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Ethiopia: Issues and Options in the Energy Sector

July 1984

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ETHIOPIA

ISSUES AND OPTIONS IN THE ENERGY SECTOR

July 1984

ABSTRACT

Ethiopia has one of the lowest levels of per capita energy consumption in the world. More than 90% of this energy is derived from biomass fuels and is almost entirely used in household cooking. The supply of these fuels historically has resulted in massive deforestation and soil erosion which now threatens an otherwise fertile agricultural base. Major programs of aforestation covering 5% of Ethiopia's landscape are required to prevent complete deforestation, to redress the imbalance between supply and demand for woodfuels for cooking, and to restore and protect the capacity for sustained agriculture in the populous highland regions. Ethiopia has very substantial hydropower resources and some small reserves of natural gas, both of which could make an important contribution to future economic development. The demand for petroleum products has grown in recent years to the point where their cost has become a major burden on the balance of payments. This report presents a strategy for greatly augmenting the supply of household fuels through reforestation, through the production of new biomass fuels, and through cooking fuel demand management. Measures are recommended which will help define the most economic means of exploiting hydropower and natural gas, and which will lead to a better understanding of the economic potential of other prospective energy resources. In addition, measures are outlined to enhance the efficient use of expensive electricity and imported petroleum. The energy sector investment needed between now and 1993 is estimated to be US$1.7 billion. Recommendations also are made on energy pricing and on strengthening institutional and manpower capabilities to implement the required investment program.

ABBREVIATIONS AND ACRONYMS

Abbreviations

bbl	barrel
bd	basic density
Btu	British Thermal Unit
ft^3	cubic feet
GDP	gross domestic product
GWh	gigawatt hour
ha	hectare
kg	kilogram
kVA	kilovolt ampere
kW	kilowatt
kWh	kilowatt hour
LPG	liquified petroleum gas
mai	mean annual increment
mc, mcwb	moisture content, moisture content wet basis
m3	cubic meter
M,m	thousand
MM	million
MVA	megavolt ampere
MW	megawatt
MWh	megawatt hour
OD	oven dry
sv	solid volume
tonne	metric tonne
toe	tonnes of oil equivalent
tpa, tpy	tonnes per annum, per year

Acronyms

EELPA	Ethiopia Electric Light and Power Authority
ERESA	Eritrea Region Electric Supply Authority
ENEC	Ethiopian National Energy Committee
EPC	Ethiopian Petroleum Corporation
ERR	Economic Rate of Return
FAWCDA	Forestry and Wildlife Community Development Authority
FCMC	Fuelwood and Charcoal Marketing Corporation
FRR	Financial Rate of Return
MME	Ministry of Mines and Energy
MOA	Ministry of Agriculture
PA	Peasant Association
SWCD	Soil and Water Conservation Department
WFP	World Food Program

This report is based on the findings of an energy assessment mission to Ethiopia in May-June, 1983. The mission assignments were H. Wackman, Mission Leader; K. Newcombe, Deputy Mission Leader; J. Besant-Jones, power system planning; C. Killoran, power engineering; A. Oduolowu, petroleum exploration and supply; T. Nayar, refinery engineering; J. Boroumand, energy balances and projections; T. Wood (cons), stove efficiency analyses; F. Werner (cons), forestry planning; P. Duiker (ILO cons), manpower planning; T. Bierschenk (ILO cons), manpower planning; B. Robinson (cons), energy conservation engineering; E. Peries, Administrative Assistance. Ken Newcombe was the principal author of the report and Linda Sullivan was the principal typist. The contribution of the ILO to evaluation of manpower training and development issues is gratefully acknowledged.

CURRENCY AND FUEL EQUIVALENTS

Currency

US$1.00 = B2.07
1B = US$0.48

CONVERSION FACTORS

1 MJ = 948 Btu
= 239 kcal
= 0.278 kWh

1 kWh = 3.6 MJ

1 ft^3 natural gas = 1,000 Btu
= 1.055 MJ

1 MMCF natural gas = 1 billion Btu = 24.7 toe

Major Fuels 1/

	MJ/liter	toe 2/ per metric tonne	M^3 per metric tonne
Petroleum Products			
Aviation Gasoline	33.1	1.11	1.43
Gasoline	34.3	1.10	1.37
Kerosene/Jet Fuel	36.7	1.10	1.28
Diesel	37.8	1.07	1.20
Fuel Oil	40.1	1.01	1.08
L. P. Gas	25.4	1.04	1.77
Woodfuels	MJ/ kg		
Fuelwood (air dried)	14.3	0.335	1.50 3/
Charcoal	29.0	0.679	
Fuelwood (oven dry)	20.0	0.468	
Basic Density of Wood (unless otherwise stated)	500 kg/m^3		

Electricity	kWh per TOE
Thermal-equivalent (supply)	3,206 (at 27% efficiency)

1/ Conversion factors are approximations only.
2/ One tonne of oil equivalent (toe) = 10.2 million kcal
= 42.74 thousand megajoules
3/ Solid Volume (SV).

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MAIN FINDINGS AND RECOMMENDATIONS

Overview

1. Ethiopia recovered well from a period of internal conflict in the mid-1970s to record a GDP growth of 5% a year between 1978 and 1980. However, despite good financial management, the economy stagnated after 1981 as the terms of trade worsened, drought persisted and foreign exchange reserves declined. Ethiopia remains one of the poorest of nations, with a per capita GDP of US$140 in 1982. The Ethiopian economy is predominantly rural, with 84% of its 32 million people living in villages and about three-quarters of the country's farms located more than a half day's walk from an all-weather road. This rural disposition is clearly reflected in the patterns of energy consumption summarized below. Of an annual per capita energy consumption of about 245 kg of oil equivalent, 93% is in the form of firewood, charcoal, crop residues and dung, and per capita consumption of petroleum products (17 kgoe) is very low even by regional standards.

Final Energy Consumption, 1982
('000 toe)

	Biomass Fuels	Electricity	Petroleum	Total	Share (%)
Industry	30	35	102	167	2.1
Transport			349	349	4.4
Agriculture		1	31	32	0.4
Households	7,402	16	18	7,436	92.8
Commerce/Government		11	21	32	0.4
Total	7,432	63	521	8,016	100.0
Share (%)	92.7	0.8	6.5	100.0	
Final Energy Consumption, 1992					
Industry	104	98	198	400	3.7
Transport	23	-	576	599	5.5
Agriculture	-	2	177	179	1.6
Households	9,570	42	73	9,685	88.8
Commerce/Government		13	29	42	0.4
Total	9,697	155	1,053	10,905	100.0
Share (%)	88.9	1.4	9.7	100.0	

The GOE intends to create a surge of economic recovery and growth through the vehicle of a ten-year plan involving some US$16 billion in investments geared to achieve an average of 7.5% p.a. GDP growth between 1983/84 and 1992/93. There is no doubting the sincerity and fervor with which this objective is being addressed, though it will require greatly increased energy sector investment to further social and economic development, together with more effective energy planning and management. This is because Ethiopia has still to systematically develop its wealth of hydropower resources, a locally significant gas resource and a variety of other energy resources with economic potential to meet the growing needs of household and commercial consumers. Growth in GDP is more likely to range between 3% and 4% a year through 1992, which should call for a desirable minimum level of energy sector investment (including energy and agroforestry) of US$1.6 billion for the 1983/84-1992/93 period, implying a major increase in the proportion of public sector investment devoted to energy. With the implementation of the optimal energy strategy devised by the mission (the accelerated investment program scenario depicted in Table 1.7), biomass fuels decrease marginally and electricity and petroleum fuels increase their relative share of total energy use by 49 and 75%, respectively.

Household Energy

2. The most important issue in the energy sector, and arguably in the future of Ethiopia, is the supply of household fuels, the related massive deforestation, and the resultant and insidious depletion of agricultural resources on which so much economic activity depends (nearly 50% of GDP, 80% of employment and 90% of exports). The increasing scarcity and cost of household fuels, particularly firewood, threatens the ability of the country even to maintain already low incomes and the quality of life of the people, particularly in the rural areas. The Ethiopian landscape has changed dramatically over this century. The estimated cover of closed canopy forests has declined from roughly 40% around the turn of the century to around 3% now, and an estimated 200,000 ha and one billion tonnes of topsoil are lost each year as land is cleared, or forests thinned, to supply new areas for crops, animals and people, and to meet the growing needs for the major fuel, firewood. The cost of firewood in the capital of Addis Ababa soared from US$9 to US$90 per tonne between 1973 and 1983 and now claims up to 20% of household income. To compensate for the worsening firewood scarcity, growing amounts of natural fertilizers in dung and crop residues are being diverted to household fireplaces, reducing crop yields by more than one million tonnes of grain a year. If no more than the present level of replanting is undertaken, in 20 to 30 years all but the least accessible pockets of forest will have gone, large parts of the north will be uninhabitable, and much of the center will be like Eritrea and Tigrai today: subject to persistent drought, crop failure, famine and outmigration. To arrest these trends and meet the estimated need for woodfuel within the next 30 years, some 6 million ha would have to be planted: in effect to reforest 5% of the Ethiopian landscape. Both the land reforms and the community

organizations are in place to implement the required program and mobilizing sufficient financial resources should be possible. Nevertheless, life-styles will have to change dramatically as tree planting and management will have to be incorporated into the very fabric of rural life. Intervention on the scale envisaged will require unprecedented political commitment. Energy and agroforestry will have to be placed among the nation's top priorities for there to be any chance of success. Although in the short-term the problem will be further aggravated due to long lead times for forest development and high population growth, there are good prospects of lessening the rate of deforestation, provided there is a major increase in the mobilization of resources to meet the problem.

High Cost of Petroleum

3. Besides the household energy crisis, the other major energy-related macroeconomic problem is the massive and worsening impact on Ethiopia's trade balance and foreign exchange availability of the cost of petroleum imports (net imports of US$185 million in 1982/83, equivalent to about half of foreign exchange earnings). Unless major demand management efforts are made, the increased demand, particularly from the transport and industrial sectors, will add to the burden through the resulting imports and will continue to constrain economic growth. Measures to alleviate the cost of petroleum imports include serious reconsideration of the future pattern of industrial development; improved technology selection; possible petroleum product pipeline and improvement in the structure and efficiency of the transport fleet; a variety of substitution measures (e.g., ethanol for gasoline and possibly natural gas for diesel in transportation, and biomass and natural gas for fuel oil in heat and steam-raising); and improved energy management in industrial and commercial enterprises.

Overall Energy Strategy

4. The major themes of Ethiopia's energy strategy for the coming decade should be as follows:

(a) To expand the supply of household energy through a greatly increased allocation of financial and trained human resources, and to this end, to pay particular attention to, and take concerted action on:

- reforestation, including improved forest management;
- expanded development and utilization of substitute fuels, like briquetted agricultural residues;
- improvement in efficiency of cooking through the use of stoves with improved fuel economy and the use of aluminum pots and mtads.

(b) The development, execution and prudent financing of a least cost power supply program commensurate with a reasonable level and structure of industrial development and expanded supply to residential and commercial consumers, taking into account the country's limited investment resources, the need for improved power system planning, the potential complimentary role that could be played by natural gas and suitably scaled hydropower developments in the long-term, and the desirability of financing a reasonable proportion of new investment through revised tariffs for increased cash generation.

