# IGAD Household Energy Programme

## Eritrea, Country Energy Status

## Overview of the political economy

**Geography:** Eritrea lies between $12.5^0$ and $18^0$ north of the equator and just north of the Horn of Africa. It is bordered in the north west and west by the Sudan, in the south by Ethiopia and in the southeast by Djibouti. Its longest border is with the Red Sea to the east. The country has a terrestrial area of 125,000 $km^2$, a coastline of over 1200 km, a continental shelf of about 52,000 $km^2$ and over 350 islands. Eritrea's proximity to the Red Sea together with its physical features account for its varied climate and rainfall. The Central Highland covers a plateau, which extends around 350 km, from the northwest to the southeast with most of the elevation being 1500 m and in total covers 1.7 million ha. Mean annual temperatures range from $17^oC$ to $21.5^oC$. With the exception of a small area of the Eastern Escarpment referred as the Green Belt Zone where rainfall could be as high as 1400mm, the highland region gets more regular rainfall ranging from 400 to 700 mm per year. Much of this area has been settled and cultivated for a very long period. Soil erosion is a considerable problem here. Crop diversity in this zone is especially high and in conjunction with the Ethiopian highlands, the region is recognised as one of the global centres of crop origin. Large areas of the central highlands are virtually devoid of tree cover, except for small remnant forests and woodlands in remote and inaccessible parts of the country.

The Green belt, which has a bimodal rainfall distribution with the highlands during June - September and gets further lighter rains during November - February, supports one of the few remaining extensive areas of relatively intact natural woody vegetation in Eritrea. Towards the east and north of the central plateau is an extensive coastal plain, which comprises the Eastern Lowlands. Altitude ranges from below sea level to around 600 m and annual rainfall averages around 200 mm. Agriculture is thus quite limited except in areas, which benefit from seasonal riverine flooding. Spate irrigation systems, which depend on the construction of barriers to divert seasonal floods into agricultural areas, are the primary means of irrigation. Pastoralism is also widely practised throughout the zone.

To the west of the main plateau are the Western Lowlands, which are divided into northern and southern sub-zones. Rainfall ranges from less than 300 mm in the north to more than 600 mm in the south. Altitude extends from 400m to 1500 m above sea level. Population pressures are quite low and pastoralism is common. Drainage from the Highlands into the Nile Basin flows through the Western Lowlands in several extensive riverine systems, which support good forest cover as well as irrigated farmlands.

**History:** In 1890, Italy set the boundaries of Eritrea and ruled it as a colony until 1941. The British defeated the Italians in the African front during World War II and took over the administration of Eritrea until 1952 under the UN mandate. After some years of intense deliberations to decide on the fate of Eritrea, the UN adopted a resolution to

Federate Eritrea with Ethiopia guaranteeing Eritrea some democratic rights and autonomy. However, during the federation with Ethiopia, Emperor Haile Selassie's government systematically violated the rights granted by the UN and actually abolished the federal status in 1962. By 1961, an armed struggle for independence had already began after the failure of years of peaceful protest.

In May 1991, 30 years after the devastating war for independence, the Eritrean People's Liberation Front (EPLF) liberated the entire country. At the same time, the Ethiopian People's Revolutionary Democratic Front overthrew the Ethiopian Military Junta, the Derge, led by Mengistu Hailemariam. In April 1993, the Provisional Government of Eritrea conducted an internationally supervised referendum in which 98.5% of the population participated of which 99.8% voted for independence. Soon after, a Constitution Drafting Commission was established and its task was concluded in 1997 with the approval of the national constitution.

**Economy: -** the 30 years war caused decades of lost development due to deliberate neglect as well as destruction of economic and social infrastructures. Today, Eritrea is one of the least developed countries with per capita income gradually rising from $ 130 in 1992 to around $ 260 per year for the year 1997 (Ministry of Finance, 1998). Reports from the IMF (August 1998) and the World Bank (August 1998) on Eritrea confirm these facts and have stated that the GDP yearly growth rate averaged out to be 7% between 1993 and 1996 and was 8% in 1997. Over 70% of the population depend for their livelihood on traditional subsistence agriculture including crop farming, livestock raising and fishing, although commercial agriculture and fishing have recently been revived. Eritrea's industrial base which was of better status compared with its neighbours in the 40's and 50's is made up of small to medium scale consumer-goods producing industries (food, beverages, leather goods, textiles, salt etc.) whose technology is now largely out of date as a result of neglect of investment during the long war. In a year of adequate rainfall, Eritrea used to produce only about 50% of its food requirements before 1998. With the Government’s new integrated farming approach food self sufficiency is rising up fast reaching almost 90% in 1999. Agriculture usually accounts for about 15 - 25% of the GDP, the latter being during good rainfall seasons, industry about 30% and the service sector covers the balance of the national income.

Eritrea has, however, ample natural resources including over 2 million hectares of potentially arable land compared to less than 5% already under cultivation i.e. about 450,000 ha and the vast Red Sea continental shelf. The Red Sea fishing grounds are estimated to be capable of sustaining a production level of around 70,000 tons of fish per annum, while the current production level is less than 5,000 tons per year (Ministry of Fisheries Report, 1998). With respect to mineral resources, studies indicate the existence of base metals (gold, zinc, copper, lead, silver etc.) in several parts of the country but the commercial viability of the deposits has yet to be established. Several companies have recently received licenses to undertake exploration and prospecting activities in the more promising areas. The potential for extracting petroleum from the Red Sea Basin is also considered good and one company has already began exploration works. Drilling of three wells was conducted in 1998/99.

