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Energy Sector Reform Initiatives and Implications in Eritrea.

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ABSTRACT (Extended)

The Government of Eritrea has given priority to the energy sector immediately after independence in May 1991 as manifested by the rapid improvement in electricity and oil supply. The generation capacity has increased from 30 MW in 1991 to over 130 MW at present. The lengths of transmission and distribution lines have similarly increased from 150 km to 400 km and from 800 to 1300 km respectively. However, as in most Sub-Saharan Africa, the national public utility is characterised by inefficient managerial, technical and financial performances, inability to mobilize the funds needed for expansion, low repair and maintenance capacity, inappropriate tariff rates, inadequate revenue collection mechanisms, etc. This has induced the government to take appropriate reform measures. The reform initiatives include: restructuring the Eritrea Electric Corporation to operate on commercial principles, setting tariffs based on real costs and reasonable profits, effective collection of revenues, the minimization of wastage and loss in the delivery of energy services, facilitating the private sector penetration in the energy business, and ring-fencing the interests of the poor by setting up Rural Electrification Fund. A Regulator body has been established to enforce the reform measures. Recognising the role of modern energy in poverty reduction and achieving the MDGs, the Government with the support of its development partners is expanding energy services to rural areas innovatively. The Government's commitment to diversify energy sources can be indicated by its agreement with GEF for a 50% sharing of cost of an on-going 4 Million Dollar pilot wind energy project. It also established an Energy Research and Training Centre to promote the application of renewable energies and improved biomass stoves.

1. Introduction

Energy is one of the key requirements for socio-economic transformation of poor societies. The energy-development relationship has numerous social and political implications in Eritrea, where the national access to modern energy services is still very low and where about 66% of the population lives below the poverty line (LSMS 2003). The Human Development Index (HDI), produced by UNDP (2004), and the Energy Development Index (EDI) of the International Energy Agency (IEA, 2004), offer an excellent picture of the relationship between energy services and overall development.

Taking energy data for 2002, the IEA has produced EDI scores for 75 developing countries, of which 25 are from Africa. The results reveal that the Middle Eastern countries and the medium income Latin American countries, rank high in both HDI and EDI, reflecting higher electrification rates and lower use of traditional biomass. The Sub-Saharan countries (See Annex I), with low real incomes and low electrification rates, are at the bottom of the ranking in both HDI and EDI. In general, HDI and EDI tend to co vary in the same direction, reflecting the close association between the two, although few exceptions like Togo and Kenya show relatively high HDI, in spite of low electrification rates. The Pearson's correlation coefficient for the 25 African countries considered was 0.907, significant at 0.01 (see Table A1). Table A1 shows that the North African countries and South Africa performed better by the EDI measure. The traditional biomass use index, which is calculated from the difference between the total energy and commercial energy consumed, was also highest for these countries reflecting the commercial sources of almost all energy supply. Very few South Asian countries like Myanmar & Nepal and Haiti from Latin America are also at the bottom. In general there is strong correlation between the HDI and EDI and this is as expected.

The EDI-HDI pattern for Eritrea is similar to the rest of sub-Saharan countries. About 70% of the Eritrean population, which lives in rural areas, has little or no access to modern energy services. At national level, access to electricity is about 32%, but only 3% of the rural population has access to it compared to 78% in urban areas ((EDHS, 2002). If the capital city, Asmara, alone is considered, access to electricity was 99%. The electricity statistics reflects the urban bias of the energy policy.

The energy transition in rural Eritrea, where the majority of the country's population lives, will not occur under a "business-as-usual" situation. The national drive to eradicate poverty and achieve the MDGs within the context of environmentally sound and sustainable development in particular demands new approaches in the energy delivery systems. A concerted effort is needed on the part of the many actors influencing the supply and demand of energy. Success in this direction requires broad reforms, leading to greater resilience in the production system, higher productivity, improved efficiency, higher incomes and minimum environmental degradation. Such reforms will become effective only when institutional linkages and coordination mechanisms between the various stakeholders are in place. In Eritrea an aggressive energy transition would be characterized by a move from the present energy use patterns, based on animate power and biomass resources, to a situation where households, services and farming activities use a range of sustainable and diversified energy sources.

1.1 Current Energy Situation in Eritrea

Biomass still constitutes the major source of energy in Eritrea. The energy balance for 2003 showed that *total primary energy supply* was around 798,360 tons of oil equivalent (toe), of which 508,510 toe or 63.7%, was derived from local biomass fuels; the remaining balance, 287,850 toe or 36.3%, was derived from imported oil products (DoE, 2003). From the oil products, 54,750 toe was used for the thermal generation of 267 GWh

of electricity at conversion efficiency of 31% from the public Eritrea Electric Corporation (EEC) systems alone. The *total final energy supply* was 717,910 toe, of which 66.8% was consumed by the household sector, 13.7% by transport, 9.2% by the public and commercial, 7.7% by the energy industry (electricity generation), and 2.5% by the manufacturing industry. The share of electricity consumption was only 2.7%, that of oil products 32.3% and the balance, or 65%, was derived from biomass.

At household level, the dependence on biomass sources is even more striking, with 94% of the domestic energy being derived from biomass sources; oil products and electricity account only for 4.5% and 1.5% respectively. However, the per capita electricity consumption, which stood at 62.5 kWh in 2003, shows nearly four-fold increase since 1991. Moreover, there are over 2000 solar PV systems with installed capacity amounting to 600 kW, mostly for welfare applications like water pumping, powering health centres, schools, communication facilities, etc. In summary, the followings are the major achievements of the energy sector since independence in 1991.

- Power generation has increased from < 30 MW in 1991 to around 134 MW by 2005;
- The length of transmission lines has increased from <150 km to over 350 km;
- The length of distribution lines has increased from 800 km to over 1300 km;
- Rehabilitation of power distribution system initiated;
- Wind and solar resources assessment from 25 meteorological stations is underway;
- Pilot wind energy applications project is being implemented;
- Dissemination of improved stove is in progress with 29,000 installed by 2004
- Energy Laws, Regulations and Standards have been enacted.