(c) A major program of demand management, including important changes in the pricing of electricity and some petroleum fuels, rationalization of future industrial structure, selected substitution options (biomass, ethanol, solar heating and possibly natural gas), a petroleum product pipeline and improved transport fleets, industrial energy management and oil refining facilities.

(d) Expanded exploration efforts and eventual exploitation of domestic hydrocarbon resources, with immediate attention to the possible utilization and development of natural gas, and hopefully, but in the longer-term, petroleum.

(e) Expanded participation by the private sector in selected areas, particularly in petroleum exploration, solar water heating, and in the supply of biomass fuels (firewood, charcoal, agricultural residues, briquettes) to households.

Key Issues and Options

Expanding Woodfuel Supply

5. Afforestation. On a large scale, this is the only realistic option for resolving the household energy supply problem in the longer-term. Peri-urban plantations must be established to make urban areas self-sufficient, and rural woodlots and agroforestry on a massive scale are essential to allowing a sustainable energy supply to meet demand in rural areas. The mission estimates the need for forestry of all kinds to be 3.3 million ha planted by 1992, but considers this to be beyond the capabilities of the country in this period due largely to the institutional constraints of manpower and management resources, and the massive organizational and logistical efforts involved. An ambitious but potentially achievable program of afforestation would be to plant by 1992:

(a) 960,000 ha of rural energy-forestry with special emphasis on agroforestry, costing B403 million (US$195 million); and

(b) 195,000 ha of peri-urban forestry costing B343 million (US$166 million).

A further ongoing commitment of B1.2 billion (US$0.6 billion) is required during 1993-97 to meet the 2002 demand. A balance between supply and demand could be achieved between 2010 and 2020 depending on the long-term population growth and the future of alternative fuels. The mission has reviewed options for the supply and management of household energy separately for the northern and the southern regions. The northern region comprises Eritrea, Tigrai, Gondar and Wollo provinces and the southern region the remainder. With full implementation of the short-term measures proposed, only a moderate shortfall need occur in the south by 1992 between absolute need for peri-urban forestry and the achievable planting rate. The shortfall in the north would be about 150,000 ha for peri-urban forestry and almost 1 million ha in rural afforestation by 1992. In short, even with the major effort here proposed, deterioration in northern agro-ecosystems and in household energy supply will increase dramatically this decade before being slowly reversed in the next.

6. Specific priority measures to be undertaken within the achievable aforestation program include:

(a) establishment of training and research and development facilities in agroforestry right down to the peasant farmer level (paras 2.39, 2.46);

(b) establishment of a national forestry management information system to optimize species, provenances, and plantation design and management for each ecological zone (para 2.39); and

(c) a national forest and tree resource inventory to be conducted as a matter of urgency (para 2.4).

In the context of peri-urban forestry, there should be:

(a) increased application of fertilizer in the new Addis Ababa plantations to boost yield and reduce rotation length (para 2.33);

(b) replanting of the 10,000 ha of dead and dying portions of the existing Addis Ababa plantations by 1992 (para 2.34); and

(c) planting of at least 10-15% of the area of state farms with boundary woodlots and shelter-belts (para 2.37).

7. Additional Household Fuels. By greatly accelerating reforestation, recovering existing surpluses of woody fuels 1/ from forests and from agriculture, and by more efficient cooking, a near balance can be achieved between supply and demand for household fuels in urban areas in the south and establish the basis for the north's improvement within the decade. During the next decade, when woodfuel supplies from the proposed expanded forestry program are minimal, it should be possible to economically supply the equivalent of about 1.7 million tonnes of wood a year by 1992 to towns in the southern region in the form of charcoal from forest clearing and logging operations, and crop residue briquettes from state farms and cash crops. This would be equivalent to about half of urban household energy demand in the south. The crop residues concerned are strictly those centralized and annually burnt off on Ethiopian State Farms, not those dispersed throughout subsistence agriculture which have much higher value as animal feed and soil conditioners. Furthermore, while the residue harvesting and briquetting equipment to take advantage of this nearly unique State farm energy resource is fully commercial, the scale of the operation proposed here is quite unprecedented and successful implementation depends greatly on good management, careful planning and consumer acceptance of these now briquetted fuels. Northern region towns will not have access to these resources, therefore it is recommended that at least 40,000 tonnes of kerosene be directed each year to northern cities including Asmara and Mekele. In the southern region, LPG and electricity from hydropower can contribute significantly to household cooking energy supply within five years. Oil-fired electricity is not economical for cooking in the north and should be strongly discouraged in favor of kerosene in the short-term. There appear to be good prospects for improving the efficiency of existing charcoal stoves and electric injera cookers, and for introducing new portable metal woodstoves for urban use, warranting immediate trial and development work for each. Huge improvements in cooking efficiency occur from using aluminum pots, thus population-wide acceptance of cooking with aluminum instead of clay pots should be evaluated immediately.

8. Priority supply measures include:

(a) expanding the production of charcoal at Bubeka and other forest clearing sites to 114,000 tonnes per year by 1987 (para 2.13);

(b) introducing integrated forest management at selected logging and clear-felling sites with complete conversion to charcoal from all forest residues (para 2.10);

(c) programming exhaustive recovery for firewood and charcoal of all savannah forest timber cleared in state farm development (paras 2.12-2.14);

1/ Woody fuels include firewood, charcoal, and crop residues such as straw, stover, coffee skins, and bagasse.

(d) beginning commercial recovery of coffee skin residues in the form of briquettes during 1984, leading to production of 150,000 tonnes per year by 1992 (paras 2.19 and 5.9-5.12);

(e) beginning pilot production of fuel briquettes from cereal straw and stover, and cotton residue in 1984/85, following an immediate review of the optimum residue harvesting practices, leading to fully commercial production from all sources by 1986/87 (paras 2.19 and 5.2-5.9);

(f) integrating recovery of sawmill wastes as sawdust briquettes and charcoal in the refurbishment of rural sawmills (para 2.11); and

(g) improving the efficiency of charcoal production with the use of improved kiln design, including portable metal kilns (para 2.15).

The combined capital cost to develop these resources, if fully implemented, is B113 million (US$55 million) and the yield is the equivalent of the annual yield from 163,000 ha of new peri-urban forests.

9. Economics of Rural Afforestation. The main economic justification for the proposed national afforestation program beyond the direct value of household fuel supply is the benefit to agriculture of allowing high value organic fertilizers--dung and crop residues--to be used in crop production rather than as fuels. The value of grain production foregone each year by using cow dung as a cooking fuel is about one billion B (US$500 million); and this can only be reduced substantially by increasing the supply of woodfuel, given the extremely high cost and foreign exchange requirements of chemical fertilizers. Economic rates of return for rural afforestation investments are estimated to range between 25% and 80%, depending on the local circumstances, making this the highest value investment in the energy sector. Typical economic returns for peri-urban plantations are estimated to be 20-25%.

10. Implementation. The implementation of the energy forestry program requires an expansion of the charter and of the manpower, infrastructure and administrative resources of the existing extension service of the Ministry of Agriculture, as well as an early clarification of the required interface and cooperation with the Forestry and Wildlife Community Development Authority (FAWCDA). The mission also recommends the establishment of a stove marketing organization to implement the improved cooking efficiency program.

Power Subsector

11. With due attention to demand management, major investments in new generation systems other than the 150MW Malka Wakana hydropower plant now under construction can be delayed until about 1988, allowing a much lower cost power system development plan to be identified and implemented than is presently being contemplated. The rate of demand growth on the

main interconnected system (ICS) of the Ethiopian Electric Light and Power Authority (EELPA) has been greatly overestimated in recently prepared forecasts, hence the impending investment of US$29 million to rehabilitate the Abu Samuel plant (6MW) and add a fourth unit to the Finchaa hydropower station (34MW) are not warranted prior to the commissioning of the Malka Wakana proposed for mid-1987. Demand management, including conservation measures, can cover a 12-18 month delay in the Malka Wakana project, though the shortfall in capacity occasioned by longer delays can be met only by access to new generating plant, not including those now under consideration. Key elements in the future demand for electricity include boiler and cooker electrification programs now under implementation, and the level and structure of tariffs which are now distorted and unreasonably low. While there is a good case for electric cooking for a small section of the urban population, there is no longer any justification for the electric boiler program, which has been implemented so late that none of the originally perceived benefits now apply, given that the extended period of hydro-based power surplus will come to an end by about 1986. The annual incremental economic cost of operating electric boilers as compared with the existing oil-fired boilers would be about US$8 million by 1986. On the supply side, planning and evaluation must be expanded to include several very large multistage hydropower projects and natural gas from the Ogaden Desert, both of which diminish the status of potentially more expensive and still prospective geothermal power resources. In the north, the smaller interconnected supply system of the Eritrea Regional Electric Supply Authority (ERESA), which for the foreseeable future will rely solely on petroleum-fired generators, must in the short-term install more efficient generating plant and review locally available power resources, e.g., geothermal, and place heavy emphasis on demand management, as the proposed interconnection with the main EELPA ICS is not expected to become economic until the mid-1990s.

12. Specific measures arising from the above include:

(a) A genuine least-cost development program for the EELPA ICS should be developed based on the revised demand forecast presented here and choosing between numerous major hydropower systems and natural gas (paras 3.33-3.39).

(b) Boiler electrification should not be extended beyond those already installed or committed and then should only be used during periods of surplus hydropower with the fuel oil or biomass fired boilers (and in the longer-term, natural gas-fired boilers) retained as the primary means of industrial steam raising. Accordingly, EELPA should cease to supply power on concessional terms to electric boilers from 1985 (the time at which present contracts expire), charging thereafter a full economic price (paras 3.7-3.8).

(c) A strategy must be devised for future power supply which would protect EELPA from supply constraints in the event of a delay in the commissioning of Malka Wakana but which would not preclude a low cost long-term generation expansion plan. The early expansion of the Tis Abai power station combined possibly with the Finchaa-Bahar Dar 230kV transmission link, and interconnection with the Sudanese grid should be considered in this regard (para 3.28).

(d) The economic viability of geothermal power should be evaluated in the context of the least cost power system development for the EELPA ICS. Emphasis should be given to exploration for geothermal power in the northern part of the country covering also the ERESA system (para. 3.40).

(e) Fuel oil-fired diesel engine generation should entirely displace diesel generation and fuel oil-fired steam turbo-alternators for supply to the ERESA ICS (paras 3.43-3.44) in the medium term. In the mid to late 1990s, there is the prospect of either natural gas for power production based on the current prospect of natural gas discovery in the Red Sea or of geothermal power as noted in (d) above.