The Government's development efforts since independence, has been concentrating on rehabilitating and rebuilding war-damaged and destroyed economic and social infrastructures, creating and strengthening the institutions of a new state, and laying down the Macro-Policy and legislative ground-works for development. The overriding objective of the Macro-Policy is " the creation of a modern technologically advanced and internationally competitive economy within the next two decades ".

**Population**: - No population census has been conducted in the country since independence. Thus, its population size is not known with any degree of precision. Some rough professional estimates mostly based on the 1993 national referendum put the country's population in the range of 2.5 to 3.5 million, with as much as 700,000 living in urban areas. Estimates of the number of Eritreans in the Diaspora range between 700,000 and 1,000,000. The population is culturally and linguistically diverse, consisting of nine ethnic groups namely; Tigre, Tigrigna, Saho, Hedareb, Bilen, Kunama, Nara, Afar and Rashaida. There are plans to undertake a census shortly.

The Department of Energy in co-operation with Lahmeyer International conducted the first ever comprehensive energy survey for the country with 1995 as the base year and taking a population figure of 2.9 million. This corresponds with the more dependable Ministry of Local Government's figure of 657,763 households in the country and an average national household size of 4.4 as conformed in the National Demographic and Health Survey of 1995.

Experiences of many countries show that fast urban development without proper planning results in chaos. High unemployment rate, crime increase, traffic congestion, serious housing shortages, frequent power cuts and adverse environmental impacts are some of the problems that are currently aching fast growing cities that have not adequately planned and invested in sound urban development. The Municipality of Asmara seems to be aware of such potential problems and is cautious not to see Asmara expand without control. The over all plan is to create satellite towns around the city. Asmara is at about 2350m above sea level and enjoys a rather mild and refreshing climate. It gets an annual rainfall of between 400-600mm. Average yearly temperature is 17.5$^{o}$C and varies from as low as 0 to 30 $^{o}$C. The City’s average monthly relative humidity ranges from 44% in the dry season to 84% in the wet season.

## Overview of the Energy Situation

The major objective in the energy sector is to ensure the supply of adequate, secured, reasonably priced and whenever possible environmentally sound energy system in order to facilitate the growth of the economy and improve the quality of life of the people.

The Ministry of Energy and Mines realizes that the future prospects for growth of the national economy and the betterment of the quality of life of the people is dependent on the ability to:-

- Provide ample, dependable and affordable energy supply,

- Rationalize the development and the efficient utilization of available energy resources, both conventionals and renewables,
- Regenerate the already degraded environment through supportive measures of developing alternative energies to traditional biomass usage
- Create conducive atmosphere to attract private investment in energy production and distribution,

To achieve these important goals, the major activities made in the energy sector since the liberation of the country in May 1991 include the following:

- The electricity generation capacity of the Eritrea Electric Authority (EEA) has been increased from as low as 35 MW in 1991 to over 70 MW by the end of 1996. Consequently, the percapita electricity consumption grew from as low as16kWh in 1991 to 53 kWh by 1998. A number of villages around our major towns got access to electricity.

- A major project for power generation and transmission expansion is to be commissioned in the first quarter of the year 2000. This project, besides providing 90 MW additional capacity will enable the inclusion of seven major towns and several rural communities into the central grid system.

- To make the power systems more efficient and to promote energy conservation measures, feasibility studies of major projects to rehabilitate the old transmission and distribution systems in Asmara and Massawa have been finalized. The Massawa project is expected to enter in the implementation process soon while that of Asmara is waiting for financing.

- To diversify the sources of energy supply:-
  - pre-feasibility study for geothermal energy potential has been conducted,
  - national wind and solar energy assessment study is in progress
  - to tackle the prevalent household energy problems, a programme to disseminate improved traditional wood-stoves has been launched and the supply and distribution of kerosene and LPG has been expanded
  - a feasibility study of wind energy applications has been finalized in the southern coastal areas of Eritrea. A project document for wind park to feed the Assab grid and many decentralized stand alone or wind –hybrid systems in the small towns and villages in the area has been prepared. Fund soliciting is also in progress

- Petroleum law and regulations promulgated and two concessions for oil prospecting awarded to a consortium of three foreign private companies. Three wells have been drilled in the concession area with the first well having oil and gas shows whereas the two wells were dry.

- Negotiation is going on to revitalize and expand the Assab Refinery with interested private companies.

- Many solar PV systems with an aggregate capacity of over 400 kW have been installed in the rural areas for various applications including 25 health centers, 60 water pumps, 70 school lights and power supply, general communication purposes, light houses, powering remote offices, etc.

- An Energy Research and Training Center has been established by the Ministry in Asmara with the purpose of undertaking research and development activities on renewable energy resources and technologies; installations, repair and maintenance of RETs; training of RETs technicians and demonstration to the public; improvement of stoves etc.

- Last but not least, formulation of new energy laws, regulations and standards is in progress. The intention is to reform and deregulate the sector so as to encourage competition and efficiency, to avoid any form of subsidy, to promote private investments, to protect the environment and to ensure public safety etc.