1.2 Socio-economic and Environmental Issues of Current Patterns of Energy Use

The heavy dependence on unmanaged biomass sources has created numerous socio-economic and environmental problems. Forest off-take is 2.4%-2.8% of the stock although the sustainable threshold is 1.25%, indicating that the current off-take rate is unsustainable (Lahmeyer 1997). This has led to massive deforestation and allied problems like soil erosion, flooding, siltation of dams, loss of biodiversity, etc. At present about 1% of the country's land surface is covered by forest compared to about 30% at the end of the 19th Century (NEMP, 1995 p 58). About 34 tree species are threatened with extinction. FAO has estimated that the current rates of soil erosion (an average of 15 tons/hectare/year) could reduce yields by 0.2% to 0.4% a year for crops and 0.05 to 0.1% for livestock (FAO, 1994). Moreover, many households have shifted to the use of cow dung with increasing scarcity of fuelwood. This deprives the soil of its organic nutrients, and the crop production foregone as result could be as high as 18-20 kg for every 100 kg of cow dung (Bojo, 1995).

There are also socio-economic problems associated with the use of biomass fuels. By tradition, women shoulder the responsibility of fuel wood collection, and they have been

observed to carry more than 35 kg of firewood over a distance of up to 10 km, although the ILO prohibits manual carrying of load more than 20 kg by women (Danklen & Davidson, 1989). They spend up to 3 hours to collect firewood to meet a week's need of energy. Moreover, women and children are the major victims of indoor smoke pollution. Many wood types emit toxic smoke, including carcinogens. Although no kitchen measurements from Eritrea are available, studies elsewhere show that suspended particulates and benezopyrene are the major health hazards emitted during the combustion of biomass fuels. The high respiratory and eye diseases observed among women and children in Eritrea may be linked to such pollutants.

Lack of access to reliable and affordable modern energy has also hindered many localities to diversify their sources of income. The development and promotion of medium, small, and micro enterprises (MSMEs) as means of income and employment generation is widely recognized. However, the potential of MSMEs has not been fully realised due to many constraints, one of which is energy. In a survey of MSMEs made in 1995, 80% did not use powered machinery due to lack of energy, capital or both (Yacob, 1996). Similarly, data collected by the Department of Energy in 1998 on energy use by MSMEs, which numbered 30,466, indicated that they consumed only 4.9% of the final energy supply. The data further showed that about 55% of the MSMEs accounted for 71% of the total energy consumed by all MSMEs. Lack of flexible, reliable and affordable supply of energy may have constrained the capacity of MSMEs to generate more employment and income. On the average, they employed 1.37 persons per enterprise, while the rural-based employed 1.27 persons per enterprise (Yacob, 1995; Zemenfes and Semere, 2001). A study in Ala irrigation farms further revealed that the energy consumption was 18.6 GJ per hectare (Zemenfes and Semereab, 2001), and compared poorly with 35 GJ in Pakistan and over 70 GJ per hectare in the USA. Studies show that energy input and output are highly correlated.

The dependence on biomass sources of energy in Eritrea has been exacerbated by a number of factors. Poverty is one of the major hindrances to shifting to non-biomass, i.e modern, sources of energy. People move up the energy ladder when their income increases, but about 66% of the Eritrean population lives below the poverty level (LSME, 2003). The low penetration of the private sector into the energy sector and market, and the presence of too many barriers for promoting RETs and other modern energy services to rural areas are other factors that require policy support. This induced the need for more rural-focussed energy policies, institutional and regulatory frameworks.

1.3 Government's Vision of Energy Reform:

Despite the dramatic increase in power generation since independence as indicated above, access to electricity is still very low, with 32% of the total population having it. Yet, 97% of the rural population still lacks access to grid-based or off-grid supply of electricity. Eritrea is committed to the achievement of the Millennium Development Goals (MDGs). However, no explicit target related to modern energy provision to the poor or the energy requirements for the achievement of the MDGs was ever stated; yet affordable energy is highly imperative for achieving all these goals. Realising this, the Government of Eritrea

stressed that access to sustainable sources and services of energy by the poor is a necessary and critical input for poverty alleviation and sustainable human development. As recognised in the Interim National Poverty Reduction Strategy Paper (I-PRSP), sustainable sources and services of energy are essential for creating and/or expanding income generation, and improving a host of social services such as educations, health care, clean water supply, communications, etc.

In its long-term program that ranges up to 2015, the Ministry of Energy and Mines in consultation with the Ministry of National Development has schemed energy development programs proper to poverty alleviation, education, water and environment sustainability, with particular attention to the development of alternative energy resources and proper utilization of the available energy resources. The goal is, "to reduce by half, between 2005 and 2015, the proportion of urban, semi urban and rural households without access to adequate lighting, and reliance on cooking methods that are not sustainable; and by 2015 to provide adequate clean and efficient energy services to all educational, health and clean water supply facilities" (Power Sector Policy Letter, 2004). The government has formulated various strategies to achieve these goals. The major energy reform measures being introduced in the country include:

i. Expansion of grid-based electrification of rural areas;
ii. Promotion of renewable energy applications
iii. Energy conservation and efficiency
iv. Market reforms of electricity and supply of oil products

Although most of these initiatives may be considered as infrastructure expansion or technological improvements, there are reform elements (e.g. new directives, cost sharing etc.) that go with them as discussed below particularly in the context of Eritrean conditions.

i) Rural Electrification through grid expansion: Rural electrification is one of the major priorities of the Eritrean Government. Electrification in the densely populated regions of highland Eritrea is proceeding through grid extension. The EEC was not in favour of rural electrification on grounds of cost effectiveness. Thus villages that wanted electricity had to pay full costs upfront. This approach to rural electrification by the EEC did not go with the government’s socio-economic development priorities. Thus, a new directive that promotes capital cost sharing, Directives No. EI.001/2001, discussed below, was issued in 2001, and current rural electrification programme are being implemented as per this Directive.

ii) Promotion of renewable energy applications: grid-based rural electrification is painstakingly slow, thus the need for faster and alternative decentralised approaches. The developments of off-grid systems, particularly renewable energy sources, are attracting attention. At present, efforts are being made to develop wind, solar and geothermal energy systems.

iii) Energy conservation and efficiency:

This goal is achievable in both rural and urban energy systems. For instance, the technical losses for electricity T & D networks are unacceptably high in the country averaging over 22%. To reduce these losses by over 50%, EEC in collaboration with the Government have began rehabilitation and upgrading the transmission and Distribution systems at least in the major cities of Asmara and Massawa.

