the highly successful Nepalese Biogas Programme which installed more than 200,000 domestic biodigesters.

The background to this program is that Ethiopia is home to the largest cattle population in Africa (50 million heads of cattle and 50 million other livestock) and it is also one of the most biomass-energy dependent countries in the world. Ethiopia has eighty-eight million people each requiring about 1 ton of biomass fuels annually: this puts heavy pressure on resources which have become less accessible as demand exceeds sustainable yields.[4] Impacts go beyond the energy sector: local resources are degraded as trees are lost and the environment services they provide in water regulation and protection of soils are also lost; these have had severe economic and social impacts because they undermine the productivity of agriculture which is the source of livelihood for eighty per cent of the population.

Project objectives:
The program was launched in 2008 with the goal of disseminating 14,000 domestic biodigesters in five years. The program installed 1,400 units by June 2011. Multiple benefits are expected from the introduction of biodigesters into rural Ethiopia, including improving access to sustainable energy, improving the indoor environment, increasing the availability of natural fertilizer, and the reduction of greenhouse gas emission from combustion of non-renewable wood fuels. The program has installed 1,500 units to date.

Technologies:
The NBPE promotes biodigesters for domestic (residential) cooking and lighting in rural areas. The program promotes the Nepalese fixed dome biodigester in four sizes (4, 6, 8, and 10m^3 gas-holding capacity). Biodigesters are made of stone masonry with concrete domes. Domestic biodigesters are installed by technicians specially trained by the program.

Stoves and lamps for biodigesters are presently imported from China. However, local manufacturers have already demonstrated capability to produce these and are expected to be the main sources in the near future. The project is also making trials to introduce a biogas baking stove.[5]

The investment cost on the domestic biogas plants ranges from Birr 8,000 to Birr 16,000, depending on size, with the most frequently installed domestic biogas system (6m^3 capacity) costing Birr 13,000 (US$765). This investment requirement is partly covered by a federal government grant of Birr 5,000 per plant, with the remaining amount coming from owner equity. Biogas users are now provided credit from micro-finance banks to cover part of their equity contributions.

Building costs for domestic biodigesters are relatively high in Ethiopia compared to other countries. The main reason for this is the high cost of building materials in Ethiopia. Biodigesters are made of stone masonry with substantial requirement for expensive cement (a 50kg bag of cement costs US$14, more than twice that in other countries).[6] Due to the high cost of building biodigesters the National Biogas Program now targets rural districts with relatively better incomes. There are now trials to reduce costs through low-cost designs, including one design (obtained through a regional experience exchange visit to Uganda) which dramatically reduces the need for cement.

Development benefits and impacts:
The NBPE has the primary objective of improving access to sustainable energy through the domestic biogas technology. However, it has very significant impacts in the following areas as well:

a) Reduces demand for wood, thus helps redress the balance between supply and demand. This has benefits in improving the sustainability of local resources, which has both economic and environmental benefits.

b) Reduces the fuel collection burden on women and children; it also reduces cooking time. Women now spend less time on fuel collection and less time on cooking (2 to 3 hours less for collecting fuel and preparing meals). Families now say they feel comfortable asking neighbours and relatives for tea and coffee because it now takes much less energy to prepare meals and drinks.

c) Improves access to natural fertilizer from biodigester waste; reduces demand for chemical fertilizers. Biogas users are now cultivating fruits and vegetable in their home gardens using the biogas slurry as fertilizer; households are also using slurry compost on cereal crops such as barley. The amount of biodigester slurry available from the plant is enough to replace a typical household's annual requirement for fertilizer (about 1 quintal of Diammonium phosphate (DAP) and 0.5 quintals of urea with annual saving of Birr 1,240). Results have been positive with substantial additional income for households.

d) Reduces indoor air pollution from inefficient biomass stoves.

e) Reduces greenhouse gas emission from non-sustainable use of wood fuels and from inorganic fertilizers. In most areas of Ethiopia, woodfuel consumption surpasses sustainable supply from forests, and woodfuel consumption contributes to greenhouse gas emissions.[7] It also reduces emission from application of inorganic fertilizers.

Opportunities and risks:

The technical market for domestic biogas in Ethiopia is estimated to be 1 million units. The market potential for the next ten years will be in the order of 100,000 units.