## Energy Demand and Supply in 1997

The 1997 energy balance of Eritrea shows that total final energy consumption was 40,250 Tera-Joules or around 958,000 tons of oil equivalent. Of this, biomass based energy accounted for 77.3%, oil products for 21.3% and electricity 1.45%. Household energy takes the lion's share in the energy balance at 77.8%, transport 13,8%, public and commercial at 6% and industrial 2.4%. From the household energy, 96.4% is biomass based, 3.1% oil products and 0.5% electricity. Per capita consumption of commercial energy (oil + electricity) was 80 kilogram of ton equivalent in 1997.

## Biomass Energy Resources and takeoffs for energy in Eritrea

The table below shows the estimated final biomass energy consumption in the country between 1994 and 1997. Note that the 1995 data is established by the comprehensive energy survey conducted jointly by the Department of Energy and Lahmayer International for that year. The entries in the rest of the years are extrapolated backwards for 1994 and forward for the years 1996 and 1997 based on 3% population growth for the household energy consumption and 7% growth rate for the consumption in the micro, small and medium scale commercials still using traditional biomass.

Table 2. Biomass Energy Consumption 1994-1997 in Physical Units (tons)

| Type of Fuel | 1994 | 1995 | 1996 | 1997 | Per capita Consumption in 1997. |
|---|---|---|---|---|---|
| Fuelwood | 1,292,430 | 1,334,070 | 1,375,230 | 1,418,199 | 457 Kg. |
| Charcoal | 113,766 | 117,419 | 121,060 | 124,831 | 40 Kg. |
| Dung | 359,986 | 371,332 | 382,678 | 394,379 | 127 Kg. |
| Agri-residue | 47,245 | 48,773 | 50,301 | 51,879 | 17 Kg. |

The percapita consumption of fuelwood ranged from as low as 120 kg in Asmara and surrounding rural areas to as high as 970 kg in the remoter areas with better availability of forest resources. The dung and agriresidue consumed is practically in the central and southern highlands where scarcity of fuelwood is prevalent. It is estimated that 70% or 80,000 MT of the charcoal consumption is from incomplete combustion of feulwood or what may be called recycled charcoal from cookstoves and the rest is proper charcoal converted according to a wood/charcoal ratio of 6:1.

It is already a major concern to the nation that the limited remaining forest resources (less than 1%) were being depleted at a rate exceeding the rate of regeneration. Lahmeyer International stated that the threshold for sustainable maintenance of a healthy stock of trees through renewal is when the forest take-off for fuelwood purposes and other uses is a maximum of 10-20% of annual yields and a maximum of 1.25% of stock (see Table 3).

Table 3. Forest resources take off for household energy purposes (MT is Metric Tonnes).

| | Takeoff/stock | Take off/yield | Take off $10^6$ MT | Stock, $10^6$ MT | Yield, $10^6$ MT |
|---|---|---|---|---|---|
| Critical Threshold | 1.25% | 10-20% | - | | |
| 19984 CESSEN | 1.47% | 20% | 1.2 | 81.6 | 6.1 |
| 1995, Lahmeyer | 2.4%-2.8% | 32-37% | 1.78-2.08 | 73-75 | 5.48-5.63 |

The present take-off of fuelwood from forest as estimated by Lahmeyer assumes an additional 20% for non household uses (mainly industry and commerce) i.e. 1.78-2.08 million MT/annum, as well as charcoal production from fuelwood.

The 1995 survey estimated that the animal dung consumption for energy of 0.37 million MT is 35% of the total dung production from an estimated cattle population of 1.3 million. The negative effect of this on soil nutrient is obvious.

Lahmeyer estimated the total stock of agricultural residue in 1995 to be around 65,000 MT from crops and 100,000 MT from Cotton stock, of which 47,0000 MT or 28.5% of this stock is being used for energy. A 4000 tonne/year capacity of a pilot cotton stalk briquetting plant is already in operation as of the first quarter of 2000.

## Electricity

In Eritrea, all electricity is generated by thermal power stations that use imported oil. Most of the power utilities in the country are owned and operated by the Eritrea Electricity Authority (EEA). This public enterprise operates two systems, namely, the Inter-Connected System (ICS) and the Self Contained System (ICS). The combined generation capacity of both power systems amounts to only 70MW whereas the aggregate capacity in the country is around 100 MW. In 1997, out of the total 180 GWh marketed electricity, 46.3% was consumed by the industrial sector, 34.2% by the household sector and 19.5% by the commercial and other sectors.

Table 4. Electricity Supply from EEA systems 1994-1998.

| Year | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|
| Generation, GWh | 130.2 | 144.7 | 161.0 | 179.7 | 186.0 |
| Consumption, GWh | 109.5 | 122.3 | 136.3 | 151.3 | 153.8 |
| Losses, % | 15.9 % | 15.5 % | 15.3 % | 15.8 % | 17.3 % |
| Number of Customers | 74,604 | 78,000 | 85,250 | 91,549 | 94,164 |

The extremely low per capita electricity consumption, which has increased from as low as 16 kWh in 1991 to 53 in 1998 is a direct manifestation of the low level of the Eritrean economy on the one hand and the development trend it has acquired after the liberation of the country. However, the fact that about 80% of generated power is consumed in the areas supplied by the Asmara-Massawa interconnected power system and the balance of 20% in the rest of the country shows the unequitable distribution of the power supply system in the country and the concentration of commercial and industrial activities around the capital.