It is known that the improved stove dissemination programme of the Ministry of Energy and Mines is gaining national and international reputation. This is manifested by the distinguished Ashden Award it received from the London based organisation in 2003 (see www.ashdenaward.org). The improved stove maintains its traditional dimensions but is improved to have better heat utilisation efficiency by incorporating modern thermodynamic principles to make it more acceptable to the people and efficient. More detail is provided in Section 2. 4.

iv) Market reforms of electricity and supply of oil products

The EEC is a public utility that controls for over 93% of electricity business in the country. As in most power sector institutions in sub-Saharan Africa, the services of the Eritrean Electric Corporation, can be characterised by unreliability of power supply, low capacity utilization and availability factor, deficient maintenance, poor procurement of spare parts, poor access in rural areas, and high transmission and distribution losses among other problems. Such problems have led to sweeping reforms in the power industry in the 1990's. Likewise the Government of Eritrea has begun taking reform measures for the electricity business by liberalising the business and corporitising the national utility as of May 2004. Corporitisation is expected to allow EEC operate on commercial principles in the urban areas and load centres, but it will expand rural electrification at subsidized costs to meet the Government's commitment to the improvement of the well-being of the population. Tariffs are to be set based on real costs and reasonable profits with equity considerations as far as possible. The interest of the poor will be ring-fenced through setting up of a Rural Electrification Fund to facilitate capital costs of electrification. The power sector reform measures were negotiated and agreed upon with the World Bank as a condition for IDA financing of 50 Million USD for the 'Asmara Power Distribution Rehabilitation and Rural Electrification Project'.

The oil distribution business is already fully in private hands, while prices are regulated by the Ministry of Energy and Mines. The Petroleum Corporation of Eritrea avails foreign currency for importation of all types of refined oil products. In this report, the market reform with respect to liquid petroleum gas (LPG) has been presented as a case study. LPG business in Eritrea has expanded dramatically with the intervention of the private sector as a result of the liberalisation in distribution.

2. Progress in Reforming the Energy Sector

2.1 Reform measures in the Power Sector

Although it is expected that the Eritrea Electric Corporation will continue to provide generation, transmission and distribution of electricity in the medium term, the Government's vision is for Independent Power Producers (IPDs) and Distributors (IPDs) to penetrate the generation and distribution systems. The transmission system will remain under public ownership with one system operator (SO). The Government has promulgated the following two Proclamations as the first steps towards reforming the power sector.

Electricity Proclamation No. 141/2004: The central objective of this proclamation is to promote efficiency, safety, environmental protection and private sector involvement in the power sector. It provides State Regulations for the establishment and operations of power plants and electrical networks, tariffs and fare trade of electricity. To enforce its implementation an Electricity Regulatory Committee (henceforth the Regulator) has been established. The Committee has five members three of which are Director Generals from Government Institutions and two from the private sector. The duties and responsibilities of the Regulator are to:

- Promote efficiency, dependability, cost-effectiveness, safety and quality of services and fair competition as well as private and community participation in electricity operations in Eritrea;

- Study, review and determine electricity tariffs and related service charges on the basis of general guidelines and principles issued by the Ministry on setting same and oversee the implementation thereof;

- Initiate and conduct investigation into standards of quality of services provided to customers and monitor standards of overall performance of permit holders;

- Protect the interests of customers, permit holders and the general public;

- Perform such other lawful activities as may be necessary for the attainment of its objectives.

Proclamation No. 142/2004 for the Establishment of the Eritrea Electric Corporation (EEC): The purpose of corporitising the public utility is to give it more autonomy in its operations and to contribute to the socio-economic development of Eritrea by providing efficient, dependable, cost-effective and environmentally safe production, transmission and distribution of electricity to the public. The responsibilities of the Corporation shall include inter-alia to:

- build, manage, maintain, operate, expand and enhance power plants, transmission and distribution lines and related facilities in accordance with the accepted standards applied in the power supply industry;
- secure and ensure that the supply of electricity is affordable, efficient and reliable;

- take necessary measures to protect the public and the environment from damages that may arise from its operations and related activities; and
- become self reliant and financially viable.

The on-going Asmara Power Distribution and Rural Electrification Project financed by the World Bank has the following major components:

- Rehabilitation and Expansion of Urban Electricity Distribution: (33Million USD)
- Rural Electrification (11.5 Million USD)
- Rural Electrification Fund (1.4 Million USD)
- Sector Reform and Institutional Capacity Building (4.5 Million USD)
- Environmental Monitoring (0.5 Million USD)

The rehabilitation and expansion component of the Asmara network includes (a) upgrading and installing substations and transformers, (b) installing underground cables, overhead lines and distribution poles, and (c) constructing transformer cabins. The third phase of the Rural Electrification Program focuses on 60 villages around the four major urban centers of Keren, Barentu, Dekemhare, and Adi-Keih. A Rural Electrification Fund is to be established as the mechanism for financing electrification of villages and semi-urban areas.

In addition, the Asmara Power Distribution and Rural Electrification Project finances environmental monitoring, power sector reform and institutional capacity building for the Ministry and EEC. The various components/activities relating to institutional capacity building and reform, their time frame, implementation modalities and current status are summarized in Table 1.

Table 1: Consulting and Training Services (2005-2008):

Description of Assignment	Expected Completion	Implementing agency	Status
Design & supervision consultant for the Asmara Power rehabilitation Component	2008	EEC*	Ongoing activity since 2003
Rural Electrification design & supervision consultant	2008	EEC	Ongoing activity since 2003
Information technology Advisor for MIS	Early 2006	EEC	Draft TORs being prepared.
Separation of EEC accounts (urban/rural businesses)	Early 2006	EEC	Not initiated
Establishment of a corporate planning function at EEC	Early 2007	EEC	Not initiated
EEC institutional strengthening/ Financial advisor	2008	EEC	Draft TORs being prepared.
Tariff study update	Early 2006	MEM**	Ongoing activity
Training coordinator for MEM	End-2007	MEM	Draft TORs being prepared.
Power sector reforms/Regulatory function	end-2006	MEM	Ongoing activity
Design of RE Fund	Late 2006	MEM	Ongoing activity

*EEC – Eritrea Electricity Corporation; **MEM – Ministry of Energy and Mines

2.2 Progress in Rural Electrification

Rural Electrification (RE) has long been seen as a factor of socio-economic development. It is believed that it is a necessary catalyst to improved rural productivity and quality of life. Although the cost of electrification is very high and not generally cost effective from utilities point of view, the values derived from services provided by electricity in terms of better opportunities for education, health, entertainment, comfort, convenience and enhanced productivity make the balance, justifying support from government and donors. To this effect international debate on the role of energy in sustainable development and achieving the MDGs is on-going. Commitments of governments of developing countries are also increasing in recent years.