Types of investment needed:

The investment on a typical domestic biogas plant (6m^3 capacity) is Birr 13,000 (US$765). Investment is composed of contributions from owners (40 per cent) and government grants (60 per cent). Farmers meet half of their required contribution through loans from microfinance banks.[8]

Program support per unit of biodigester installed is Birr 5,800 (US$350). The support includes capacity building and program administration in one program-coordinating office at the federal level, and four regional executing offices.

The total investment on one unit of biodigester is Birr 18,800 (US$1,150). Investment required to extend the program beyond its first phase of 14,000 biodigesters by 2013, to 100,000 biodigesters in 2018 will be US$99 million. The investment required may be composed of:

- farmer contributions: US$34 million (US$400/unit, 50 per cent of plant investment)
- funding from other sources: 34 million (US$400/unit, in the form of farmer investment support)
- the typical domestic biodigester will abate 4tCO2e/y, thus reducing 80tCO2e over a twenty year period. The investment support (which could be a leapfrog fund, LFF) will be US$5/tCO2e abated.

Other types of support to the project:

A program to disseminate 100,000 domestic biodigesters in rural Ethiopia will require continued capacity building and institutional support. This capacity is currently being built but requires sustaining and further expansion. A major element of capacity building and institutional support will be to extend the present support to the district (Wereda) level for extensive reach.

Table 2. The National Biogas Program of Ethiopia: opportunities, risks and challenges

	Opportunities	Risks and challenges
Financing	• Increasing incomes and purchasing capacity in rural areas. • Access to credit from micro-finance banks. • Potential viability for carbon financing.	• Relatively high investment requirements. • Significant inflation of costs; system cost has increased by 40% since the launch of the program. • Availability of co-financing after present supports are withdrawn.
Economic	• Increased access to energy. • Increased application of labour for income augmentation. • Increased access to natural fertilizer. • Increased availability of livestock feed from crop residue (which were partly used as fuel).	• Significant investment for farmers.
Environmental	• Reduction in the non-sustainable harvest of trees for fuel. • Removal of smoke from the home. • CO2 emission reduction.	• Health risks due to handling of animal and human waste. • Potentially increased exposure to mosquitoes.
Social	• More time for social networking.	
Technical	• Trained technicians for promotion and installation of systems.	• Availability of adequately trained technicians at the district level. • Continued availability of service in the mid and long term.
Institutional	• Decentralized political and economic administration.	• Availability of district level capacity to manage projects.

2.2 Humbo Natural Regeneration Project

Background:
Humbo is located in the Southern Regional State of Ethiopia in the Great Rift Valley about 420km from Addis Ababa. The Southern Region, in general, is the most densely populated region in Ethiopia. With a population of about 50,000, Humbo is one of the most densely populated rural areas in the Southern Regional State. Due to high population pressure and lack of responsible ownership, the natural resources in Humbo have been continuously degrading since the early 1970s – mainly due to unsustainable cutting of trees for firewood, charcoal making and construction, and over grazing.

A Participatory Rural Appraisal of communities in Humbo indicated that the natural forest in the area was intact, and was a shelter for wildlife and a source of livelihood for communities (World Vision Ethiopia, 2008). Due to high population density and increasing demand for firewood, the forest has been grossly harvested beyond the sustainable supply of biomass. Additionally, with a decline in agricultural productivity, caused by rainfall variability and environmental degradation, part of the forest was converted into farmland to meet the growing demand for food. Studies indicated that the loss of wood from forests due to over exploitation of the resources base for firewood is several times greater than that due to forest clearing for agricultural expansion in the Southern Region.[9] In Humbo, such over utilization and over dependence has turned the dense natural forest into a barren land with only a few clusters of bushes. Absence of user rights and appropriate legislation exacerbated the degradation of the natural forest.

The deforestation around Humbo was so severe that it threatened the livelihood of over 60,000 people living in and around the project area. It degraded the quantity and quality of ground water, which is the source of their potable water supply (Project Design Document, 2009); due to severe soil degradation agricultural productivity fell by 70 per cent (World Bank); and the natural forest was so highly degraded that it hardly provided enough firewood for local communities. The natural forest has been denuded and anthropogenic pressures prohibited natural regeneration. The situation was so severe that an estimated 85 per cent of people living in the Humbo area lived in poverty prior to the reforestation project.