Eritrea faces a huge challenge in electrifying its villages. It is a fact that rural electrification via the Electric Authority is nor economic as the loads are not concentrated enough and the demand per household is estimated to be too small. The present income level of the rural communities is also not high enough to cover capital costs for electricity connection. Thus the only viable option is to establish a revolving fund (Rural Electrification Fund) with contributions from Government, the EEA, the benefiting communities and donors to cover capital costs.

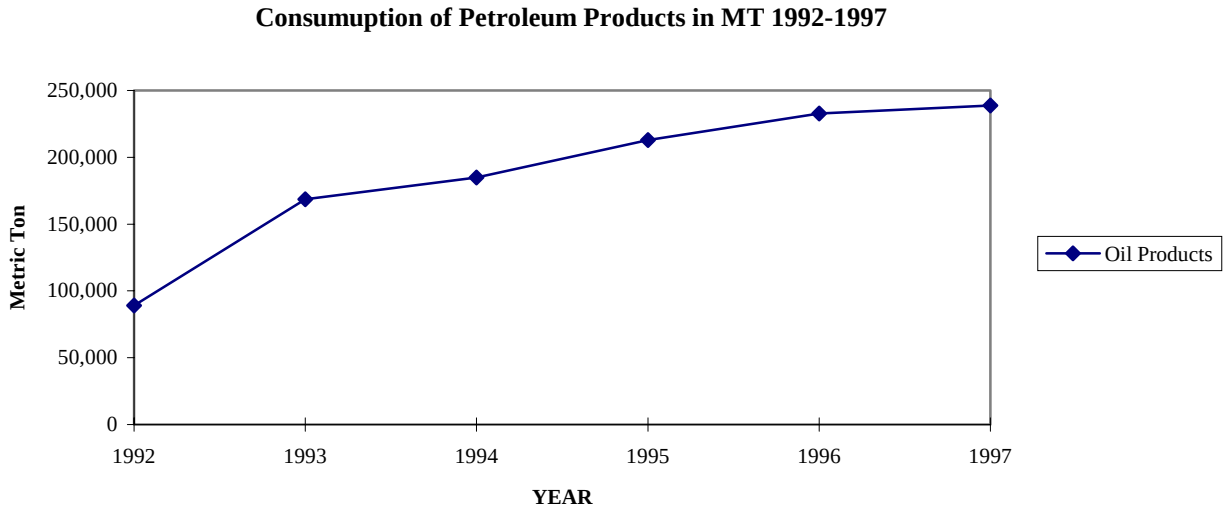
**Oil Products**

Petroleum products is the second major source of energy and the only fossil fuel used at present in Eritrea. The consumption as shown in Table 5 and the graph that follows, has been increasing at an average of 11.4% between 1993 to 1997 but there was a big jump of 89% in 1993 compared with the previous year. The graph is showing a tendency of saturation in the oil market in the later years of 1996/97, the increment being only 2.6%.

**Table 5** Consumption of Petroleum products in MT 1992 -1997

| PRODUCTS | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| LPG | 300 | 430 | 847 | 1255 | 1631 | 1504 |
| MGR | 6096 | 10228 | 11613 | 12596 | 14035 | 14,733 |
| KERO | 8146 | 12263 | 14181 | 17237 | 19721 | 21086 |
| JET A-1 | 3525 | 3889 | 4211 | 5411 | 9612 | 9859 |
| ADO | 55685 | 103028 | 114369 | 128792 | 134147 | 137730 |
| IFO | 11722 | 23657 | 26396 | 34829 | 45064 | 43160 |
| BFO | 3642 | 11903 | 9723 | 10793 | 6460 | 7972 |
| BITUMEN | - | 3265 | 2158 | 220 | 213 | 483 |
| LUBRICATS | - | - | 1301 | 1795 | 1961 | 2475 |
| TOTAL | 89116 | 168,663 | 184,799 | 212,928 | 232,844 | 239,002 |

Of the total final supply of oil products amounting to 8555 TJ or 203,690 toe, 65.1% was consumed in the transport sector, 11.2% in household, 16% in public and commercial and 7.7% in industry. Between 1993 and 1997, Table 5 shows that LPG yearly consumption grew by 36.8%, gasoline by 9.5%, kerosene by 14.5%, jet A-1 26.2%, gasoil 7.5%, light fuel oil 16.5%, while bunker fuel oil decreased by 10%. The demand for the household fuels kerosene and LPG is increasing fast as they are partially substituting the already scarce biomass consumption for cooking in the cities and rural areas respectively. The quite high fuel oil demand rise is due to the commissioning of 3x5.7 MW gensets at Beleza in the ICS in November 1995.



The estimate of the national biomass energy consumption for 1996 was based on the 1995 base year data established after the comprehensive survey. This was done by assuming the **household** biomass energy consumption to grow by just the population growth rate of 3%, whereas the **commercial** biomass consumption followed the economic growth rate of 7%. The population was assumed to be 2.91 million in 1995, + 3% or 3 million in 1996 and +3% or 3.1 million in 1997. The same assumption is being followed for estimating the 1997 over that of the 1996 data base for the traditional biomass consumption. The consumption of electricity and oil products for these two sectors is obtained form EEA and PCE. Table 7 shows the energy demand, fuel by sector in physical units of 1997. The column under public and commercial sector includes energy consumed by the public institutions like EEA, the telecommunications, mass media, hospitals, education, defence, agriculture, banking and insurance, port services, hotels, micro, small and medium scale manufacturing enterprises etc. The oil products consumption registered for these institutions is directly to their premises not through the filling stations.