Petroleum Supply and Transportation

13. The most important problem facing Ethiopia in this area is the burgeoning cost of oil imports. In this respect there are a range of options for supplying refined products and transporting them from the coast to the central highlands market, and there is a good prospect for developing natural gas. In addition, petroleum exploration is being renewed with exploration promotion assistance from the World Bank and from the Soviet Union, which has financed four wells in the Ogaden desert region some 800 km east of Addis Ababa. The petroleum exploration and promotion facility financed by the recent IDA credit must be complemented with rationalized petroleum sector management and lead to a strong effort to engage private sector participation in further petroleum exploration and development. Preliminary mission estimates indicate that the most expensive option for supplying petroleum products over the next 12-15 years is to continue operating the refinery at Asseb in its present form. The competing lower cost options are either to close down the refinery and import all refined product requirements, or invest at least US$70 million in conservation, debottlenecking and secondary conversion facilities, resulting in greatly improved fuel efficiency in the refinery, as well as a product mix much closer to the pattern of domestic consumption. While the rate of return on new investment appears attractive, the early production of natural gas for local use could well reduce the economic benefits now foreseen by reducing the market for liquid fuels and greatly altering the required product mix. Nevertheless, further engineering and economic study of refinery expansion/modernization is recommended. Regarding the inland transport of petroleum fuels, the mission finds a proposed 850 km, US$270 million product pipeline from Asseb to Addis Ababa more economic than high-volume efficient truck transportation. However, if there is any prospect of replacing diesel with compressed or liquified natural gas in road transportation in the early- to mid-1990s, the cost of the competing alternative of restruc-

tured road transport will be significantly reduced. The refined product pipeline therefore must be subjected to more detailed study in the context of broader transport sector issues for its economic viability is closely related to the future growth of liquid petroleum consumption. In line with the finding that natural gas is a potential competitor in the power market, the mission recommends prompt drilling of at least one additional well to better define the volume of gas in place in parallel with a preliminary gas utilization study already funded under the aforementioned IDA credit.

14. Specific measures arising from the above include:

(a) a detailed refinery engineering study to establish the costs of the proposed refinery modifications and the maintenance costs for the refinery over the life of the new equipment(para 4.10);

(b) detailed study of the product pipeline option with, in the short term, gradual replacement of 24 tonne tanker trucks with 35-40 tonne trucks, road quality permitting, due to the significant improvement in fuel economy entailed (paras 4.14 and 4.28); and

(c) the use of either the joint Ethiopia-Soviet exploration program or an additional program to drill at least one additional well on the Calub structure to better define the existing gas resource in the Ogaden (para 4.20).

In addition, there is need for immediate modification to the refinery's LPG process train, and to refinery operation, to ensure the recovery of a further 8,000 tonnes of LPG now flared, and the production of 54,000 tonnes of kerosene a year. To increase the availability of kerosene for household use and avoid its use as an industrial fuel, kerosene blending in fuel oil to lower viscosity should be minimized and eventually discontinued as industrial combustion systems and fuel handling facilities are upgraded, including heated storage tanks and tanker vessels, to cope with high viscosity fuel oil.

Petroleum Demand Management

15. In addition to the measures mentioned above, the mission recommends that low cost options to improve the economy of petroleum use be implemented quickly, primarily in industry and transportation, which account for 20% and 67% of petroleum consumption, respectively. In industry, key measures should include:

(a) improved combustion control, water treatment, and new heat recovery systems throughout the manufacturing sector, particularly in such energy-intensive industries as cement, textiles, glass and iron-casting (paras 4.22, 4.23);

(b) industrial-scale solar water heating systems in tanneries and in hotels, hospitals and hostels (paras 4.24 and 5.20); and

(c) converting cement kilns to being partly fueled with crop residues (para 4.24).

In the transport sector there is a serious undercapacity problem which has nearly eliminated routine maintenance, contributing to highly inefficient vehicle operation and fuel consumption rates. The measures proposed by the mission for energy savings in the transport sector will not be fully effective without first investing some B50 million in new and larger trucks and additional servicing facilities. The specific measures to be adopted include:

(a) aquisition of diesel pump testing equipment and the servicing facilities for the bus and truck fleet (paras 4.27-4.28);

(b) turbo-charged engines and radial tires for the truck and tanker fleet operated on the Addis Ababa-Asseb route (para 4.28); and

(c) the implementation of a detailed management information system for the transport fleet and revised policies for truck and bus procurement due to the wide variation in fuel economy, maintenance requirements, and longevity experienced between different makes and models and the substantial economy of large (35-40 tonne) over smaller trucks, particularly for major bulk commodities such as petroleum products (para 4.29).

<u>Other Energy Sources</u>

16. In comparison to the need for expanded fuelwood production, conventional power, and petroleum supply, most other energy sources are of relatively minor importance and should not absorb valuable skilled staff time, administrative, or financial resources out of proportion to their potential to contribute economically to future energy supplies. This is especially true of biogas, producer-gas power generation, solar electricity and wind energy. The exceptions are the recovery of agricultural residues from state farms and major cash crops, production of ethanol from molasses, solar water heating and, possibly, geothermal and coal resources. Pilot production of various crop residue fuel briquettes should begin immediately, as should consideration of relocating the geothermal exploration effort to the north. Other priority actions in this subsector include:

(a) an immediate review of the potential to create surplus bagasse by upgrading the process energy efficiency of the existing Metahara, Wonji-Shoa sugar mills, and the future Finchaa sugar mill (para 5.13);

(b) proceeding with the production of about 29 million liters a year of ethanol as proposed, providing adequate arrangements are made for product storage and blending, vehicle fuel system compatibility and pricing (para 5.18);

(c) undertaking a national review to determine the economic potential for solar water heating and the viability of local collector production facilities (para 5.20); and

(d) accelerating and broadening the scope of the coal resource inventory now in progress (para 5.21).

Energy Pricing

17. The most serious energy pricing issues concern electricity tariffs and petroleum pricing. Petroleum products are generally underpriced against the full economic cost of supply when the shadow price of foreign exchange is taken into account. Net of taxes, only gasoline is priced well above the border price, although with its highly regulated market and mainly non-productive consumption, this is of little consequence. The mission recommends that:

(a) the price of diesel be increased by about 7% to encourage efficiency in use and to raise revenue (paras 6.6, 6.7); and

(b) no subsidy be applied to kerosene and LPG, because at their full economic cost they are clearly competitive with the market price of firewood and charcoal and tend to be used relatively more by higher income households (paras 6.6, 6.7).

18. Electricity prices have been kept artificially low in all power systems and huge cross-subsidies occur both within and between the EELPA ICS and the oil-fired ERESA ICS. The declining block tariff structure now in place in which the price per unit declines as consumption increases is now inappropriate due to its promotional nature in the face of supply constraints and the heavy cost burden placed on small consumers. Tariffs will have to be adjusted both for financial and economic reasons, as the GOE is now rightly insisting that EELPA meet a certain proportion of its future investment requirements from its own revenues. Tariffs in the ERESA ICS and the EELPA SCS systems are as little as one-fifth of the true costs of supply. The mission recommends that:

(a) tariffs be raised to reflect the full economic costs of supply and to make a reasonable contribution to the cost of new investment (paras 6.10-6.17);

(b) uniform national tariffs be removed in favor of very substantial differences in prices, reflecting as far as practical the real variation in costs between supply systems (paras 6.10-6.17);

(c) the near-term price of electricity in the ERESA ICS and SCS, and the EELPA SCS, at least meet the variable costs of production which are 35-40 ec/kWh (paras 6.10-6.17); and

(d) time of day charges be applied over an otherwise flat tariff structure in all systems (paras 6.10-6.17).

19. While the Government is attempting to intervene in the woodfuel and charcoal markets to bring prices down, its current impact is minor. The issue is really whether Government should be involved at all in the woodfuel market at the wholesale/retail level when it could concentrate on moderating price levels by adopting policies to enhance supplies from the forests and other sources (see para 22). There appears to be no economic distortion at official government prices for firewood and charcoal, but prices in the private market are well above long-run economic production costs, reflecting the growing scarcity in good quality woody fuels.

Manpower Training and Development

20. The availability of skilled manpower and its effective deployment and management is regarded as the main barrier to implementing the national program of afforestation here proposed. A total of about 2,330 new skilled staff, ranging from university graduates to short-course certificate holders, will have to be trained at a cost of about US$6.5 million during this decade, and a significant start must be made in 1984. Community and agroforestry will be prime foci of this training program, which should better utilize the existing agricultural training facilities. Training in the power and petroleum sectors needs to be reviewed and redirected. The mission finds a substantial mismatch between the type of skill training in progress and the future skill requirements of the power sector. Plans affecting the EELPA training institute also could burden it with responsibilities for more general education, duplicating the work of existing educational institutions. Consequently, there is a need in the power subsector for:

(a) a detailed manpower assessment and development plan and, in parallel (para 7.9);

(b) a review of the role and responsibilities of the EELPA manpower training unit and the EELPA training institute (para 7.9).

Specific measures proposed in the petroleum subsector over and above those included in the petroleum Exploration Promotion Project include:

(a) further and marked increases in incentives to work and undertake further training at the Asseb refinery (para 7.10); and

(b) revitalized efforts to recruit staff for the in-house training unit and to establish a fully equipped training workshop (para 7.10).

Institutional Arrangements

21. The GOE recognized at an early stage that the pressing problems of energy sector development called for a coordinated approach and established the Ethiopian National Energy Committee (ENEC) within the MME as early as 1979 to assist in policy making and setting priorities. At present, the arrangements for truly integrated energy policy analysis and investment planning in the energy sector are quite inadequate, however. Difficulties arise through the low status accorded ENEC by the major implementing agencies which is related, in turn, to ENEC's position of minimal influence over energy policy formation and investment. Furthermore, there are insufficient qualified energy staff in the Central Planning Supreme Council. The result is that key decisions on project priorities, pricing and other policies, studies, and so on, are taken through different channels in an uncoordinated fashion. The need for a strong and independent secretariat to review energy plans and policies is confirmed, though it must be much better equipped for the task and associated more directly with decision making at the highest level. Nevertheless, its role should be analytical and advisory only: the implementing status and management integrity of the energy parastatals must be preserved. The mission emphasizes the need for establishing clear principles and operational objectives to govern the interaction between an energy secretariat and the implementating agencies and consuming sectors as the first stage in rehabilitating an energy policy and planning capability. The energy secretariat need not be part of the Ministry of Mines and Energy and could conceivably be more effective in the Ethiopian government structure if it had more direct links with the Cabinet (Council of Ministers) or, provided the CPSC retains a strong influence on policies and priorities, attached to that body. Its location in the structure, and whether or not it is advised by a group of independent individuals, is secondary to the need for it to be comprised of highly skilled analysts with considerable status who appreciate the interrelationships between the various energy supply and consuming subsectors of the economy and who are permitted to review all major energy sector decisions prior to commitment.

22. There are two additional issues of institutional management which deserve early attention: the role of FAWCDA in woodfuels (firewood and charcoal) marketing and the charter of the EPC. FAWCDA should not attempt to compete with the vast network of wholesale and retail trade already established by small-holder entrepreneurs. Its role is more to increase supply and to assist with quality control. The mission recommends:

(a) maximizing the involvement of the private sector in biomass fuel distribution and marketing and, wherever possible, in production (paras 7.14-7.15); and

(b) a review of the utility of a possible wholesale marketing and reprocessing facility for biomass fuels in Addis Ababa (paras 7.14-7.15).