The Humbo Natural Regeneration Project aims at the regeneration of 2,728 hectares of degraded natural forest in Humbo. The project affects a total number of about 50,000 people in seven communities surrounding the forest. The project was started in 2006. Carbon credit through the Clean Development Mechanism (CDM) for sequestration of carbon is incorporated to the project to stimulate local communities. The project was initiated by World Vision Ethiopia and implemented with full participation of local communities. The benefit from CDM is to increase the incomes of local communities as a component of a rural development strategy. The real benefit, though, is the regeneration of biodiversity, poverty alleviation and establishment of sustainable livelihood where communities manage their natural resources and obtain social and economic benefits.

To ensure sequestration of carbon and benefits from CDM credits, the project is designed to work with the whole community and ensure that there are significant local benefits apart from the CDM ones.

Project objective:
The goal of the Humbo natural regeneration project is poverty reduction, through the rehabilitation of the degraded natural environment to restore the local agro-ecosystem on which the livelihoods of the local communities depend. Main objectives of the project include the revival of biodiversity, enhancement of firewood supply through sustainable forest management practices, removal of greenhouse gas, reduction in soil erosion and flooding, and provision of income stream through sustainable management of forest resources. The project aims to regenerate 2,728 hectares of degraded natural forests. A carbon financing element through CDM is also attached to it.

Technologies:
Farmer Managed Natural Regeneration (FMNR) technique, the planting of seedlings and traditional good practices in forest management, comprises methods that have been employed for the regeneration of the natural forest in project areas (Project PDD, 2009). FMNR is a participatory and low-cost forest management practice that brings results in a short time. With FMNR method, communities are able to harvest firewood and fodder within a year of project time; and wild fruits and other non-timber forest products (such as apiculture) within three years (Brown et al, 2010). FMNR method has been developed in West Africa for over 20 years. It is a scalable and replicable technique where agro forestry is used for environmental restoration and income generation. FMNR technique has also been spread to many other African countries.

For the Humbo natural regeneration project, communities are organized in seven cooperatives. With user rights granted to them, the communities developed a sense of project ownership and have been motivated for more sustainable management of their common land.

To minimize potential pilferage in the form of fuelwood collection, the project established a fuelwood plantation site within the project area that will supply the cooking energy needs of the communities. Additionally, the project recently involved the Rural Technology and Promotion Centre in the area for dissemination of improved biomass cook stoves in Humbo communities. The project will also establish plantation sites in non-forested areas in the project boundary for the supply of wood for construction purposes.

Development benefits and impacts: The regeneration project has brought multifaceted benefits to the local and global environment, and local communities.

a) Regeneration of the natural resource base has helped the recovery of biodiversity. Migratory species such as birds and other small wildlife started living in the forest. The local ecosystem has been re-established. Groundwater recharge has improved since the start of the project.[10]

b) Regeneration of vegetation is reducing the level of solid erosion from the project area. The World Bank study indicated that the project area was losing between 4 and 10 tonnes of topsoil per hectare per year due to erosion. This has improved the water supply system for communities around the natural forest.

c) There is an enhanced supply of firewood for cooking. The project established a plantation site (outside the natural forest but within the project area) primarily for sustainable supply of firewood to meet the cooking energy demand of communities around Humbo. Additional supply of firewood also comes from the removal of branches and twigs as a result of thinning and pruning activities in the protected natural forest areas. Studies have established that the pre-project supply of firewood from the forest was 4.3 tonnes of firewood per hectare per year; harvest of firewood from the same area (from pruning) one year after project implementation was 5.1 tonne per hectare. As the forest grows, yield as deadwood and litter will also increase, enhancing supply of firewood; periodical harvesting of timber from the forest will also leave abundant supply of firewood.

d) Communities are allowed to harvest fodder from the forest area. This has increased the supply of fodder for animals compared to the pre-project period.