Eritrea is also embarking on quite extensive rural electrification programme. The primary goal is to provide electricity to rural areas from the national whenever accessible and decentralised systems (wind, solar, gensets etc.) in other places.

Initially, rural communities were asked to pay full costs upfront when they requested for electricity connection. On the basis of this arrangement, 13 villages close enough to the national grid were electrified up to 1998. Clearly this arrangement was found to unaffordable for a population in which two-third fell below the poverty line. Thus, the Government had to approach development partners to co-finance its electrification programmes. Between 1999 and 2001, around 14,100 households in 27 villages and 4 towns benefited from electrification, which was partially financed by Sida (see also Table A2). The total cost of this electrification phase was 1.45 Million USD, yielding an average of 103 USD per household, excluding connection and internal house wiring costs. This was followed up by Phase II electrification programme, again partially financed by Sida, where 32 villages and around 13,000 households became beneficiaries between 2002 and 2004 at a Sida contribution of 1,203,107 USD for imported components only. Phase III is to start in 2005 and around 59 villages and 25,000 households and 1400 commercials are expected to be connected at a cost of 11.5 Million USD. This yields around 435 USD per household which is almost four fold of the cost in Phases I and II. This is mainly because Phases I and II were undertaken by the local utility, but implementation was extremely slow while Phase III is to be implemented by an external engineering turn-key contractor arrangement. This strongly points to the need to build local capacity for electrification to reduce costs and timely implementation.

Realising the opportunities rural electrification creates in terms of better social services and income-generating activities, a new rural electrification Directive has been issued, whose central goal is capital cost sharing. According to this directive, the Government covers the cost of medium voltage extension from nearest source while the benefiting villages/semi-urban areas cover the low voltage distribution costs. The village communities are allowed to pay in two or three instalments to make benefit of equivalent number of harvests, compared to full upfront costs payment practiced earlier. This arrangement is much appreciated by the villagers and request for electrification is now overwhelmingly high. As the grid penetrates the rural areas, agricultural or non-

agricultural income generating activities are expected to benefit by shifting from diesel-based machinery like gensets and pumpsets to electrical machinery.

Moreover, the Electricity Proclamation Number 141/2004, makes provision for the establishment of a Rural Electrification Fund, to be administered by the Ministry of Energy. This Fund shall be used to support the electrification of rural areas as well as areas considered economically non-viable for electrification by the permit holder. The financial source for this Fund is from the GoE, donors, 1% levy on electricity sales and community contribution. The World Bank has already committed 1.4 Million USD as seed money and this is expected to encourage other donor contributions.
To date electrification has proceeded through three-phase extension of the grid. This was mainly due to the proximity of focus areas to major urban centres where high load growth is anticipated in near future. However, this option is costly for settlements located further away from urban centres. Thus, the introduction of cheaper options such as (a) Phase to Phase, (b) Phase to Neutral and (c) Single-Phase-Earth-Return systems in the Phase III electrification programme is being considered. The Single-Phase-Earth-Return, Phase to Neutral and Phase to Phase systems i. e. c, b, and a above, are most economic in the order arranged. Hence even if the single-phase-earth-return is not found feasible, introduction of (b) and (a) is highly recommended, as they are much cheaper than the three-phase system EEC has been adopting in the past and current programs. In system (a) two phase conductors are used and this means a saving of 33% and (b) one phase conductor and one neutral conductor are used implying a saving of about 50% and if (c) is feasible a saving of about 67% can be achieved. The adoption of such systems depends on the soil situation of the area to be electrified and as such the soil condition of the areas have to be investigated.

Institutional and Implementation Arrangements for Rural Electrification

The institutional and implementation arrangements indicate that, EEC has been responsible for physical implementation of the rural electrification component to date. For the ongoing World Bank assisted rural electrification component, EEC has formed a project team, at least one Forman and two assistants have been assigned one each for the Dekemhare-Adikeyih and Keren-Barentu project areas.

The Department of Energy, through its project Co-ordination Office, will prepare and establish the business model for the co-operative distribution company in close collaboration with the relevant Governmental Ministries/Departments and with assistance from the various institutions and organizations, local and foreign consultants and staff seconded from other organizations as necessary. Each electrified village will be advised to establish an Electric Membership Co-operative to co-ordinate the management of electricity services inside the village. This may include, meter reading, bill distribution and tariff collection, conducting minor electrical extensions to new customers, etc. The benefits and responsibilities of the Co-operative will be clearly explained to villagers. The plan is to start formation of Co-operatives with a pilot phase at village level, then successful proceed to sub-regional and regional levels and finally at National level. It will be excellent if this could be achieved. However, there are signs that the villages are less

enthusiastic to establish cooperatives, despite the fact that the Department of Energy has developed basics of draft constitution for them and general guidelines on how to collect tariffs. In the first place, the educational level in the villages is very low and the members will have difficulty in keeping accounts and preparing reports.

The alternative approach of engaging the private sector phase by phase in the management of rural electricity services should also be tested at least in villages not prepared to form co-operatives. The Department of Energy and EEC have a plan to train electrical practitioners for each village to be electrified which will take responsibility to conduct in-house wiring as this is not done by EEC staff as part of the project. Potential trainees are the demobilised youth who were engaged in the defence of the country. These trainees could be selected as EEC agents for the village who will take the responsibility to distribute and collect electric bills and conduct minor extension to new customer sites. They will get commission from EEC proportional to the services provided. They could also widen the scope of their services by engaging in other energy systems like distribution of LPG, kerosene or even renewable energy technologies. As rural electrification intensifies, these private practitioners could develop into *rural energy service companies* or even Independent Power Distributors. The DOE in close association with EEC, the private sector, and academic institutions will monitor the institutional development.

Socio-economic impact of rural electrification will be appraised according to both socio-economic and financial criteria both before and after electrification. Data for rural electrification costs and benefits distinguishing between low and moderate electric load densities, between lighting and motive power, between the substitution of fuels currently used and the new consumption that the availability of electricity at competitive prices are essential for this study.