So far, the EPC has confined its role to petroleum refining although it is now clear that the benefits of investment in the existing or new refinery facilities can be quickly negated if oil is discovered or natural gas reserves are developed. Also, petroleum exploration efforts to date have been somewhat fragmented. The need for close coordination and rational investment in this sector leads the mission to recommend that:

(a) the EPC assume responsibility for all investigations into the commercial production of existing and prospective petroleum resources, including natural gas (para 7.16); and

(b) its manpower and resources be upgraded by recruiting and training lawyers, financial analysts and additional managers to adequately fulfill this new integrating role in petroleum supply and resource management (para 7.16).

Future Energy Demand

23. The growth in energy demand depends largely on the level of investment possible in the more energy intensive sectors of the economy, particularly industry and transport, and the degree to which fuel economy and substitution measures here proposed are implemented. With the World Bank's forecast of a maximum yearly GDP growth rate of 4% for the decade, with the implementation of fuel substitution and conservation measures proposed by the mission, and through close review of the committed program of industrialization, the mission foresees an overall growth in petroleum demand of about 7% a year if there is an early economic recovery and sustained GDP growth of 4% throughout the decade. Demand for fuel oil and kerosene will grow fastest, with diesel growing at less than 6% a year in the most likely scenario. It is not anticipated that natural gas will be in production before 1994. Growth in public power supply of 8.5% per year is expected and the demand for traditional biomass fuels will parallel population growth although, with the mix of supply, will change rapidly towards crop residues and dung away from firewood and charcoal as deforestation is intensified. It is likely that there will be an additional 2.5 million tonnes of organic residues a year diverted from agriculture to household cooking by the end of the decade. With the recommended expansion of reforestation and forest management as well as some degree of substitution by briquetting crop residues, more efficient charcoal production, and greater supply of petroleum fuels and electricity to households for cooking, this trend of using unprocessed residuals and dung and the rate of deforestation could be reversed by some time in the 1990s.

Energy Sector Investment

24. The proportion which energy sector investment makes of total national investment must be greatly increased from recent levels if significant economic development is to ensue. The mission estimates that of the B15-20 billion (US$7-10 billion) that could conceivably be available for public sector investment in the 1983/84-1992/93 period, about B3.6 billion (US$1.7 billion) should be allocated to the energy sector. Power

development will consume more than one-half and forestry and household energy investment generally about one-quarter of the required funds, with the remainder primarily for petroleum exploration, refining and distribution. However, it is the capacity to implement projects and to disburse funds as well as the availability of funds that are key constraints to afforestation during the next ten years. The highest priorities for investment are outlined in tabular form at the end of this chapter. It must be reiterated that several major investments are to be made during the ten years from 1983/84-1993/94 which will not yield substantial benefits until five to ten years later, such as in the development of prospective power resources, or for fuelwood plantations in drier regions. The investment program proposed is balanced between economic options for alleviating rapidly worsening deforestation and for reducing the cost of imported oil in the short-term, and greatly expanding the sustainable supply of cheaper indigenous fuels in the longer term.

Summary of Priority Actions

25. The foregoing describes the state of the energy economy in Ethiopia, the key issues and the subsector-by-subsector options, and the more important recommendations. The key recommendations for action are summarized under four general categories of activities below (investments, policy changes, institutional improvements, and studies).

Investment Planning

26. A realistic and detailed energy sector investment plan is required, selecting projects and programs to be funded on the basis of their relative contribution to energy supply and their relative economic return. The most urgent need is for investment planning in energy forestry and household fuel supply which demands close cooperation among the various primary production ministries (State Farms, Agriculture, Coffee and Tea Development), FAWCDA and the Ministry of Mines and Energy. Investment planning by EELPA also must be quickly rationalized and upgraded in the light of new prospective power resources and changing demands for electricity. During the next five years, while the government's own planning capability is being enhanced, there may be need to resort to external assistance to provide the required expertise.

Policy Changes

27. Pricing policies for petroleum and power must be reviewed as soon as possible because in both subsectors levying correct economic prices is the key to demand management and desired interfuel substitution measures. There is also an urgent need to reconsider the role of government and encourage private sector participation in the production, delivery, and marketing of biomass fuels if woodfuel supply targets are to be met. Hence, a major review of the most profitable and efficient organization of this sector should be undertaken immediately by independent management consultants.

Institutional Improvements

28. There are five immediate focal points for quickly strengthening and broadening the energy policy and planning capability:

(a) upgrading ENEC and/or taking action on the institutional arrangements of the energy sector to ensure effective coordination of energy policy planning; defining a constructive and workable relationship between the energy policymaking body and implementing agencies (EELPA, EPC, FAWCDA, etc.);

(b) developing EELPA's competence in power system planning;

(c) defining the respective roles of FAWCDA and the MOA in delivering the rural forestry program (para 2.46);

(d) broadening the role of the EPC into petroleum production, expanding its skill base accordingly, and streamlining petroleum exploration under one agency (para 7.16); and

(e) establishing a coordinated approach to manpower training to meet the growing deficiency of appropriately skilled staff in the EPC, EELPA, FAWCDA, MOA and ENEC (paras 7.7-7.10).

Studies

29. Of the very many pre-feasibility, pre-investment and basic policy and strategy studies recommended in this assessment, the most urgent studies by subsector include the following.

(a) Petroleum: (i) refinery engineering, including LPG recovery (para 4.9); (ii) preliminary natural gas production and utilization study (para 4.8); (iii) fuel oil conservation in industry, defining detailed engineering and costs (para 4.23); (iv) prefeasibility studies on solar heating and crop residue-fired cement kilns (paras 4.24, 5.20); and (v) diesel conservation in transportation, defining diesel pump facility requirements, costs of increased servicing and fleet capacity, and improved structure of the truck fleet (paras 4.27-4.28).

(b) Electricity: (i) defining a strategy for covering supply constraints though 1990 (paras 3.26, 3.27); (ii) major hydropower options inventory (para 3.33); (iii) undertaking mini-hydropower and fuel oil displacement of diesel generation prefeasibility studies (all as inputs to a least cost development study for the EELPA ICS) (paras 3.44 and 3.48). An urgent review is required of electricity conservation in the ERESA ICS system, including energy audits of major power consuming industries, plus a review of domestic solar water heating potential in the ERESA ICS and elsewhere in Ethiopia (para 3.45).

(c) Household Energy: In forestry, special studies are needed on species selection and provenance screening and strategies for agroforestry in each major agro-ecosystem, and the design and cost of a national fuelwood resource inventory for ongoing monitoring. Studies to facilitate short-term supplies of household fuels include (i) the least-cost method of corn stover and cotton stalk harvesting and briquetting (paras 2.28 [d], 5.8); (ii) the logistics, technology packages and investment planning for carbonizing forest residue (para 2.28 [c]); and (iii) an urgent review of potential and investment requirements to generate surplus bagasse in the sugar industry (para 5.14). A special review is required of the least-cost method of meeting the cooking fuel requirements including possible improved stove prospects for Asmara, Mekele and other northern towns during the next decade (para 2.30).

The combination of these initiatives and the implementation of the investment program and the policies arising should result in:

(a) measurably enhanced supply and lowered cost of household fuels within the decade;

(b) a rational and efficient use of expensive imported petroleum fuels and electricity; and

(c) a marked reduction in the balance of payments pressure for the supply of modern energy forms.

High Priority Investments for 1982-92

Sector and Item	Objective	Estimated Capital Cost (US$ million 1983)
Household Fuels		
Rural Forestry	. equivalent of 960,000 ha of plantations in woodlots and agroforestry	175
Peri-urban Forestry	. upgrading existing and establishing 195,000 ha of new plantations	212
New biomass fuels and cooking efficiency	. briquetting 750,000 tonne crop residue and carbonizing 900,000 tonne wood annually by 1992, and implementing improved stove programs	73
Power Sector		
New power generation	. to supply 30-40MW in 1988-89 and 200-300MW by 1994	360
Displacing diesel generation	. replacing diesel generation in the ERESA ICS and both SCS systems with cheaper hydropower and fuel oil.	45
Transmission projects	. connection of SCS diesel generation new industrial loads and new hydropower or gas generation with existing EELPA ICS	180
Petroleum Sector		
Oil and gas inventory and utilization study	. continued oil and gas drilling reconnaissance work, and exploration promotion	30
Natural gas resource	. drilling to better define the Calub resource, and gas utilization studies	8
Gas pipeline, and field development	. investment in development of Calub resource in the Ogaden desert and transmission to markets	300 (before 1993) of 600 total

I. ENERGY AND THE ECONOMY OF ETHIOPIA

Background

1.1 The land area of Ethiopia is 1.22 million square kilometers, making it the tenth largest country in Africa. In 1981, its population was estimated to be 32 million, 85% of which is classified as rural. Population growth is about 2.8% overall, although urbanization is proceeding at about 6.5% per year. With a GDP of US$4,430 million and a per capita income of about US$140 in 1981/82, Ethiopia is among the five poorest nations in the world. The mainstay of the country's economy is agriculture, which accounts for about 50% of GDP, followed by industry, 15%, and transportation 5%. Agriculture also accounts for about 85% of employment and 90% of exports. Coffee contributes 60% of total exports, supplemented by hides and other animal products from Africa's largest livestock population. Manufacturing contributes only 10% of GDP, being limited mainly to food processing, beverages, leather, textiles, cement and petroleum refining.

1.2 In describing recent economic performance it is useful to divide the post-revolutionary era into three periods. The period from 1974 to 1977 was marked by political upheaval, armed conflicts and little economic growth. In the second period, beginning in 1978, the economy recovered as security improved. The gross domestic product grew at 5.2% and 5.5% in real terms during FY78/79 and FY79/80, respectively. Growth came mostly from agriculture which benefited from good weather, and from industry after the resumption of industrial activity in and around Asmera and a rapid expansion in capacity utilization in the Addis Ababa region. Improved security also permitted the resumption of normal transport and commercial services. However, this impressive performance was short-lived. During FY80/81 and FY81/82, real GDP growth slowed to 3.0% and 1.5% respectively, mainly due to persistent drought, to the exhaustion of utilized capacity in industry, and severe investment constraints. Following a sharp increase in imports and a significant decline in coffee prices, Ethiopia's terms of trade declined by about 23% over this period. Efforts to raise non-coffee export earnings were unsuccessful for many reasons, including the continuing world economic recession. In FY81/82, Ethiopia's merchandise imports reached a level more than twice the value of merchandise exports, and the current account deficit widened substantially to more than 7% of GDP.