e) The project generates income for communities through sustainable harvesting of both timber and non-timber products. The project area is expected to be harvested at 12, 22 and 31 years, maintaining only 50 per cent of standing biomass for the benefits of biodiversity and environmental protection. Revenues from sales of timber products supplement incomes of communities around forests. Sales of non-timber products, such as honey and fruits, generate continuous income for households.

f) The project creates a long-term employment opportunity for those employed in the planting, tending and protection of the forest management.

g) The project has a technology transfer and capacity building component, where members of the communities will be trained in livestock rearing, sustainable forest management, agro-forestry, improved agricultural practices, eco-tourism, forest-fire management, community conflict resolution, fodder development and others through the network of the seven community cooperatives. The project also anticipates introduction of alternative energy technologies to communities.

h) Communities expect US$726,000 from the World Bank for the sales of part of the Certified Emission Reduction (CER) within 10 years. Communities have already obtained the first payment from sales of CER. By the end of this year they will get the second payment. Funds are mainly used for forest management practices. With part of the fund from CER sales, communities established credit schemes in which members of the communities access income-generating activities such as livestock rearing, poultry, etc. The fund from the CER will also be used for local capacity building activities.

i) The project is expected to mitigate 850,000 tons of carbon dioxide by sequestration of carbon in the forest in the project period. CDM crediting period is for 30 years from 1 December 2006 to 30 November 2036.

Opportunities and risks: The opportunities and challenges for wider replication of this type of project are summarized as follows:

Type of investment needed: Pre-project expenses for the Humbo project were covered by World Vision Ethiopia and World Vision Australia. Project management will be financed by revenue from sale of CERs. A wider replication of this type of project can be supported by a leapfrog fund, which can be used to cover the pre-project costs; income from CERs can be used for project management activities.

Other types of support to the project: Scale-up of this project will require the full engagement of regional and district Bureaus of Agriculture. Technical and institutional building at the regional and district levels will be required.

2.3 Solar energy for rural electrification

Background: Energy costs for rural households are considerable with 9 per cent of their income spent on energy for cooking, lighting and dry cell batteries. The quality of services they obtain for this expense is totally inadequate and fraught with many undesirable health and other impacts. The quality of light from kerosene lamps (and wood fires) is insufficient to undertake any activity that requires close attention, such as reading, and may cause serious damage to health if used for extended periods. Exposure to smoke from kerosene lamps and from wood fires contributes to respiratory and eye diseases.

The Solar Energy Foundation (SEF) developed a concept of providing Solar Home Systems (SHS) to meet the lighting and audio-visual

requirements of households in rural areas. The concept was based on the realization that Ethiopia has excellent solar energy resources (5 to 6kWh/m^2/day) and the SHS are scalable to meet any size of demand. SEF piloted the concept in one village, called Rema, in 2008 and has since replicated the model in four other villages in different parts of Ethiopia.

Project objectives:
The mission of SEF-Ethiopia is to provide alternative means of electrification to rural communities. The goal of the project is to contribute to sustainable rural development by providing services through solar systems. The SEF also seeks to build capacity for local production and management of solar energy systems.

The five projects implemented so far have provided electricity to 3,740 homes and businesses and improved water supply and health services to more than 10,000 people. The first solar village became operational in 2008; there are now four other solar villages around the country. The plan is to increase the solar villages to 50 and users to 50,000 by 2013.

Technologies:
SEF projects disseminate SHS in capacities ranging from 1Wp to 60Wp. The most common system has a 10Wp PV module, an 18Ah maintenance-free rechargeable battery, a charge controller, and up to four LED lamps. This system provides four-hour lighting every evening and enough power to operate a radio and a mobile charger. The system replaces two kerosene lamps, dry cell batteries required to run a radio (two batteries a month), and adds a new and now important capability to charge mobile phones.

System components are robust and durable: the PV module and charge controller last more than ten years, the battery lasts five years, and the LED lamps for 8,000 hours or more. Few and minor problems have been faced so far, which technicians residing in local communities have been able to address easily.

A real choice of the people! The people of Rema, the first rural village to be electrified with solar systems, chose solar systems over a diesel generator. They had the choice to install a diesel generator promised to be provided by an NGO but chose solar energy after visiting a nearby village that had been provided with solar systems earlier.