In Eritrea, **industrial** energy consumption is limited to the sources electricity and oil products while consumption in the **transport** sector is limited to oil products distributed through the existing filling stations only. The information as entered in the relevant columns of Table 7 was made available from EEA for electricity consumption and PCE + oil companies for the oil products. Table 8 shows the same energy demand, fuel by sector, for 1997 but in common energy units whose conversion factors are shown below.

Table 7 Energy Demand, Fuel by Sector, 1997 in Physical Units

| Fuel/Unit | Household | Industry | Publi/Comm | Transport | Total |
|---|---|---|---|---|---|
| Electricity, MWh | 49,113 | 84,233 | 29,204 | - | 162,550 |
| LPG, tons | 1,504 | - | - | - | 1,504 |
| Gasoline, tons | - | - | 1038.31 | 13,694.4 | 14,733 |
| Kerosene, tons | 20,546.17 | 4.71 | 534.66 | - | 21,086 |
| Jet Fuel, tons | - | - | - | 9,859 | 9,859 |
| Diesel, tons | - | 1086 | 38,769.26 | 97,874.55 | 137,730 |
| Light F. Oil, tons | - | 14,792.22 | 28,367.61 | - | 43,160 |
| Bunker, tons | - | - | - | 7972 | 7,972 |
| Bitumen, tons | - | - | 483 | - | 483 |
| Lubricants, tons | - | 184.92 | 787.48 | 1502.31 | 2475 |
| Firewood, tons | 1,372,403 | - | 45,796 | - | 1,418,199 |
| Charcoal, tons | 121,107 | - | 3724 | - | 124,831 |
| Dung, tons | 388,470 | - | 5910 | - | 394,379 |
| Agri-residue, tons | 50,017 | - | 1862 | - | 51879 |

## Conversion Factors and Energy Equivalents

| | |
|---|---|
| 1 Calorie (Cal) | 4.186 Joules (J) |
| 1 Ton of oil equivalent (toe) | 42 GigaJoules (GJ) |
| 1000 kWh = 1 MWh | 3.6 GJ |
| 1 Tera Joules (TJ) | $10^{12}$ GJ = 1000GJ |

The following energy values per physical unit of fuel type where adapted from the LEAP/EDB computer programme installed at the Department of Energy in 1996 by Stockholm Environment Institute.

| Fuel Type | Energy value |
|---|---|
| Fuelwood | 16.6 GJ/ton |
| Charcoal | 28.88 GJ/ton |
| Agri-residue | 12.5 GJ/ton |
| Dung | 8.4 GJ/ton |
| Electricity | 3.6 GJ/MWh |
| Kerosene | 43.195 GJ/ton or 33.692 GJ/$m^3$ |
| Liquid Petroleum Gas | 45.252 GJ/ton |
| Diesel (or ADO) | 42.499 GJ/ton or 35.274 GJ/ $m^3$ |
| Inland Fuel Oil (IFO) | 41.062 GJ/ton or 38.188 GJ/ $m^3$ |
| Bunker oil, Export oil | 40.224 GJ/ton or 38.213 GJ/ $m^3$ |
| Lubricant oil | 41.481 GJ/ton |
| Jet Fuel | 43.199 GJ/ton or 33.695 GJ/ $m^3$ |
| Gasoline (or MGR) | 43.961 GJ/ton or 31.652 Gj/ $m^3$ |

Table 8 Energy Demand, Fuel by Sector, 1997 in Common Energy Units (GJ)

| Fuel/Gigajoules | Household | Industry | Publi/Comm | Transport | Total |
|---|---|---|---|---|---|
| Electricity | 176,807 | 303,239 | 105,134 | - | 585,180 |
| LPG | 68,059 | - | - | - | 68,059 |
| Gasoline | - | - | 45,645 | 602,020 | 647,665 |
| Kerosene | 887,492 | 203 | 23,095 | - | 910,790 |
| Jet Fuel | - | - | - | 425,899 | 425,899 |
| Diesel | - | 46,154 | 1,647,655 | 4,159,571 | 5,853,380 |
| Light F. Oil | - | 607,398 | 1,164,830 | - | 1772,228 |
| Bunker | - | - | - | 320,666 | 320,666 |
| Bitumen | - | - | 19,428 | - | 19,428 |
| Lubricants | - | 7,671 | 32,665 | 62,317 | 102,653 |
| Firewood | 22,781,890 | - | 760,214 | - | 23,542,104 |
| Charcoal | 3,497,570 | - | 107,549 | - | 3,605,119 |
| Dung, | 3,263,148 | - | 49,644 | - | 3,312,792 |
| Agri-residue, | 625,213 | - | 23,275 | - | 648,488 |
| **G. Total (GJ)** | **31,300,179** | **964,665** | **3,979,134** | **5,570,473** | **41,814,451** |
| **G. Total (toe)** | **745,242** | **22,968** | **94741** | **132,630** | **995,582** |
| **Percentage (%)** | **74.9** | **2.3** | **9.5** | **13.3** | **100** |

When converted into common energy units, one can clearly see the degree of market penetration of the fuel types. For example, the totality of electricity demand is only 90% of the energy content of gasoline consumed and only 10% of diesel. Note that Table 2.2 does not take into account the energy lost during transformation e. g., the about 63% thermodynamic loss in generating electricity from oil products, or the 6:1 weight ratio required to convert woodfuel to charcoal or the distribution loss of electricity and oil products during transport.