Energy Consumption

1.3 Table 1.1 presents the growth of GDP against the growth in demand for modern energy forms. Petroleum consumption has increased 1.8 times, and public electricity supply at three times the rate of GDP growth during the five-year period between mid-1977 and mid-1982. Portrayed in per capita terms the growth in demand for petroleum is smaller, although per capita power consumption is still spectacular, being more than double GDP growth. The growth in electricity consumption results from an expansion of the reticulation network from a relatively small base, whereas petroleum products are available more widely. Regrettably, the growth in the volume and value of exports has not been commensurate either with the growth in demand for petroleum products or with the growth in imports as a whole. In FY81/82, Ethiopia's merchandise imports reached a level more than twice the value of merchandise imports, and the current account deficit widened significantly to more than 7% of GDP. The growing cost of imported petroleum is a major factor in this equation. Ethiopia imports crude oil and refined products and exports fuel oil. The fixed pattern of refinery production is such that additional middle-distillate products must be imported to meet the demand, and 70% of the fuel oil produced must be re-exported because it cannot be consumed domestically. In FY77/78, the proportion of export earnings devoted to purchasing oil products (net of re-exports) was only 17%, but reached 53% in 1981/82, dramatically underscoring Ethiopia's need to maximize the economy of petroleum consumption and develop more economic energy sources. Investment in the energy sector has been below 5% of total public investment in the last three financial years and clearly will have to increase markedly to have a major impact on the average cost of supply in the next decade, and to satisfy energy demand (see Chapter 7).

Table 1.1: CHANGES IN THE GDP SECTORAL GROWTH, 1978/79-1981/82
(million Birr)

	Financial Year					Growth Rate (%) a/
	1977/78	1978/79	1979/80	1980/81	1981/82	
GDP (million Birr) at Constant Factor Costs	4,009.3	4,219.2	4,451.6	4,586.2	4,653.8	3.8
Population (million)	29.0	29.8	30.7	31.5	32.3	2.8
Petroleum Consumption (M kgoe) b/	453.4	512.8	557.8	580.2	603.8	7.4
Electricity Demand (M kWh)	406.0	493.0	553.0	569.0	661.0	13.0
GDP per capita (Birr) (constant factor prices)	138.0	142.0	145.0	146.0	144.0	1.1
Petroleum Consumption per capita (kgoe)	15.6	17.3	18.4	18.7	19.0	5.1
Electricity Demand per capita (kWh) c/	14.0	16.6	18.2	18.3	20.8	9.8

a/ Growth rates for petroleum and power consumption were high for this period due primarily to the redeployment of industrial capacity left idle following earlier civil disturbances.

b/ Petroleum consumption data have been adjusted to Gregorian calendar year from Ethiopian fiscal year for this comparison.

c/ Public supply only.

Source: Bank estimates.

Table 1.2: PETROLEUM IMPORTS, RE-EXPORTS AND TOTAL EXTERNAL TRADE, 1978-82
(million Birr)

	1977/78	1978/79	1979/80	1980/81	1981/82
A. Petroleum Imports					
Refined Products	9.0	34.5	80.6	94.3	105.6
Crude Oil	128.3	152.6	221.8	286.6	341.4
Total	137.3	187.1	302.4	381.1	447.0
B. Petroleum Re-exports a/	25.3	38.0	50.3	58.2	64.4
C. Net Petroleum Imports	112.0	149.1	252.1	323.0	382.6
D. Total Imports	1,270.6	1,367.9	1,652.4	1,642.1	1,824.2
E. Non-petroleum Merchandise Exports	640.8	698.8	927.3	791.0	728.3
F. Net-petroleum Imports as % of Total Imports (C of D)	8.8	10.9	15.2	19.7	21.0
G. Net-petroleum Imports as % of Total Exports (C of E)	17.5	21.3	27.2	40.8	52.5

a/ Mainly surplus fuel oil.

Source: GOE and World Bank estimates.

The Pattern of Energy Consumption

1.4 An energy balance for Ethiopia for 1982 is provided in Annex 1.1. The gross energy supply is about 8.8 million toe and final consumption is about 8.0 million toe. The configuration of final energy consumption is provided in Table 1.3. Biomass fuels comprise 93% of final consumption in the form of fuelwood (37%), cattle dung (32%), cereal straw (23%), charcoal (1.3%), and bagasse (less than 1%), and 7% of modern fuels in the form of imported petroleum (6%) and electricity (1%). On the basis of sectoral end-use, households dominate with 93%, followed by transport, 4% and industry, 2%. The agriculture and commerce sectors each consumed less than 1%.

Table 1.3: FINAL ENERGY CONSUMPTION, 1982
('000 tonnes of oil equivalent)

	Fuelwood	Dung	Crop Residue	Bagasse	Char-coal	Elec-tricity	Petroleum Products	Total	Share %
Industry				29	1	35	102	167	2.1
Transport							349	349	4.4
Agriculture						1	31	32	0.4
Households	2,958	2,539	1,804		101	16	18	7,436	92.8
Commerce/Gov't						11	21	32	0.4
Total	2,958	2,539	1,804	29	102	63	521	8,016	100.0
Share (%)	36.9	31.7	22.5	0.4	1.3	0.8	6.5	100.0	

Source: Mission estimates.

Household Energy Consumption

1.5 Household energy consumption in cooking is believed to average about 2 kg of air-dried wood (25% mcwb) per person per day; however, consumption levels vary greatly depending on local supply constraints (see Chapter II). There is a strong cultural preference for woodfuels, either as firewood or charcoal, but their increasing cost and scarcity has resulted in dung and crop residues now accounting for over half of total energy consumption, with serious implications for agricultural productivity due to an adverse impact on soil fertility (see para 2.4 and 2.5). Per capita consumption of modern energy forms (petroleum and electricity) is now about 25 kgoe, which makes Ethiopia one of the least energy intensive countries in the world. A comparison of energy intensities is made in Table 1.4 for 1980 with countries in the region. Ethiopia is shown to have only about one-third or less of the consumption of modern fuels of its direct neighbors.

Table 1.4: ENERGY INTENSITIES FOR NEIGHBORING COUNTRIES, 1980

Country	GDP per capita (US$)	Consumption of Modern Energy Forms Per Capita (toe/1,000 people)	Consumption of Modern Energy Forms Per Unit GDP (toe/million US$)
Ethiopia	140	20	177
Kenya	390	143	341
Niger	300	37	108
Somalia	260	58	225
Sudan	360	69	192
Uganda	200	25	125

Source: UNDP/World Bank Energy Assessment Reports.

Table 1.5: RECENT CONSUMPTION TRENDS FOR POWER AND PETROLEUM
(growth rate in percentage)

	1978/79	1979/80	1980/81	1981/82	Overall
Power Sales by:					
EELPA	12.7	10.6	1.7	19.6	10.6
ERESA	190.0	24.1	11.1	3.8	12.8
Petroleum Products: a/					
LPG	18.8	18.4	8.9	6.1	12.9
Gasoline	11.2	6.5	3.1	2.5	5.8
Avgas and Jet Fuel	12.4	-12.2	9.3	17.6	1.3
Kerosene	-58.0	-9.5	100.0	113.2	12.8
Diesel Oil	15.5	13.1	4.7	1.2	8.5
Fuel Oil	5.1	32.4	12.4	-5.1	10.4

a/ Original calendar year data have been adjusted here to reflect consumption in Ethiopian fiscal years.

Source: Power sales from ACRES International, EELPA and mission estimates. Data on petroleum products from the Ethiopian Petroleum Company and mission estimates.

Electricity

1.6 The industrial sector was the largest consumer of electricity (55.1%), followed by households (25.7%), and commerce/government (17.5%). Consumption in the agriculture sector is very small (1.7%), and electricity is not used directly for transport. Recent trends in the consumption of petroleum and electricity are indicated in Table 1.3. Electricity consumption in Ethiopia is concentrated in the central highlands, where sales by Ethiopian Electric Light and Power Authority (EELPA) were 585 GWh in FY81/82. Sales of 83 GWh were made by Eritrean Region Electrical Supply Agency (ERESA) in the northern region, which accounted for 12% of national power consumption, and the balance of 7% was supplied from other widely dispersed sources. EELPA's sales grew by less than 3% during the post revolutionary period up to 1978, then increased sharply to average 12% a year during the ensuing period of economic recovery. Since 1981, EELPA's sales have, for reasons explained in Chapter III, been erratic, growing by 1.7% in FY80/81 and by 19.6% in FY81/82. Because of localized conflict, power consumption in FY77/78 dropped in the northern region to one-fifth of the supply in the pre-revolutionary period. After the decline in hostilities in 1978/79, sales once again grew rapidly, recovering to the previous peak by FY81/82. Approximately 70% of Ethiopia's electricity is generated in hydropower systems, 26% from imported petroleum, and the balance from bagasse within the sugar industry.

Petroleum

1.7 The end-use of petroleum products by sector is provided in Table 1.6. The largest component of petroleum consumption is transportation (67%). The remaining one-third is consumed by industry at 19.6%, followed by agriculture, 6.0%; commerce/government, 4.0%; and households, 3.4%.

Table 1.6: FINAL CONSUMPTION OF PETROLEUM PRODUCTS BY SECTOR, 1982

(10^3 x toe)

	LPG	Gasoline	Avgas	Jet Fuel	Kerosene	Diesel Oil	Fuel Oil	Total	Share (%)
Industry	0.2				0.2	34.3	67.2	101.9	19.6
Transport		122.4	5.8	52.1		168.8		349.1	67.1
Agriculture						31.0		31.0	6.0
Households	5.0				11.2	1.6		17.8	3.4
Commercial	0.2				0.1	18.3	2.2	20.8	4.0
Total	5.4	122.4	5.8	52.1	11.5	254.0	69.4	520.6	100.0
Share (%)	1.0	23.5	1.1	10.0	2.2	48.8	13.3	100.0	
Memo Item:									
Power Sector Consumption						48.8	20.1		
Total	5.4	122.4	5.8	52.1	11.5	302.8	89.5	589.5	
Share (%)	0.9	20.8	1.0	8.8	2.0	51.4	15.2	100.0	

Source: Mission estimates.

1.8 Over half of the petroleum consumed in Ethiopia is in the form of diesel, 56% of which is used in transportation, 16% in electric power generation, and the remainder for motive power in industry (11.3%), agriculture (10.2%), and the commercial (6.0%) sector. A minimal quantity is used in households for lighting in lieu of kerosene. Diesel consumption grew by over 14% p.a. between 1978 and 1980, during which period the annual growth in GDP exceeded 5%. Growth in diesel consumption was sharply curtailed between 1980/81-1981/82 in response both to the general economic recession and to high industrial plant factors. The demand for transportation, per se did not, however, slow down appreciably; the number of trucks and buses grew at an average annual rate of almost 7% throughout the 1978-81 period. Despite a considerable expansion of the vehicle fleet, the vehicle availability is still inadequate, causing a considerable latent demand for diesel and quite possibly inhibiting the growth in GDP.

1.9 Gasoline accounts for 21% of petroleum consumption in Ethiopia. Gasoline consumption recovered to pre-revolution levels in 1977 and grew by about 11% during FY78/79, although consumption has grown progressively slower since then, declining to an annual rate of only 2.5% in 1981/82. This reflects more the impact of policies to restrain gasoline consumption than low growth rates for related economic activites. Gasoline is rationed in urban centers and taxes on gasoline-powered automobiles exceed 200% of the CIF price. Jet fuel comprises 9% of petroleum consumption whereas aviation gasoline, kerosene and LPG comprise no more than 2% of total consumption. Kerosene and LPG are used mainly for household cooking. The supply of jet fuel and kerosene varies directly with government policy as, in the refinery, the production of kerosene and jet fuel are interchangeable. Kerosene was diverted to the production of jet fuel in 1978/79-1979/80 and made available once again for household consumption in 1981 and 1982. Fuel oil, which accounts for 15% of petroleum consumption, is used for heat and steam raising in industry (78%) and for power generation (22%). The spectacular growth rate of 20% p.a. reported between FY78/79 and FY80/81 was again due to the use of excess capacity in the manufacturing sector. The decline (-5.1%) in fuel oil consumption in FY81/82 was most likely due to the first stage of the boiler electrification program (see Chapter III) because, during the same period, all major fuel oil consuming industries were operating at close to full capacity, and large scale manufacturing grew by more than 4% (Table 1.1).