Development benefits and impacts:
The projects have provided considerable social, environmental and economic benefits to the communities involved. The main benefits and impacts have been the following:

a) The solar systems have increased opportunities for education for children and information for adults. Children now have adequate light to read and adults can now go to literacy classes in the evenings. Families now have reliable energy to power their radios and have improved their access to information.

b) Families now spend more time together working and in leisure.

c) Smoke and fire hazards from kerosene lamps have been eliminated. This has removed the threat of chronic respiratory and eye diseases from smoke, and loss of life and property from fires. Solar systems have improved the extent and quality of service from local health posts.

d) The solar systems have improved water supply to the village; water is now available within the village (using solar water pumps) whereas it used to be transported on foot (involving a two hour walk each way).

e) A total of 650tCO2e/y emissions have been removed (Rema village only).

f) Local pollution from disposal of dry cell batteries has been avoided.

g) Extended hours of work for people (essential to increase productivity and incomes).

h) The project has trained and opened employment opportunities for local people.

i) Micro businesses in the village can now extend their operating hours, thus increasing their incomes.

Opportunities and risks:
There are 67 million people in 14 million households in rural Ethiopia (2010). This number will grow to 87 million people in 18 million households by 2020. Traditional rural electrification programs cannot be expected to address more than half this population in ten years, i.e., 9 to 10 million households by 2020. This leaves at least 8 million households who will not be served with electricity by 2020. The off-grid market is therefore huge in Ethiopia.

Solar electricity is financially now competitive with existing lighting (and audio-visual) alternatives in rural Ethiopia. The financial competitiveness is improving due to considerable reduction in supply costs (product and dissemination costs). The market that can be addressed with solar home systems is more than five million households. The government has made plans to promote SHS into three million households by 2015 (MWE, 2010).

Types of investment needed:
The solar home systems disseminated by the SEF range from 1Wp to 60Wp. The most common system is a 10Wp system that costs Birr 3.000 (US$175); smaller systems cost proportionally lower. Households in SEF projects are provided with the SHS freely and pay only US$1 per month to cover the cost of maintenance, service and replacement of parts.

The average investment required per system, excluding program support costs, is US$175 (for a 10Wp system). The total investment required to provide for 200 households in a rural village is US$45,000 (US$35,000 system,

Table 3. Solar energy in Ethiopia: opportunities, risks and challenges

	Opportunities	Risks and challenges
Financing	• Opportunities for carbon financing.	• Taxes and duties on PV equipment. • Uncertainty of electrification progress with the power company (to select off-grid areas for projects). • Rising inflation, increased prices. • Financing to scale-up project into thousands of rural villages.
Economic	• Improved access to energy. • Improved business opportunities.	• Investment requirement may be too high for the poor.
Environmental	• CO_2 emission mitigation. • Removal of smoke from the home.	
Social	• Health benefits of potable water supply and power from health posts. • Increased opportunities for learning. • Reduced travel and water-carrying burden for women.	
Technical	• Growing technical capacity for installation and service.	• Willingness of technicians to be stationed and work in rural areas.
Institutional	• Working/successful private-public partnership in current projects.	• Replication of PPP to a large number of districts.

US$10,000 project support). A leapfrog fund can finance the full project support cost and half of the investment on the system; the other half of the investment on the system will be paid by users. User contributions may be financed by rural micro-finance banks (which are now providing credit for domestic biogas plants, and can extend services for solar electrification). Users can repay their loans from their savings on kerosene and batteries.

Other types of support to the project:

Scale up of this project to more rural villages in Ethiopia will require capacity building at the regional, district (Wereda), and user community levels. Regional government offices (Bureaus of Energy) will promote this model of rural electrification to districts in their region; district-level government offices can provide support services to user communities; user communities must have the technical and business capability to sustainably run the systems.

- Institutional support to Regional Bureaus of Energy: to promote solar electrification within their region; to help link user communities with micro-finance banks.
- Institutional support to district bureaus: to provide technical backstopping and administrative support to user communities.
- User community support: capacity building for local technicians and business managers.