The major policy issue for the Rural Electrification component is the need for the government to produce an electrification access policy, defining indicators and setting targets. This would both signal the government's commitment to expanding access to electricity and provide a benchmark against which to measure the effectiveness of and electricity access programme. A consultant will soon be recruited to prepare a rural electrification framework and establishment of an Rural Electrification Fund for its operationalisation.

2.3 Promotion of Renewable Energy Technologies (RETs)

The Ministry of Energy and Mines has installed 25 wind and solar monitoring stations throughout the country', and a five-year data is available. Wind data collected so far indicate that about 300 villages, located mainly in the Central Highlands and southern Red Sea coastal areas, can benefit from wind-generated electricity. A pilot wind energy applications project funded jointly by the GoE and GEF, involving a small wind farm (3x250 kW) to strengthen the Port of Assab local grid, six decentralised wind-diesel hybrids to electrify semi-urban communities along the southern Red Sea coast and two wind mechanical pumping systems for irrigation are just being installed. The plan is to

replicate these wind energy applications elsewhere in wind-rich regions of Eritrea and/or feeding the national grid. There is also a plan to manufacture mechanical wind water pumps in collaboration with a local manufacturer. Such pumps for human and livestock consumption and irrigation could be installed anywhere in the country as per the wind resource assessment done so far. Ice making for fishermen and sea water pumping to salt fields along the coasts are among the productive functions of wind energy that we would like to promote.

The two most densely populated Administrative Regions receive the highest solar irradiation averaging around 6 kWh/m^2/day. Over 600 kW aggregate capacity involving over 2000 solar PV systems are in service in the country for applications like powering: health centres/stations, village water pumps, remote primary and junior schools, remote offices, light houses, telecommunications centres, solar home systems and even water pumping for drip irrigation. One private company has installed 100 solar home systems on monthly fee for hire basis, with two lights and battery charger for radio/radio cassette operation, in two villages. More Government-private partnership and donor support is required to expand the application of solar PV systems especially in areas far away from the grid, islands, pastoral communities etc. The Ministry of Agriculture itself is powering most of the rural livestock vaccination centres through solar PV. The Energy Research and Training Centre established to promote renewable and appropriate energy technologies has trained many technicians for the institutions and companies involved in solar business. This Centre is coordinating the analyses of wind and solar data and this is expected to lead to the preparation of strategic development plans and legislative framework for private sector participation.

At present there is a favourable policy environment for the promotion of wind and solar energy technologies. As indicated above, the Government is showing its commitment by allocating resources to the development of such energy systems. However, the quality of energy technologies, particularly, their capacity to deliver the anticipated energy services is crucial for their wider dissemination and continued use. The Eritrean Standards Institute is supposed to responsible for quality control and certification of such technologies but does have the institutional capacity to do so. In view of this, the Department of Energy has taken the responsibility to set standards and guidelines for renewable energy technologies. To this effect the Department has prepared draft standards/regulations for RETs based on International Standards Organisation.

Geothermal Energy: Part of Eritrea is situated in a volcanic area predominantly in the East African Rift Valley. Measurements made by Clynne *et.al* (1996) at the volcanic mountain Alid indicate an underlying hydrothermal reservoir with a temperature in the range of 250 - 350^{o}C., and concluded that the water to rock ratio in the reservoir is high enough for a developable hydro-thermal electricity generation system. It appears possible to install one or several power stations in this area. The distance to the existing transmission line is not more than 100 km, which makes the site even more interesting for development. More detailed studies are however necessary for an assessment of the financial and environmental feasibility of exploiting this geothermal resource. Initiatives

are being taken by the Rift Valley countries of Eastern Africa, in collaboration with UNEP, GEF and GTZ, to design a regional project to develop geothermal resources.

Modern biomass energy: The development of biofuels like biogas and briquetting from agricultural residues for fuelwood/charcoal replacement are still in their experimental stages. Investment in innovative new energy systems like hydrogen based fuel cells when found economically feasible will be considered for development.

2.4 Dissemination of improved stoves: (Adhanet Mogogo)

The task of developing and designing a more efficient, improved stove (*mogogo in local language)* for baking *injera* (a spongy bread consumed as staple food) has been one of the priorities of the Ministry of Energy and Mines. Energy use surveys conducted by the Department of Energy (Lahmeyer, 1997 and DoE 1998) showed that about 50 % of the energy used by Eritrean households is for baking *injera*, and more than 80% bake it using wood. The stoves used are very inefficient, inconvenient and unhealthy with the following characteristic design problems: -

- The heat from the burning fuel is not enclosed in a firebox, so much heat escapes;
- The *mogogo* geometry is not optimised to transfer heat well to the baking surface;
- Much smoke is produced causing health problems;
- Due to poor air supply, it is often difficult to get the fire started. Blowing, and kerosene are often used;
- With the exposed flame and floor-level construction, the burning stove is dangerous.

Through research efforts by the Ministry, an improved version of the traditional stove has been developed. The efficiency of this stove is over 20% which is more than double of its traditional version. As most of the stove components are producible in the villages, chain reaction is being promoted by training artisanal women to transfer skills from one village to the neighbouring villages. The improved stove dissemination programme of the Ministry of Energy and Mines is gaining national and international reputation. This is manifested by the distinguished Ashden Award it received from the London based organisation in 2003 (see www.ashdenaward.org). The improved stove has the following advantages.

- Improved stove use will decrease deforestation pressures, as well as reduce the emission of greenhouse gases, which now stands at 0.6 tons of CO_2/household/year;
- The standard of living will increase at the household level;
- Wood or dung collection labour will now be reduced by at least 50%;
- Due to decrease in wood collection duties, students will be able to spend more time studying;
- Cooking time is reduced, and so is cooking labour;
- Household cash expenditures are reduced from reduced wood and kerosene purchases;

- The health of people in the household will improve due to nearly eliminating the inhalation of smoke, respirable particulates, and other toxic emissions during cooking;
- There is also a social benefit, as cooks will no longer have clothes that smell of smoke.