The energy balance for 1997 indicates that the Total Final Energy Supply (TFES) amounted to 40,251 TJ or 9616 Tcal or 958,357 tons of oil equivalent (toe). This shows that the per capita final energy supply is 309 kilogrammes of oil equivalent (kgoe). The household sector consumed 77.8% of the TFES , transport 13.8%, public and commercial 6% and industry 2.4%.

- 77.3% of the TFES is biomass based amounting to 31,108 TJ or 740,667 toe. Fuelwood accounted for 75.7% of this total, 11.6% charcoal, 10.6% dung and 2.1% agricultural residue.

- 21.3% of the TFES is covered through oil products and

- Electricity accounts for the balance of 1.45%. This is almost identical to the previous year.

**Solar energy utilization**

Photovoltaic electricity generation is being used in special applications like telecommunications, powering rural health centres and clinics, village water pumping, school lighting and power supply, electricity for remote offices, solar radio communications, battery charging, etc. There is no record of installed solar home systems eventhough it is known that there are some. Due to the relatively high initial capital investment, in total energy terms the contribution is still negligible at below 0.4% of the national electric generating capacity. The Energy Research and Training Center of the Department of Energy has so far installed over 240kW capacity of Photovoltaic systems of which the following are representatives.

- ♦ 26 rural health centers are supplied each with 2kW solar photovoltaic power for refrigeration, lighting, operating theatres, fans, laboratory equipment and battery storage facilities each at capital cost of around $45,000. On average 30,000 people are served from each center. In addition most of the over 140 rural clinics are equiped with solar powered vaccine refrigerators.

- ♦ About 60 villages, out of the total 2500 villages in Eritrea, have been supplied each with 0.8 to 1.2kW of PV electricity to power water pumps to supply drinking water, each system for a minimum of 300 households with their livestock. The cost of such an installation is around $20,000.

- ♦ Over 70 rural schools (out of 700) have been provided with lighting and power supplies at a cost of $5,000 each.

In addition, other organisations have installed about another 180 kW of solar power, again for a high value community based applications. Thus, overall solar systems installed in the country is now over 400 kW capacity.

## Household Energy Overview:

The Department of Energy conducted a national survey of household energy consumption patterns with the purpose of updating the corresponding 1995 database for the year 1998. The survey covered 20 urban and semi-urban areas and 40 representative rural villages throughout the country altogether involving over 5000 respondents. The overall report is at the moment being written and not yet ready but the key results are incorporated in Table 10 in comparison with that of 1997. Note that the resident population in Eritrea has been assumed to be 3.1 million in 1997 and 3.2 million in 1998. Table 11 shows, the state of household energy consumption, per capita/per annum in urban, semi-urban and rural areas of Eritrea.

Table 10. Household Energy Consumption in 1997 and 1998.

| Fuel type / unit | 1997 | | | 1998 | | |
|---|---|---|---|---|---|---|
| | Total | Per capita | Energy content | Total | Per capita | Energy content |
| Electricity,MWh | 49,113 | 15.84, kWh | 57.1MJ | 57,036 | 17.82 kWh | 64.2 MJ |
| LPG, tons | 1,504 | 0.49 kg | 22.2MJ | 1,759 | 0.55 kg | 24.9 MJ |
| Kerosene, tons | 20,546 | 6.63 lt | 223MJ | 21,371 | 6.68 lt. | 225 MJ |
| Firewood, tons | 1,372,400 | 442 kg | 7338MJ | 739,703 | 231 kg | 3835 MJ |
| Charcoal, tons | 121,100 | 39 kg | 1126MJ | 70,687 | 22 kg | 635 MJ |
| Dung, tons | 388,470 | 125 kg | 1050MJ | 261,473 | 82 kg | 689 MJ |
| Agri-residue | 50,017 | 16 kg | 200MJ | 87,266 | 27.3 kg | 341 MJ |
| Total | | | 9959MJ | | | 5814 MJ |

Table 10 shows a clear trend in shifts towards the modern fuels electricity, kerosene and LPG. There is a big decrease in the usage of traditional biomass especially fuelwood and charcoal. This may be as a result of the Government's decree not to cut live tree for energy purposes and not to produce and sell kiln charcoal. The observation is that people are respecting this regulation to a great extent. The actual LPG consumption in 1998 was 824 Tons and not 1,759 tons as shown in Table 10. It was obvious that the supply was supressed as the 2000m3 storage depot in Massawa was under construction upto mid 1999. The respondents were asked to state their usual consumption per month assuming that the supply will be normalized within few months. Thus, the entry represents a trend which we are observing in practice in the second half of 1999 (consumption for the year was over 1300 tons).