3. LEAPFROG FUND POTENTIAL

3.1 Applications and beneficiaries

Leapfrog funds are better used where they will bring large low-carbon and poverty reduction impact. They should be used on projects that are in line with current policies and on projects that scale-up practices that have proven successful locally. These criteria put projects that focus on the household and community levels as the top priority, compared to large infrastructure projects. In the Ethiopian context such projects will include:

Household level: household energy efficiency, promotion of domestic biodigesters, rural electrification through solar systems.

Community level: forest regeneration, micro hydropower, wind water pumping, renewable energy for community services (water supply, health centres and schools).

These actions will increase access to energy and promote sustainable management of local resources. They mainly address the rural poor who are under-served by energy and other services. They are priority actions for the government: it has stated its intention to promote these widely (GTP, 2010). Several of these actions can also be integrated to increase impact. For example, the three case study projects discussed in the previous section can be part of a larger project that promotes energy access with local resource management.

3.2 Types and roles of financing mechanisms

The major decentralised renewable energy dissemination projects being implemented in Ethiopia utilize a combination of user equity, government and donor grants. Micro-finance banks are providing finance to cover user equity. Four of the largest renewable energy and forest management projects have the following financing structure:

- The Rural Improved Cooking Stove Program (Ministry of Water and Energy). This project covers finance for production workshops for rural stove producers. Finance is provided to producers through micro-finance banks. Improved stoves are sold to users at market price.
- The National Biogas Program (Ministry of Water and Energy). Domestic biodigesters are financed by a combination of user contributions and grants from government and donors. Investment in biodigesters is covered by owners (40 per cent) and government grants (60 per cent). Micro-finance banks provide half financing for half of owners' contributions.
- The Humbo Natural Forest Regeneration Project (World Vision, an NGO). Pre-project costs were covered by World Vision. Carbon finance through the CDM is expected to generate revenue to cover recurrent costs.
- The Rural Electrification Fund (REF, Ministry of Water and Energy). Solar electric systems for homes, health centres and schools are provided by the project. The project has been partly funded by World Bank and GEF grants and loans. Users form electric service cooperatives, and receive finance to cover their system and installation costs. Finance is administered from the REF to the ESCOs through a trust administrator (Development Bank of Ethiopia).

The essential elements of these projects are: (a) investment support is provided to owners and distributors, (b) owners' share of investment is financed by micro finance and development banks, and (c) recurring costs could be financed through carbon financing. The leapfrog fund is best applied to support owner investment in a mix of grants and loans channelled through local micro-finance banks.

3.3 Need for complementary support

In addition to investment support, the leapfrog fund could be used to improve the effectiveness of institutions engaged in research and development, promotion and implementation. Projects can only be scaled-up if institutions can provide effective and sustained support. Institutional capacity building is required in the chain of activities ranging from research to implementation. Specific areas for the leapfrog fund include:

- Support for program implementation for government and non-government agencies, both at the central and district levels. Support is required for capacity building in the areas of strategy development, program design, promotion, information, and program monitoring and evaluation.
- Support to renewable energy and forestry research and technology transfer. The local component for renewable energy is very low in Ethiopia: solar, small hydro, and wind energy conversion systems are mostly imported; capacity to design, install and service relatively larger systems (such as small hydropower) is limited. The leapfrog fund could be used to support renewable energy system design, adaptation and service centres in selected universities and development agencies.
- Technical and business capacity development for private companies working in the areas of renewable energy. Private companies are key for large scale deployment of renewables: they are the link between program implementers and users; they are vital not only for producing and supplying systems but

also for market development for renewables. Technical and business development capacity of private companies will help accelerate scale-up for renewables.

- Support to private sector renewable energy companies through their renewable energy associations. These associations will be used to promote local private industry, provide renewable energy information, compliance to quality of products and services.

3.4 Role of the private sector and PPP

The major renewable energy programs being implemented in Ethiopia are examples of public and private partnerships:

In the National Biogas Program the role of the private sector includes promotion of the program, user identification, system installation and service. The private sector also imports and produces components of the biogas system (stoves and lamps). The program is implemented by national and regional program coordination offices supported by the government.

In the rural improved cooking stove program, stoves are distributed through mainly women-owned micro enterprises that promote their products. The program supports the micro enterprises through technical and business training and by providing start up financing.