By the end of 2004, over 27,000 stoves were installed in rural households; the target for 2005 is to install 10,120 stoves. This will be of great benefit to women as they shoulder the responsibility of fuelwood collection and cooking. The Ministry in collaboration with the local administrations has nearly managed to localise the production of key components, the fire grates by artisanal women and the cement block pipes for the chimneys by local manufacturers. The Department of Energy has started to benefit from carbon trading for the saved CO_2 emissions of 0.6 tonnes/stove/year at the rate of 6 USD/ton of CO_2. The Home Economics Unit of the MoA is one of the collaborating organisations in the dissemination program.

The Department of Energy had recently organised a stakeholders' workshop to explore opportunities for accelerated dissemination of the stove. To enhance the reduction of CO_2 emissions the workshop made the following recommendations:

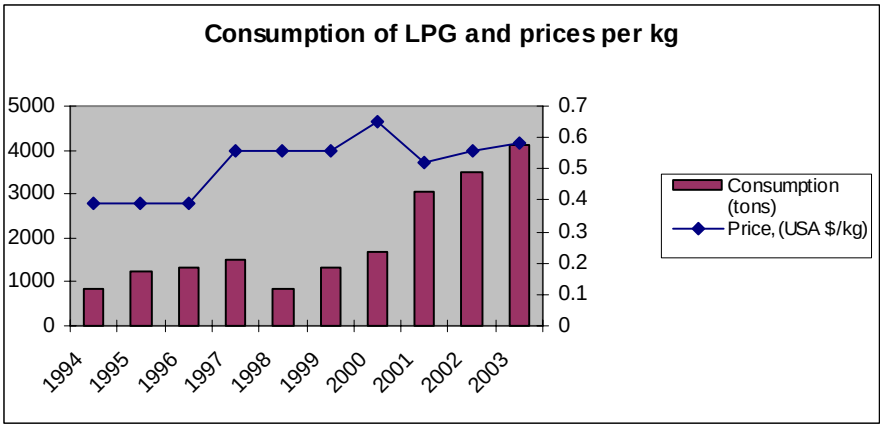
- Villages are to declare part of their common land as a closure to allow natural regeneration of biomass;

- Where the above is not possible, each household installing the stove is to plant at least 5 trees around its premises.

Local Governments and village administrations will take the responsibility to enforce these recommendations. The verifier of the carbon credit scheme will further monitor the implementation.

2.5 Distribution of LPG and associated cylinders and stoves: Case of Energy Market Reform

The Ministry of Energy and Mines wants to encourage the market development of LPG which is the preferred alternative cooking fuel for households and commercials. The consumption of LPG has been steadily increasing (see diagram below), but its market remained limited to the capital city, Asmara, and the ports of Massawa and Assab until recently.



The LPG business in Eritrea was considered too small by the petroleum companies -, Shell, Mobil and Total - , and none of them was willing to invest in it. Hence, a local private company, Erigas, was established and soon began the construction of 2000 m^3 LPG depot in Massawa. This greatly facilitated the importation of LPG since mid-1999. Earlier, Erisoc, another local private company, had began manufacturing LPG cylinders and stoves. The participation of Keren Shipping Line, a local company owning a gas tanker, has contributed a lot in lowering the cost of importation. The combination of these three factors is responsible for the sharp rise in the LPG market which is now almost totally private driven.

LPG prices are perceived by many people as quite high, despite the fact that the cost of useful energy for cooking is cheaper for LPG than electricity and fuelwood when efficiency is taken into consideration. Computations made in 2001, for instance, indicated that the cost of making one i*njera* using LPG was 2.3 USD cents compared to 4.3 cents using electricity (Habtetsion and Tsighe, 2002, p 1111). This misconception arises from the high costs of the gas bottles and stoves. To become LPG user, the smallest investment, in 2005 price, is around USD 127, which is quite beyond the affordability margin of poor households. This points to the need for payment mechanisms that allow potential LPG users to pay in small instalments over a long period. This mode of payment is being pursued by the private companies Erigas, Erisoc and Keren Shipping lines. This mechanism is attracting new users, and many new dealers are emerging in the provincial towns and big villages. Erigas estimates that there are over 45,000 gas bottles (cylinders) of 12.5-15 kg under circulation in the country.

The above discussions make it clear that the private sector can play a leading role in expanding modern energy services both for household use and income generation. Indeed, over a short period of time, the private sector has succeeded in the popularisation and delivery of LPG. What is even more interesting is that the private companies are doing fairly good business in what the big companies like Shell, Mobil and Total thought had no market. The findings also show that governments can accelerate the participation of the private sector both by removing market constraints and modernising and expanding the energy infrastructure particularly where either the risk factor or the required investment level is too high for the private sector. Realising this, the Government has modernised the old LPG distribution facility in Asmara. This suggests that so long as governments do not compete with the private sector for profit making and limit themselves to the facilitative activities, the roles of the governments and the private sector become complementary.

2. 6 Challenges in Implementation

Funding Requirements:

As the energy dimension of the national poverty alleviation programs of the different sectors has not been clarified, it is quite difficult at this moment to prepare a detailed 10-year implementation plan, budget breakdown, yearly investment requirements, type of energy technology and geographic area of beneficiaries, human and institutional capacity requirements etc., to meet the energy requirements for achieving the MDGs especially those related to improving agricultural productivity. Indicative projected investment requirements only for the parallel energy targets stated above, which the Ministry of Energy and Mines has planned to undertake, is provided below.

Table 2: Summary of investment requirements for improving energy access to the poor (in Million USD)

		2005	2010	2015	Total 2005-2015	Average 2005-2015
Rural grid based electrification	Capital costs	3	4	5	43	3.9
	Operating cost	1	1.2	1.2	12.4	1.13
	Total	**4**	**5.2**	**6.7**	**55.4**	**5.04**
Electrification through wind of villages/semi-urban areas	Capital costs	1.2	2	3	22.6	2.05
	Operating cost	0.8	1	1	10.4	0.95
	Total	**2**	**3**	**4**	**23**	**3**
Wind Water Pumping Units	Capital costs	1	1	1	11	1
	Operating cost	0.4	0.4	0.4	4.4	0.4
	Total	**1.4**	**1.4**	**1.4**	**15.4**	**1.4**
Solar PV for schools, health facilities, water pumping, solar home systems, MSMEs	Capital costs	1.64	1.64	1.64	18	1.64
	Operating cost	0.22	0.22	0.22	2.4	0.22
	Total	**1.86**	**1.86**	**1.86**	**20.4**	**1.86**
Improved stoves 400,000 households	Capital costs	0.5	0.8	1.0	8.2	0.75
	Operating cost	0.1	0.2	0.3	2.1	0.2
	Total	**0.6**	**1.0**	**1.3**	**10.3**	**0.77**
Biogas units of different sizes	Capital costs	0.4	0.4	0.4	4.4	0.4
	Operating cost	0.12	0.12	0.12	1.32	0.12
	Total	**0.52**	**0.52**	**0.52**	**5.72**	**0.52**
	Grand Total	**10.38**	**12.98**	**15.78**	**130.22**	**12.59**

As indicated in Table 2, an average of 12.6 Million USD per year is required between 2005 and 2015, bringing the total investment to over 130 Million USD. The estimated financial needs compares favourably with the average yearly investment – around 17 Million USD - for the power sector alone in the last 12 years.