Future Energy Demand

1.10 The mission has assumed that a reasonably favorable set of economic, social and environmental conditions will apply during the next decade in defining the parameters for growth in economic demand. GDP growth is assumed to be sustained at 4% a year throughout 1983 to 1992 1/, being most influenced by growth in industrial output, and greatly increased crop production, hence a substantial growth in exports. The methodology applied to demand forecasting and the macro-economic and energy subsector assumptions utilized is provided in Annex 1.2, along with energy balances for 1992. The mix of fuels and, by implication, the cost of energy to the economy varies under this set of economic conditions according to whether or not energy management and development measures proposed in the following chapters are implemented. The level of funds available to the government for total public investment under this economic growth scenario is estimated to be around US$7-10 billion over the ten years concerned; 15-20% of this directed to energy sector investment should be sufficient to cover the program and projects proposed by the mission. However, it must be stressed that GDP growth may not be able to be sustained at 4% a year, at least in the short term, and that both the demand for modern energy forms and the need for investment in supply measures may be reduced considerably. In Table 1.7 the pattern of final energy consumption for the major fuels is compared by sector under the two sets of conditions assumed, i.e., no change from the

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1/ Preliminary Government target is 7.5% p.a.

present in energy management and development, or the "business as usual" scenario, and full-scale implementation of the energy development and management proposals, or the "accelerated" scenario. Within industry and transport, the main influence on demand growth is through the implementation of recommended conservation measures, and the production of ethanol, whereby the growth in diesel and gasoline consumption in road transport falls from 7% to 5.1% and from 5% to 3.7%, respectively, and fuel oil in the manufacturing sector declines from 9.2% to 7.4%. The combined savings are about 90,000 toe, comprising about 20% of the projected supply of these fuels and valued at about US$30 million (1983 prices) a year. Furthermore, a saving in crude oil requirements of about 4% of refinery imports, or about 30,000 tonnes per year may be economically justified through conservation measures in the GOE refinery at Asseb if the recommended refinery engineering studies confirm that continued operation of the refinery is the most economic option. By contrast, in the household sector the main impact is likely to be seen through the exploitation of new biomass fuel sources and the production of woodfuels from planned energy forestry. Without any substantial effort to augment the supply of household cooking fuels, there could be an increase of 60% within ten years in the annual use of dung and crop residues for fuel (an additional 7 million tonnes per year), greatly intensifying soil erosion and the deterioration in agricultural productivity. However, if the mission's recommendations in the household sector are adopted, the rate of expansion in the use of these natural fertilizers and soil conditioners as fuel will be slowed almost to zero.

1.11 In summary, the pattern of future demand can be modified during the next ten years by practical and economic measures to lessen the severe cost burden of imported oil on the balance of payments and to arrest the rate of deforestation and deterioration of agricultural ecosystems. Overall final energy demand increases by about 3.3% p.a. in the 'Business as Usual' scenario, and 3.1% in the 'accelerated' scenario. The lower growth in the latter case is due to greater efficiency in end-use of the changing mix in cooking fuels towards electricity, LPG, and kerosene, and the new biomass fuels of residue briquettes and charcoal. The growth rate in demand for petroleum products is about 7.5% under both scenarios, although the mix changes as the increased supply of kerosene and LPG to households somewhat compensates for reductions made through energy conservation and interfuel substitution in industry and transportation.

Table 1.7: FINAL SECTORAL CONSUMPTION OF SELECTED FUELS UNDER TWO ENERGY MANAGEMENT AND DEVELOPMENT SCENARIOS

Sector/Energy Form	Consumption ('000 toe) Present	BAU	"Accelerated" Investment	Annual Growth Rate (%) BAU	"Accelerated"
	1982	---	1992	----	1982-1992 ----
Industry					
. Fuel Oil	69	167	142	9.2	7.4
. Diesel	34	58	58	5.4	5.4
. Biomass	29	88	103	11.7	13.5
Road Transport					
. Diesel	169	332	297	7.0	5.1
. Gasoline	122	199	176	5.0	3.7
. Ethanol	--	--	23	--	--
Households					
. Existing Fuelwood & Charcoal a/	3,060	3,060	3,060	na	na
. Dung	2,539	3,982	2,868	4.6	1.2
. Crop Residue	1,804	2,825	2,015	4.6	1.2
. New Biomass Fuels b/	--	--	547	--	na
. New Fuelwood c/	--	--	1,180	--	na
. LPG, Kerosene Electricity & Solar	33	58	113	6.0	13.3

a/ Existing forest resources are assumed in the demand projections to be preserved so that the net annual production is sustained at the present level (3,060 mmtoe). However, in reality the annual yield is expected to decline slightly this decade due to ongoing clearing of the forest and to fall sharply in the next two decades unless reforestation occurs (see Chapter II).

b/ New biomass is charcoal from new sources, briquetted crop residues and bagasse.

c/ Firewood from new fuelwood plantations.

na = not applicable as either there is no base year production, or "no growth" as part of scenario assumption.

BAU = Business as usual.

Source: Mission estimates.

II. HOUSEHOLD ENERGY

Introduction

2.1 The shortage of woodfuels for household cooking is the most important energy problem facing Ethiopia. For almost all of the rural population, and the majority of the urban population, cooking fuels constitute the only significant energy use besides the utilization of animal power and the natural flow of solar energy. Cooking is highly energy intensive in Ethiopia due to the practice of "open-fire" baking of injera 2/ bread on flat clay discs ("mtads"). Although some adaptation to household energy shortages (including the use of more efficient stoves) has taken place historically in areas of extreme deforestation, such as in the Northern Highlands, there appears to be rigid adherance to energy intensive traditional cooking practice which will only make it more difficult to alleviate the problem.

2.2 In estimating the present and likely future demand for cooking fuels, account has been taken of the strong preference of the great majority of the population for woodfuels (firewood and charcoal) for cooking. The mission estimates that an average of 2 kg of air dried wood (25% moisture content wet basis: mcwb) per capita per day is required to sustain Ethiopian cooking traditions and to respect other uses of fire (such as heating, lighting and small household industry). There are, of course, variations around this average; for example, the people of Chefa, a small town in the forest of the Southwest, use 5 kg of wood per day each, whereas residents of Moyale in arid lands close to the border with Kenya now use 1 kg per day each. 3/ The current average level of cooking fuel consumption in Addis Ababa, the center of wealth and home for 40% of the countries urban population, slightly exceeds 2 kg per capita per day. The estimated national consumption of household cooking fuels is indicated in Table 2.1. Overall consumption is 7.4 million toe, about 93% of the total national energy supply. Animal dung and crop residues now constitute more than half of the cooking fuels, with fuelwood and charcoal about 41%, and petroleum fuels and electricity a mere 0.4%. 4/ This massive diversion of organic materials which used to be used as animal

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2/ Injera is a thin spongy pancake-like bread a few millimeters thick and usually 40-60 cm in diameter. It is made from ground and fermented teff (Eragrostis teff) or a mixture of teff and the modern grains of wheat, corn, sorghum or barley.

3/ Survey funded by Italian aid and conducted by CESEN, an Italian government-owned company.

4/ The miniscule consumption of kerosene is due partly to allocation constraints for it is not marketed beyond Addis Ababa and it is released by the Ethiopian Petroleum Corporation to the market in strictly limited quantities.

feed and as fertilizers from agriculture to fireplaces has an economic impact which reaches well beyond the energy sector and which must be reversed if Ethiopia's extensive agricultural activities are to continue to produce adequate income for the population.

Historical Transition

2.3 It has been reported that at the turn of the century tropical forests covered more than 40% of the Ethiopian landscape. Natural forest cover with closed canopy declined to 16% by the early 1950s and is now only 2.7%, or possibly less. From the description of present day forest resources provided in Annex 2.1, it is evident that, of the remaining high forest cover, already 15% is much degraded, with a standing biomass less than one quarter that of its virgin state. Moreover, the widely cited resource of 20 million ha of Acacia savannah land has in fact been increasingly diminished. Once reckoned to hold a biomass stock of 30 m^3 per hectare, it is now believed that the average stocking density is only 10 m^3 per ha. The gradual thinning of savannah woodlands is just as serious an erosion of the woodfuel resource base as clear felling of natural high forest even though, ironically, the area under this forest cover is deemed not to have greatly changed during the past decade. The current rate of deforestation can only be roughly estimated. There is no comprehensive data base from which to monitor change. The best data are from an inventory by sample conducted between 1974 and 1979 by the British Ministry of Overseas Development, and these refer only to commercial timber volumes of the natural forests. Estimates presented below are consistent with the reported activities of FAWCDA 5/ and the Ministry of State Farms, and with a recent satellite study of the Munessa state forest by SIDA:

Source of Forest Loss by Clear Felling	Annual Loss (ha)
- natural high forest for farming largely by subsistence agriculturalists	80,000
- Acacia woodlands for charcoal and for state farms	50,000
- Woodland, thickets and brush for fuelwood	30,000
Total	160,000 ha

Note: It is prudent, given the poor quality of the data, to refer instead to a range of 150,000-200,000 ha/year.

Source: Consultation with FAWCDA.

5/ FAWCDA = Forestry and Wildlife Conservation Development Authority.

Table 2.1: CONSUMPTION OF HOUSEHOLD FUELS, 1982

	Quantities As Utilized	Tonnes of Oil Equivalent	Fuel Consumption
	(estimated)	('000 toe)	(%)
Firewood a/	8,829,000 te	2,958	39.80
Charcoal	150,000 te	101	1.36
Animal Dung	7,864,000 te	2,539	34.16
Crop Residues	5,138,000 te	1,803	24.26
Electricity	47 GWh	16	0.22
Kerosene	10,200 te	11	0.15
Liquified Petroleum Gas	4,800 te	5	0.07
Total		7,433	100.00

a/ Including twigs and leaves.
Source: Mission Estimates.