In the off-grid Rural Electrification program private companies provide installation and service for solar systems provided to ESCOs; private companies can also take loans from the REF to service ESCOs.

The lesson from these and other projects is that the private sector is critical for scaling-up renewable energy programs: private businesses, ranging from women-run micro enterprises in rural areas to medium scale businesses in the capital, promote renewables, help develop the market, and provide renewable energy products and services. Because the renewable energy market in Ethiopia is still small, effective business chains have not been formed, and the financial and technical capacity of companies is also limited. The leapfrog fund can be used to finance start-up capital for businesses, help build sustainable value chains for renewable energy, build the technical and business capacity of private companies, and support renewable energy associations.

3.5 Conclusion

Ethiopia depends on a limited range of sources to meet its energy requirements. It depends on biomass energy for more than ninety per cent of its energy supply. The power sector is completely dominated by large hydropower systems. Transport is exclusively based on imported petroleum and the medium and large scale manufacturing sector relies heavily on imported solid and liquid fossil fuels.

The Ethiopian economy is growing rapidly from a very low base; Ethiopia requires growing energy to sustain this growth and provide for basic services. Energy access and its sustainable and secure supply are, therefore, major concerns for Ethiopia: a large proportion of the population, particularly in rural areas, does not have access to electricity and sustainable energy for activities such as cooking; limited diversity in its energy supply structure exposes it to significant risks of sustainability and access.[11]

Energy demand in Ethiopia is expected to grow faster than the economy. The conventional route of development for the energy sector will increase greenhouse gas emissions and amplify the risks outlined above. Emissions from Ethiopia will become significant in the coming twenty years as the economy becomes more carbon intensive due to very rapid growth in manufacturing, infrastructure and transport.

Ethiopia has a diverse range of renewable resources and it has a large potential market for them in its large population with growing incomes. Renewable energy development is growing but still only a small fraction of the potential is realized. The main barriers for large scale adoption of renewable energy in Ethiopia are the relatively high investment requirement and the limited capacity in institutions.

The low-carbon leapfrog fund could be used to scale-up renewable energy and forest management programs in Ethiopia. The main areas where such a fund will have major impacts and benefits will be in dissemination of decentralized renewables and forest management, which meet the main challenges of access and sustainability in the energy sector.

Potential programs at the household level: household energy efficiency, promotion of domestic biodigesters, rural electrification through solar systems.

Potential programs at the community level: forest regeneration, micro hydropower, wind water pumping, renewable energy for community services (water supply, health centres and schools).

These projects will mainly benefit the rural poor who are the least served with energy and other services. Some of the above projects can also be integrated to maximize impacts and benefits. Scaling-up these programs will require that the main barriers in investment and capacity development be addressed. The low-carbon leapfrog fund can thus be used to finance investment by users, communities, and private sector renewable energy promoters. The fund can also be used to develop implementation capacity in the public sector and in private companies.

ENDNOTES

1 The rate of growth was 12% annually; however, there have been frequent and substantial power cuts during the period.

2 This excludes emission from non-renewable biomass. Inclusion of non-renewable biomass will increase the share the energy sector from total emissions to 60% or more.

3 The target regional states are Oromiya, Amhara, Southern Nations, Nationalities and Peoples' and Tigray.

4 Biomass fuels used for residential cooking in Ethiopia include wood, charcoal, crop residues and livestock dung.

5 Injera is the local bread in Ethiopia and it consumes about half of the total amount of energy used for cooking in households.

6 Bricks are very expensive in Ethiopia: one brick (dimensions of 200x100x50mm) costs Birr 2 (US$ 0.12).

7 The non-sustainable fraction of biomass for Ethiopia is estimated at 86% (Bird, Neil, et al, 2009).

8 Terms from micro-finance banks for the biodigester loans are 16% annual interest for 2 years.

9 Wood loss, due to non-sustainable harvest of firewood from forests in Southern Region for 2010, was estimated to be 26 times more than wood loss due to clearing of forest for agricultural expansion (Ministry of Agriculture and Rural Development, 2005).

10 Communication with Mr Assefa Tufa, Head of the Humbo Regeneration Project at World Vision Ethiopia.

11 The risks are to climate variability for bioenergy and hydropower, and international politics and economics for fossil-fuel imports.

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