Thus, significant government and donor support is required to realise the stated energy goals. The Government of Eritrea and the World Bank have been collaborating on the power sector for some time which has provided a strong foundation for the partnership cited in previous sections. The European Union Energy Initiative for Africa, GEF, NEPAD and the Clean Development Mechanisms of the Kyoto Protocol are also envisaged as potential sources of financing.

Harmonization Requirements:

The Ministry of Energy and Mines is pursuing an aggressive approach in providing modern energy services to the rural communities. The initiatives include grid expansion, improved stove dissemination, wind energy for grid reinforcement and stand alone systems for villages, solar PV systems for community benefits, expansion of LPG and kerosene supplies, exploration of geothermal energy, etc. Note that the main targets are the village communities and income generating activities within villages. It is up to the beneficiaries and or their mentors like the Ministry of Agriculture to extend electricity services at cost e.g., to irrigation farms, grinding mills, rural agricultural or construction industries, mining sites, etc. Thus, when the Ministry of Agriculture or private firms intend to develop an agricultural area requiring modern energy services, they have to include the provision of this energy in the project design. As to the type of the most feasible energy or appliance technology, they can consult and negotiate with the MEM and the local network operator like EEC. The same trend also applies to the other rural infrastructure requirements for such agricultural projects. To facilitate these matters, the MoA is recommended to establish a Rural Infrastructure Unit which acts as a liaison with the concerned Ministries or other institutions and stakeholders. Moreover, the Ministry of Agriculture should play a lead role in replacing diesel powered irrigation pumps to the more dependable and cheaper electrical pumps in newly electrified villages. This may include designing credit facilities for the replacements.

The Ministries of Energy and Agriculture should also collaborate in harmonising their policies for biomass energy or its replacement by other sources. While development effort of biomass resources is the responsibility of the whole nation in general and Ministry of Agriculture in particular, any energy substitution (e.g., through biogas, LPG and natural gas) or conservation effort (e.g., improved stoves) to reduce dependence on biomass energy is largely the responsibility of the MEM. Rural villages should be encouraged to plant their own trees in common land or own farms for whatever uses including for firewood or charcoal. One area of interest which requires harmonisation is the development of forest resources for the production of electric poles for rural electrification. Considering the arid and semi-arid atmosphere of the country, the authors have the impression that this may not be feasible, but wherever it is requires promotional efforts.

Global increase in oil prices:

One of the major threats to the realization of the energy vision is increasing oil prices. Eritrea is a low-income oil-importing country, and it is extremely vulnerable to oil price increases. Due to its limited economic capacity, it is unable to stand oil price shocks the world is witnessing these days. Eritrea spends about 140 Million USD on oil importation in 2004, accounting for around one quarter of its GDP. These puts heavy pressure on its balance of payments and reduce its GDP. Saghir (2005) contends that an increase of a $10 a barrel reduces GDP on average by between 0.4 and 1.5 per cent in countries that are net oil importers.

The impact of international oil price increases on EEC's finances was particularly adverse. In 2004 the average price of crude oil was about 25% higher that in 2003. this lead to two tariff

adjustments in 2004 that increased EEC's billing rate by 15%, but this was not enough to cover the power generation cost. As a result, EEC suffered operational loss in 2004. The average price of crude oil for the first quarter of FY 2005 was about 42 US$/bbl, another 25% increase in fuel price from 2004. Given the less than required increase of tariff in 2004, EEC will have to increase its tariff by about 55% to break even (IDA, 2005).

To reduce the impact of oil price increases on the economy, the Government has introduced certain measures like, fuel rationing, price controls to discourage consumption, particularly for petrol driven cars. However, as Saghir (2005) has rightly observed, the impact of large energy price increases is often regressive. This means that it is the poor who are the first to be adversely impacted and often carry the burden. This points to the need of designing protection mechanisms to safeguard the energy needs of the poor, like kerosene in the case of Eritrea.

3. Expected and Actual Impacts of Energy Reforms

The impact of power sector reforms on the poor is becoming controversial. Karekezi and Sihag (2004) argued that the power sector reforms in Kenya and Uganda appear to have been detrimental to electrification of the poor. Power sector reforms are effected with the intention of attracting investment and improving the performance of utilities often leading to tariff increases and removal of subsidies. These resulted in reduced electricity consumption by households and lower rates of connection in both countries. These points to the need for protecting the interests of the rural population through "ring-fencing" mechanisms and to conduct rural electrification side by side with power sector reform measures as recommended by Karekezi and Sihag (2004). Paradoxically, slow reforming countries like Mauritius and China have achieved very high electrification rates mainly due to electrification policies favourable to rural areas. Eritrea's quite extensive rural electrification program while simultaneously undertaking power sector reform seems to be in par with this recommendation. The cost-sharing principle enshrined in the Rural Electrification Directive of the Ministry, the establishment of Rural Electrification Fund, the introduction of cheaper options such as (a) Phase to Phase, (b) Phase to Neutral and (c) Single-Phase-Earth-Return systems in the Phase III electrification programme, and the involvement of the benefiting communities in the management of electricity services in electrified areas are all manifestations of innovative approaches.