2.4 The lack of hard data on existing forest and tree resources is a serious deficiency, making the provision of a comprehensive wood resource inventory a matter of the highest priority. It is now possible to survey the scattered "single" tree resource (woodlots, household trees, etc.) with low-level aerial photography. The latter is Ethiopia's least known timber resource, and the one for which baseline data is most urgently required. While the conclusions drawn here regarding afforestation and fuelwood supply are not significantly influenced by the lack of precise data on forest cover, the estimates provided of fuelwood supply and demand are nevertheless crude. In 1982, it is estimated that the demand for fuelwood was 2.5 times the sustainable supply, based on existing tree cover. However, this global figure is not particularly relevant due to the enormous regional variations indicated in Table 2.2. Of the overall estimated shortfall in 1981/82 of 20 million m^3, almost 60% arises in the north, in Eritrea, Tigrai, Wollo and Gondar. The middle band of provinces of Gojjam, Shoa and Hararghe are only marginally better off, though their urban centers are within economic reach of the more heavily forested areas of the southwest and, with the exception of the lowland areas of Hararghe, they are more fertile and have moister climates. All of these provinces contrast sharply in fuelwood supply and demand balance with the heavily forested provinces of Ilubabor and Kaffa in the southwest. The table points to the need for 1.7 million ha in full production just to meet the 1982 deficit between rural woodfuel consumption and demand (paras 2.41 and 2.48).

Conceptual Basis for Strategy Formulation

2.5 At the rate at which peasant agriculturalists are currently clearing the fringes of natural high forest, this resource will be lost in about 30 years. As in the past, during this first stage of forest clearing for the purpose of developing land for food production, local fuelwood is abundant. At present, perhaps 20 million cubic meters of wood, the same quantity that is consumed in all the households of Ethiopia, are burnt off during agricultural clearing each year. It is only sometime later that trees begin to be harvested primarily for fuel. Beyond this point it appears that a critical transition of decline begins within subsistence agriculture whereby the growing scarcity of woodfuels is linked inextricably to falling crop and animal production. This transition leads to, and is clearly exacerbated by, growing urbanization in Ethiopia as the nature and level of fuel use for household cooking for most urban dwellers closely resembles that for their rural counterparts. The demand for woodfuels, and ultimately for any combustible residue, by urban dwellers or members of any concentrated settlement without a sufficient independent resource base (i.e., state farms) becomes an intolerable burden on rural productivity. A conceptualization of the perceived stages of this transition follows below and in Figure 2.1.

Stage I: The rate of timber harvested locally for all purposes (fuel, construction, tools, fences) exceeds, for the first time, the average rate of production. The existing timber resource is then progressively "mined"; firewood remains the main fuel source. Nutrient cycle No. 1 begins to decline though with imperceptible impact on food production. The general reason for the imbalance is population growth. The specific reasons include urbanization and major land clearing (e.g. state-farms) whereby firewood and charcoal become cash crops leading to overcutting relative to purely local subsistence requirements.

Stage II: The great majority of timber produced on farms and on surrounding land is sold out to other rural and urban markets. Peasants begin to use cereal straw and dung for fuel: the relative proportions depend on the season. Both nutrient cycles No. 2 and No. 3 are breached for the first time and nutrient cycling diminishes. Combustion of crop residues and dung leads to lower inputs of soil organic matter, poor soil structure, lower retention of available nutrients in the crop root zone and reduced protection from the erosive effect of heavy rainfall. Hence, topsoil nutrient reserves begin to decline (See "spill" in the Figure).

Stage III: Almost all tree cover is removed. Now a high proportion of cow dung produced is collected; the woodier cereal stalks are systematically collected and stored; and both are sold for cash to urban markets. The yields of cereal crops and, in consequence, animal carrying capacity begins to decline. Draft animal numbers and power output is reduced, hence, the area under crop also falls. Soil erosion becomes serious. Nutrient cycle No. 1 ceases altogether.

Stage IV: Dung is the only source of fuel and has become a major cash crop. All dung that can be collected is collected. All crop residues are used for animal feed, though they are not sufficient for the purpose. Nutrient cycle No. 2 is negligible and No. 3 is greatly reduced. Arable land and grazing land is bare most of the year. Soil erosion is dramatic and nutrient-rich topsoil is much depleted. Dung and dry matter production have fallen to a small proportion of previous levels. In such a situation, extended dry periods can be devastating because the ecosystem loses its capacity to recover quickly.

Stage V: There is a total collapse in organic matter production, usually catalyzed by dry periods which were previously tolerable. Peasants abandon their land in search of food and other subsistence needs. Starvation is prevalent. Animal populations are devastated. Rural to urban migration swells city populations, increasing demand on the rural areas for food and fuel, and the impact of urban demand is felt deeper into the hinterland (the "urban shadow" effect).

This transition from the first to the final stage is in process right across Ethiopia and has reached the terminal phase in parts of Tigrai and Eritrea.

2.6 The only way to prevent the current situation in the remaining populous and fertile areas from sliding toward the terminal state of Stage V is to develop a strategy which will:

(a) remove the dependency of urban settlements on their rural hinterlands for woody fuels, and

(b) reestablish a dynamic equilibrium between supply and demand for firewood in rural areas.

While the development of peri-urban fuelwood plantations is an obvious component of a strategy to serve the first objective, the time required to do this is such that, even if design work began immediately, the production of woodfuels would hardly begin to be augmented before the end of the decade. Without urban self-sufficiency it will be extremely difficult to achieve the second objective, as biomass fuels will continue to drain from the rural areas to the towns and cities. In addition, the situation of Northern Ethiopia where, in many places, agricultural ecosystems have deteriorated to stages IV and V, demands special, and possibly separate, consideration because of the huge scale of the problem and the implied investment, and the added complexity of local hostilities.

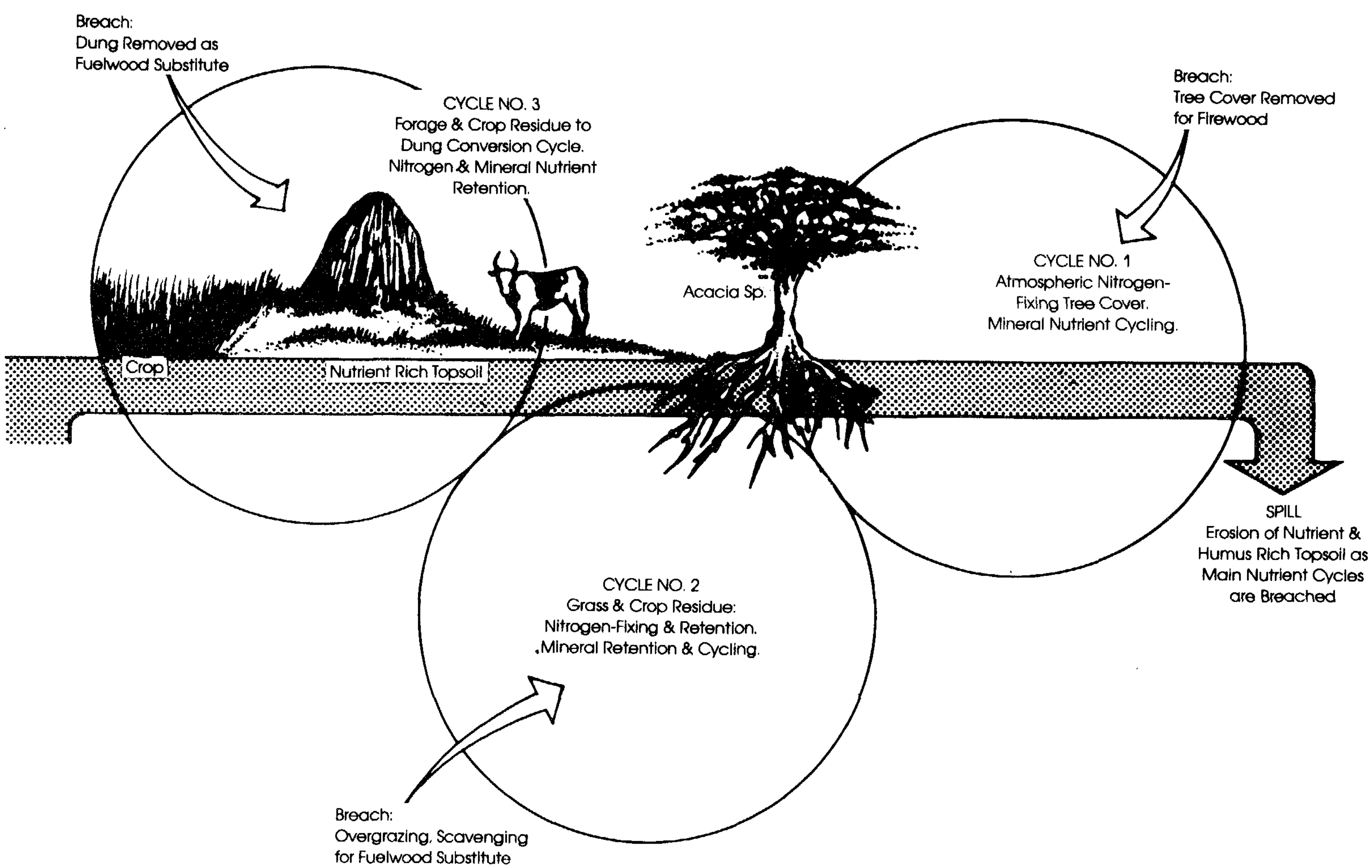
Table 2.2: RURAL FUELWOOD DEMAND AND PLANTATION REQUIREMENTS, 1982

Region	Rural Population	Demand Fuelwood & Poles a/	Demand Satis-faction c/	Additional Supply Needed	Plantation Production	Needed Plantation b/ area
	('000)	('000 m^3)	(%)	('000 m^3)	m^3/ha/year	('000 ha)
Arsi	1,124	1,338	50	669	18	37.2
Bale	877	1,044	40	627	15	41.8
Eritrea	1,804	2,147	10	1,931	8	241.4
Gemo Gofa	1,003	1,194	50	597	12	49.8
Gojam	1,976	2,351	40	1,411	15	94.1
Gondar	1,993	2,372	20	1,897	12	158.1
Hararghe	3,018	3,591	40	2,155	12	179.6
Illubabor	820	976	95	49	20	2.5
Kaffa	1,574	1,873	95	94	20	4.7
Shoa	4,876	5,802	30	4,061	18	225.6
Sidamo	2,744	3,265	70	979	20	49.0
Tigrai	2,105	2,505	10	2,254	8	281.8
Wollega	2,028	2,413	60	965	15	64.3
Wollo	2,552	3,037	10	2,734	10	273.4
Total	28,479	33,908	(40)	20,423	12	1,703.3

a/ Volume in solid m^3 on bark. Allowance is made for 1.09 m^3 per person per year fuelwood, plus 0.1 m^3 per person per year for building poles, agricultural implements, etc. Rural is defined as population outside of centers of 5,000 or above.
b/ In fact the tree planting is needed in small woodlots and as part of agricultural systems, as well as plantations per se.
c/ Estimated demand satisfaction is the proportion that the sustainable mean annual increment of new wood production makes of the estimated demand in the province concerned.

Source: Mission estimates.