Table 11 Per capita Consumption by fuel type

| | | | **Fuelwood kg/cap/an** | Charcoal Kg/cap/an | Dung kg/cap/an | Agri-Residue kg/cap/an | Kerosene lt/cap/an | Electricity kWh/cap/an | LPG kg/cap/an |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NRS | Urban | 334.15 | 90.41 | 168.29 | 67.31 | 15.09 | 175.80 | 16.17 |
| 2 | | Semi Urban | 420.22 | 69.44 | 45.42 | 174.40 | 12.67 | 20.91 | 0.00 |
| 3 | | Rural | 350.55 | 82.26 | 78.13 | 215.23 | 10.65 | - | 0.00 |
| 4 | | **Sub Total** | **328.33** | **30.32** | **6.31** | **22.16** | **10.95** | **17.68** | **0.11** |
| 5 | Anseba | Urban | 216.49 | 84.04 | 128.48 | 62.89 | 10.55 | 52.27 | 23.28 |
| 6 | | Semi Urban | 222.83 | 61.47 | 133.67 | 83.50 | 16.36 | 18.92 | 0.00 |
| 7 | | Rural | 194.33 | 64.77 | 219.75 | 139.57 | 7.40 | 27.41 | 0.00 |
| 8 | | **Sub Total** | **192.57** | **11.59** | **104.65** | **35.12** | **7.99** | **6.40** | **0.06** |
| 9 | Gash Barka | Urban | 355.51 | 168.00 | 57.66 | - | 8.26 | 10.01 | 0.00 |
| 10 | | Semi Urban | 474.35 | 154.75 | 39.32 | 304.71 | 8.42 | - | 0.00 |
| 11 | | Rural | 307.00 | 150.57 | 294.25 | 263.51 | 7.38 | - | 0.00 |
| 12 | | **Sub Total** | **310.20** | **45.49** | **89.53** | **29.76** | **7.02** | **0.26** | **0.00** |
| 13 | Debub | Urban | 204.31 | 90.51 | 128.07 | 110.98 | 20.72 | 37.06 | 17.27 |
| 14 | | Semi Urban | 226.08 | 72.38 | 99.43 | 120.00 | 11.03 | 30.72 | 0.00 |
| 15 | | Rural | 211.76 | 146.01 | 246.46 | 139.01 | 15.16 | 18.75 | 0.00 |
| 16 | | **Sub Total** | **200.31** | **10.81** | **147.15** | **40.03** | **14.89** | **3.50** | **0.04** |
| 17 | Meakel | Urban | 176.71 | 60.63 | 122.92 | 85.93 | 22.75 | 95.43 | 15.92 |
| 18 | | Semi Urban | 113.14 | 32.64 | 194.86 | 112.75 | 20.04 | 23.60 | 0.00 |
| 19 | | Rural | 134.07 | 71.28 | 299.74 | 106.99 | 19.14 | 1.89 | 10.69 |
| 20 | | **Sub Total** | **96.58** | **15.64** | **63.97** | **6.84** | **21.14** | **65.60** | **2.72** |
| 21 | SRS | Urban | 334.15 | 91.26 | 168.29 | 100.97 | 15.09 | 160.53 | 15.97 |
| 22 | | Semi Urban | 420.22 | 46.77 | 45.42 | 174.40 | 12.67 | 20.91 | 0.00 |
| 23 | | Rural | 349.75 | 51.03 | 78.12 | 215.24 | 10.66 | - | 0.00 |
| 24 | | **Sub Total** | **329.95** | **18.89** | **6.58** | **25.14** | **10.62** | **14.38** | **0.08** |
| 25 | | ***Grand Total*** | **231.16** | **22.08** | **81.71** | **27.27** | **12.57** | **17.82** | **0.55** |

Legend: NRS – Northern Red Sea Province (Zone), SRS – Southern Red Sea Province,

Rural Household Energy Consumption and their Price Ranges

| Type of Fuel | Per capita consumption | Price Range Nakfa/unit | Aggregate Price (Nakfa/year) | |
|---|---|---|---|---|
| Fuelwood, | 457 kg | 0.14-0.80 | 64-366 | |
| Charcoal –proper<br>-Recycled | 6.2 kg<br>33 kg | 2.2-2.8<br>0.39-1.00 | 14-17.4<br>13-33 | |
| Animal dung | 126 kg | 0.10-0.25 | 12.6-31.5 | |
| Agri-residue | 16 kg | ~ 0.0 | ~ 0.0 | |
| Kerosene | 6.63 letres | 2.21-3.30 | 14.65 –21.88 | |
| Electricity[1] | 480 kWh | 0.75-1.0 | 360-480 | |

[1] Note that this consumption is the average for electrified figures and it is highly likely that a group of customers share a single meter. In other areas tariffs are rated per bulb and typical charges are 10 Nakfa/month, which for two 40 watt bulbs adds up to 240 Nakfa.

A typical household with five members in rural areas will consume around 320 Nakfa (sum of the medians) for energy excluding transport in non-electrified area and around 500 Nakfa in electrified area.