The on-going 50 Million 'Asmara Power Distribution and Rural Electrification Project' will potentially have a number of beneficial impacts on the natural and the socio-economic environment, both during its construction and its operational life. The major positive benefits of the Asmara Power Distribution component will be the reduction of electrical losses by about 9% and the reduction in overall distribution operations and maintenance costs, inducing a lower cost of production per kWh of electricity. The reduction in technical power losses may be translated to the reduction of CO_2 emissions thus has global environmental benefit. The new generation facility at Hirgigo near Massawa is consuming around 170 grams of heavy fuel oil per kWh of electricity generated compared to the average consumption of around 250 grams of diesel or light fuel oil in the replaced old systems. From the new Hirgigo Power Plant 234 GWh of electricity was generated in 2003, which means a reduction of CO_2 emissions by around 59,000 tons in that year.

To make the power systems more efficient and to promote energy conservation measures, major projects to rehabilitate the old transmission and distribution systems in Asmara and Massawa have been designed. The Massawa project, funded by the EU, has already been completed while implementation of the Asmara component will start in 2005. When finalised, the current technical losses in transmission and distribution system will be reduced by at least 50%. Assuming that oil fired stations produce about 0.7 ton of CO_2/MWh generated, this reduction in technical loses implies CO_2 abatement of 21,000 tons/year. Other secondary benefits include better supply quality, less disturbances and outages, voltage drops will be avoided and/or maintained at acceptable levels, less connection costs for new customers, all of which will contribute to much better satisfied customers. Other positive benefits to the natural environment will be the reduction of visual intrusion by above ground distribution infrastructure in the Asmara City centre.

That of the Rural Electrification component, the major benefit will be the availability of the most preferred and versatile energy form, electricity, to motivate rural development. Substitution of kerosene lighting and diesel operated pumpsets and small gensets by electricity in the rural project areas will have global environment benefit. These extensions of grid electricity supply are expected to remove some of the energy-related barriers to sustainable development. Many income-generating facilities are expected to mushroom and existing ones strengthened. The large unserved needs for water pumping and lighting in rural areas will have electric options, and the over-utilisation of biomass fuel for cooking and heating which has led to degradation of the forests and soil fertility at an alarming rate will be reduced. The rural population will also be able to enjoy associated improved facilities for entertainment at home, refrigeration, electronic communications and services, small-scale industrial production, etc. In many areas, economic activity is constrained by factors other than electricity supply, thus the need for integrated approach. The economic impact of electricity supply improvements alone may be limited in the initial years, but eventually access to electricity is expected to generate socio-economic benefits and income generating activities in otherwise marginalised areas. These benefits apply to all electrification schemes using grid extension or using the renewables wind, solar, geothermal etc. However, there is global environmental benefit of 1.6 ton of CO_2 reduction from each kW of RETs capacity.

It is obvious that the most important barrier for providing modern energy services to transform the rural communities is lack of financing for energy technologies. Effort is in progress to solicit such funds from national and international financing sources. Other major observed problem which can significantly delay the implementation of projects or programs is the under-capacity of implementing national institutions.

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Table A1: Energy Development Index for African Countries

Rank	Country	EDI	Commercial energy per capita index	Traditional biomass use index	Electrification index	HDI	EDI	HDI world ranking
1	Libya	0.775	0.341	0.985	0.998	0.794	0.775	58
2	Tunisia	0.772	0.538	0.827	0.950	0.745	0.772	92
3	Algeria	0.693	0.098	0.996	0.985	0. 704	0.693	108
4	Egypt	0.679	0.078	0.983	0.977	0.653	0.679	120
5	Morocco	0.589	0.035	0.956	0.774	0.620	0.589	125
6	S. Africa	0.588	0.226	0.868	0.671	0.666	0.588	119
7	Namibia	0.414	0.051	0.844	0.347	0.607	0.414	126
8	Gabon	0.333	0.061	0.460	0.479	0.648	0.333	122
9	Ghana	0.304	0.016	0.412	0.485	0.568	0.304	131
10	Cote'd Ivoire	0.290	0.014	0.349	0.507	0.399	0.290	163
11	Senegal	0.280	0.016	0.510	0.314	0.437	0.280	157
12	Cameroon	0.253	0.014	0.338	0.407	0.501	0.253	141
13	Zimbabwe	0.251	0.032	0.311	0.409	0.491	0.251	147
14	Nigeria	0.238	0.021	0.246	0.449	0.466	0.238	151
15	Sudan	0.229	0.013	0.365	0.310	0.505	0.229	139
16	Benin	0.205	0.010	0.357	0.248	0.421	0.205	161
17	Congo	0.189	0.008	0.364	0.196	0.494	0.189	168
18	Zambia	0.179	0.018	0.335	0.184	0.389	0.179	164
19	Togo	0.176	0.001	0.359	0.170	0.495	0.176	143
20	Eritrea	0.165	0.005	0.305	0.184	0.439	0.165	156
21	Angola	0.149	0.022	0.373	0.050	0.381	0.149	166
22	Kenya	0.124	0.012	0.271	0.091	0.488	0.124	148
23	DR of Congo	0.118	0.008	0.262	0.083	0.365	0.118	168
24	Mozambique	0.107	0.009	0.226	0.087	0.354	0.107	171
25	Ethiopia	0.037	0.002	0.084	0.026	0.359	0.037	170

Source: IEA, World Energy Outlook 2004.

Table A2: Rural electrification completed (1999-2001)

Project Area	Number of Villages/towns	Project cost (US$)
Aditekelezan	11 villages + 1 town	297,189
Dibaruwa	10 villages + 1 town	403,131
Elabered	2 villages + 1 town	142,737
Hagaz	1 village + 1 town	193,043
Teseney	3 Villages	413,900
Total	27 Villages +4 towns	1,450,000

Table A3: Rural villages and towns planned to be electrified, 2002-2008

Project Area	**Number of Villages/towns**	**Project cost (US$)**	**Status of implementation**
Himbirti	17 Villages	319,029	In progress
Mekerka	12 Villages	484,175	In progress
Mendefera	13 Villages	399,903	In progress
Keren	14 Villages	2,420,437	Expected to start in 2005
Barentu	7 Villages	2,498,559	"
Dekemhare	40 Villages	3,314,014	"
Adikeyieh	26 Villages	1,633,461	"
Nakfa	1 Town	324,660	"
Afabet	1 Town	324,660	"
Omehajer	1 Town	242,718	"
Tsorona	1 Town	242,718	"
Tio	1 Town	324,660	"
Total	129 Villages + 5 towns	11,367,378	"

Source: Ministry of Energy and Mines, Eritrea Electric Authority 2002-2004 Budget (EEC,2001)