**Overview of Household Energy Technologies**

- Charcoal stoves producible locally by artisans in Medeber, cost about US$ 2
- Kerosene cook -stoves and wicks also locally produced, Us $ 3.5
- LPG stoves and cylinders locally manufactured, US$ 50 for both
- Imported electric stoves and water boilers
- Traditional woodstoves own made by users efficiency around 10%, US$ 3
- Improved woodstoves designed by the Department with efficiency over 20%, US$ 27
- Imported PV modules, US$ 600 for a system of four lamps
- Fluorescent lamps now being assembled in Eritrea, imported incandescent lamps
- Solar water heaters now being produced locally, US $ 650 -750

## Key household energy stakeholders

A number of institutions, associations and interest groups are relevant and important to the provision of modern energy services to rural localities, and the household energy programme can not be adequately addressed without including them. These institutions and interest groups may be collectively called the “stakeholders”. These stakeholders include Government Ministries / Agencies (Energy, Finance, Community Development, Local Government, Agriculture, Public Utilities), Regional organizations like IGAD, NGOs, CBOs, potential investors, donors, producer and service co-operatives, rural saving and credit associations, religious institutions, research / training institutions, and the end users.
Overview of renewable energy resources

## Summary and recommendations

Biomass fuel is the major motive force of Eritrean rural economy. As a matter of fact biomass energy accounted for 77% of the national energy consumption in 1997 in Eritrea. Since about 75% of the total population of Eritrea live in rural areas, the greater part of the biomass fuel consumption also takes place in the rural areas. Whereas almost all forms of modern energy is consumed in urban areas (settlements having populations of 2000 households or more), rural inhabitants rely on firewood, animal waste, charcoal and crop residue. In rural Eritrea, it is estimated that up to 97% of the energy consumed is derived from such sources of energy. Small quantity of kerosene is used for lighting while most of cooking, space-heating and other activities like smithery, pottery, beer brewing, etc. depend on biomass fuel. Subsistence crop production, which is the major source of livelihood for Eritrea’s rural population, almost totally depends on animate energy. Although kerosene stoves have been introduced in certain villages recently, their diffusion and adoption still leaves much to be desired. Modern sources of energy in the form of electricity or oil are almost unknown in rural Eritrea. Most of the biomass fuel is used in its crude and unprocessed form, and hence, is wasteful and inconvenient. Since the traditional houses (*agudo* and *hudmo*) are poorly ventilated (only small openings are left on the walls for reasons of security), the heavy emission of smoke and other toxic substances have adverse effects on the health of people, particularly women and children. Biomass fuel-generated

pollutants are implicated to be responsible for the many respiratory and eye problems in the rural areas.

Eritrea's heavy dependence on biomass fuel has also produced certain environmental problems. Eritrea lies within the vulnerable and already affected area of the Sahel Region of Africa where the threat to desertification is of the highest concern and where the energy picture is obviously implicated to be one of the major causes of environmental degradation resulting from poor management of traditional fuels. Forest cover which was about 30% of the total area of the country a century ago, had been reduced to 0.4% at the time of independence. Colonial timber exploitation, forest clearance for agricultural purposes, biomass use for energy, drought and 30 years of war were the combined forces that have accelerated desertification in Eritrea. These and other similar problems call for new sources of energy, particularly renewables and related technologies.

The current exorbitant price of firewood is also a significant factor that is forcing many villagers to look for affordable alternative sources of energy. Though the price of firewood varies from place to place, statistics indicate that in the last two decades, the price in Asmara has increased four folds from US $ 25 to 100 per ton. In some highland villages where shortage is very acute there are some that argue that the cost of cooking the food is almost equivalent to the value of the raw food. Wide scale deforestation in turn has forced many poor people in the highlands to shift to even less efficient fuel sources such as cow dung and agricultural residue. Such a shift is depriving farm lands from their organic nutrients and making the households without livestock to be dependent on the households with livestock.

Due to modern energy supply constraints in the rural localities, there are only small and micro enterprises in the rural areas. In a survey made in 1996, of the 52,191 licensed medium, small, and micro-enterprises (MSMEs), only 20,746 or 39.7% were located in rural localities. These rural-based MSMEs employed only 28,477 persons accounting for 30.9% of the total employment in all MSMEs. On the average, the rural-based enterprises employed 1.37 persons per enterprise. According to the same survey, over 80% of the surveyed enterprises did not use powered machinery either due to lack of capital or due to lack of power (particularly electricity) supply. This implies that most of the enterprises found in the rural areas are household-based, self-employed activities that depended on inefficient, albeit low-cost, biomass fuel or animate power. Clearly, the level of employment opportunities created and/or income generated through these enterprises is too little to effect any significant shift from traditional to modern fuels. The expansion of modern and sustainable sources of energy as well as energy technologies, thus, offers tremendous opportunities for the expansion and upgrading of the existing enterprises and for the emergence of new ones. In this way, income generation, poverty alleviation and sustainable or modern energy supply are inseparably linked.

However, for people to shift to modern energy, their income should first increase. Studies done elsewhere indicate that as income increases, there is a strong tendency for households to shift to modern fuels like kerosene, diesel, and electricity. This implies that participation of rural inhabitants in income-generating activities is imperative for such a shift to occur.

**Areas of Possible Co-operation with IGAD**

1. Capacity development, human as well as institutional
2. Endogenous energy resource development including;-
   feasibility study and development of geothermal energy resource,
   development of wind and solar energy applications for grid connection and stand alone systems in remote areas (high priority)
3. Extensive rural electrification by extending the grid (high priority)
4. Strengthening the Energy Research and Training Center (high priority)
5. Dissemination of improved wood-stoves (very high priority)