PATTERN OF DETERIORATION IN ETHIOPIAN AGROECOSYSTEMS



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Preview of the Analysis and Main Findings

2.7 The remainder of this chapter deals with more detailed technical and economic options for alleviating the critical shortage of appropriate cooking fuels. The presentation is divided into options for the short-term (1983-92) and for longer-term (1992 and beyond), considering first the urban and then the rural context, and examining prospects for expanding supply and for demand management in turn, where relevant. When considering a program of afforestation a distinction is drawn with respect to both peri-urban and rural forestry between planting requirements to meet the identified need and a rate of planting -- invariably lower -- which is thought to be achievable. The costs of the achievable forestry program and options for supplying household fuels from new sources in the short-term are then examined and summarized, followed by a review of the economic justification for the investment program outlined. In conclusion, comment is made on the economic and environmental implications of failing to implement the proposed or similar programs of afforestation and new resource mobilization. The findings presented are placed in perspective by the following tables (2.3 and 2.4) dealing with the supply/demand situation in the short and longer-term. During the next decade it is not possible because of the long establishment phase, for energy forestry to make a significant contribution to household fuel supply. Consequently, only about 20% of the demand for high quality cooking fuels can be met by 1992. However, new and expanded fuel sources and biomass fuel, particularly charcoal and crop residue briquettes, could make a major contribution (2.1 million tonnes of wood equivalent a year) to the supply of urban cooking fuels although these are available only to the southern urban centers. As a result, more than 70% of the southern urban household fuel demand could be satisfied by 1992 if the specified production programs begin promptly. The only short-term option so far identifed for the urban north is expanded kerosene (and possibly LPG) supply from the existing refinery which could meet about 20% of the local demand. By 2002, it is possible to meet about two-thirds of the total unsatisfied national demand for household cooking with new fuel sources, and production from fuelwood plantations, woodlots and agroforestry systems established during the late 1980s and early to mid-1990s. During this second decade, the contribution from energy forestry is over half of the total demand, and over 80% of the new supply of cooking fuels, compared with 15% and 60%, respectively, during the first decade. By continually expanding energy forestry at the rate prescribed here, supply and demand for cooking fuels balance sometime between 2010 and 2020 (see Table 2.13). The most important conclusions arising from the presentation which follows are that it is possible and desirable by 1992 to:

(a) plant 1.16 million ha of trees around cities and throughout rural agro-ecosystems;

(b) harvest 1.7 million tonnes of wood equivalent a year in the form of charcoal and woody briquettes from existing forestry and agricultural wastes;

(c) increase the supply of electricity, LPG and kerosene to household cooking by about 0.4 million tonnes of wood equivalent.

Table 2.3: SUMMARY OF SUPPLY AND DEMAND PROSPECTS FOR HOUSEHOLD FUELS IN THE SHORT-TERM (up to 1992)
(tonnes of wood equivalent: twe)

	Estimated Need in 1992		Annual Contribution Possible by 1992 From New Sources: Achievable Plantations & Other Tree Planting Ready for Harvest b/		Annual Contribution Possible by 1992 From New Sources: New Biomass Fuels, Petroleum & Electricity Supply	Deficit a/
	(ha/'000)	(twe/ million)	(ha/'000)	(twe/ (million)	(twe/ (million)	(twe/ million)
Northern Region						
Peri-urban	240	1.77	15	0.11	0.35	1.31
Rural	1,406	8.62	186	1.14	--	7.48
Southern Region						
Peri-urban (including Addis Ababa)	270	3.34	30	0.35	2.01	0.94
Rural	938	14.54	124	1.92	--	12.62
Total	2,850	28.27	355	4.09	2.36	22.35

a/ This is a deficit in fuelwoood or other high quality cooking fuel and will, in practice, be met at whatever level by a combination of dung, crop residue, twigs and leaves and by simply making do with less cooking fuel.
b/ Planted by 1987.

Table 2.4: SUMMARY OF SUPPLY AND DEMAND PROSPECTS FOR HOUSEHOLD FUELS IN THE LONG-TERM (1993-2002)

	Estimated Need in 2002		Annual Contribution Possible From New Sources by 2002: Achievable Plantations & Other Tree Planting Ready for Harvest a/		Annual Contribution Possible From New Sources by 2002: New Biomass Fuels, Petroleum & Electricity Supply	Deficit
	(ha/'000)	(twe/ million)	(ha/'000)	(twe/ million)	(twe/ million)	(twe/ million)
Northern Region						
Peri-urban	482	3.53	324	2.38	0.71	0.44
Rural	1,560	9.57	910	5.58	--	3.99
Southern Region						
Peri-urban (including Addis Ababa)	550	6.49	206	2.50	3.12	0.87
Rural	1,580	16.33	920	9.51	--	6.82
Total	4,172	35.92	2,360	19.97	3.83	12.12

a/ Planted by 1997.

Short-Term Supply Options, 1983-92

2.8 Since the lead time for afforestation is long, fuelwood production from new planting will have no significant effect on supply before 1992. The only near-term prospect, then, is to harvest fuel-value materials which are already in production and accessible at a comparatively low opportunity cost. A review of potential sources indicated good prospects for improved recovery of:

(a) logging and sawmill waste;

(b) clear felled timber from state farm development; and

(c) agricultural residues from state farms (wheat and barley straw, corn and sorghum stover, cotton stalks), and major commercial crops (coffee residues and sugar cane bagasse).

2.9 In addition to an absolute increase in the supply of primary energy from these sources, improved carbonization efficiency can add measurably to final energy supply for wood wastes. Furthermore, there are prospects for improving the household supply of existing fuels--electricity, kerosene and LPG.

2.10 The woodfuel resource is comprised of the remainder of the selected sawlogs, all of the noncommercial species in the logged areas, and the wastes remaining at sawmills from processing delivered sawlogs. Despite the decimation of tropical high forest, the remaining resource is still significant in absolute terms. With few exceptions this waste is left to rot, or is burned on the spot during clearing for replanting. An analysis of the quantities of logging waste available at the 1981/82 logging level is provided in Annex 2.2. It is estimated that 530,000 m^3 (solid volume, 500 kg/m^3 basic density) a year are now accessible, of which about 50,000 m^3 are harvested, leaving 480,000 m^3 per year of untapped fuelwood resource which increases to 780,000 m^3 in 1987 and 1.1 million m^3 in 1992. Due to the low bulk density of firewood, and hence the high cost of transporting it per unit energy, it is almost always desirable to carbonize these wastes in order to make the delivery of this wood energy to a distant urban market economic. The recovery of logging wastes and noncommercial species for fuel should be a component of integrated forest management to upgrade the long-term productivity of the existing high forest resource. A schema showing the place of charcoaling in improved forest management is provided in Annex 2.3.

Sawmill Wastes

2.11 An analysis of available sawmill waste is provided in Annex 2.4. A total of 38,000 m^3 of slabs and 25,000 m^3 of sawdust are deemed accessible. It is proposed that slab waste be carbonized and that sawdust be dried and briquetted. The economic costs of producing sawdust briquettes at the sawmill are estimated at B49/tonne (1983 Birr). Sawmills are located between 350 and 500 km from Addis Ababa, thus the delivered cost is approximately B98/tonne or roughly 30% of the present market price for firewood. Charcoal production costs for the slab waste are provided below. Sawmill wastes are expected to grow to 130,000 m^3 in 1987 and 215,000 m^3 in 1992 as sawmills are rebuilt and relocated. Hence, it is important to design efficient waste recovery into the new sawmill and sawmill refurbishment program.

Recovery of Woodfuel from Agricultural Clearing

2.12 For the short-term, the focus of recovering timber from clearing land for agriculture must be in respect of state farm development, for it appears that the more massive resource lost in forest clearing by peasant agriculturalists, amounting to half the total yearly supply of energy for cooking, cannot be recovered without formally recognizing this "illegal" practice. Steps to resolve this dilemma are warranted though it is acknowledged that the issue is complicated. There are two options within the state farm sector which deserve urgent attention: immediate recovery of the rich Bubeka forest resource in Kaffa province, and expanded recovery of mostly savannah land timber in the process of regular expansion.

2.13 The Coffee Plantation Development Corporation within the Ministry of Coffee and Tea Development will clear for coffee plantations a further 5,000 ha at Bubeka during the next four to five years. The availability of wood net of other uses is about 880,000 m^3 (sv 6/) per year through 1987, equivalent to 110,000 tonnes of charcoal per year, or more than 70% of the estimated annual production for Ethiopia as a whole. At present, only 500-1,000 te charcoal per year are produced at Bubeka. The recovery of this resource using fast, efficient portable metal charcoal kilns is of the highest priority. The charcoaling operation mounted here can be transfered to recover the logging residues specified above (para 2.09) and timber cleared on other state farms, dovetailing well with that program by 1987 when the Bubeka clearing ceases. It is essential, however, that adequate incentives be provided for the full cooperation of the Coffee Plantation Development Authority in this program.

2.14 State farms are planned to expand a further 258,000 ha between 1983 and 1993. Some of this expansion will be in heavily forested areas though most will be over savannah land. A conservative estimate of timber accessible from clearing is 130,000 m^3 (sv) a year based on 13,000 ha per year at 10 m^3ha, equivalent to 120,000 tonnes of air-dry wood, or about 10% of the current energy supply to Addis Ababa (see Annex 2.6).

Efficient Charcoal Production From Available Wood Wastes

2.15 Traditional Ethiopian charcoaling is done by above-ground earthen kilns. Evidence from the mission's own field tests suggests

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6/ sv = Solid volume, denoting the important difference in energy value between a solid and a stacked cubic meter of wood.

that, in practice, average efficiencies of 20% and 15% are achieved in savannah and moist forest conditions, respectively. Metal kilns have three clear advantages over traditional kilns in the Ethiopian context: a higher rate of conversion, greater yield and better product quality. Charcoal production with metal kilns has about 2.5 times the labor productivity of earthen kiln production, and a 70% greater yield. Charcoal produced under controlled conditions will be of higher quality and energy value. The direct economic cost of charcoal from metal kilns is about 10% less than that from earthen kilns (B174 compared with B192 per tonne delivered) as lower labor and resource costs more than compensate for the consumption of imported steel, although the economic benefits of using metal kilns are considerably greater because wood wastes are recovered at a much higher rate than with earthen kilns, displacing household fuels of high opportunity costs to higher value uses elsewhere in the economy (see para 2.41). It is therefore recommended that portable metal kilns be used as part of all forest-based woodfuel recovery systems. The first step towards implementing this recommendation is a major study of the management, institutional and specific technical and funding requirements of a comprehensive, efficient, forest residue carbonization program addressing, as well, the special transport requirements. At sawmills, the construction of cheaper fixed kilns made of local bricks or of mixed clay and metal construction should be examined.

2.16 The transportation of charcoal over such long distances (400-700 km) on rough roads requires both special transportation measures and some reprocessing and repacking. Charcoal has a low bulk density (200-400 kg/m^3), especially that from mixed species of the tropical forest (measured in Ethiopia at 230 kg/m^3). The full economic cost of moving charcoal from Bebeka to Addis Ababa is about B60/te in 22te trucks. FAWCDA is now paying B140-180/te because its trucks cannot be loaded to their weight capacity due to the low volume (bulk density) of charcoal. Trucks carrying charcoal should be equipped with four meters high mesh or wooden-slatted sides to increase the loaded volume up to 80-100 m^3. In addition, after long hauls, fines production may reach 20% of total charcoal weight, especially that produced from softer forest timber. Charcoal derived from logging waste recovery and other high forest operations should, therefore, be screened and repacked, and the fines briquetted at bulk depots in the major urban centers. Fortunately, a suitably inexpensive briquette binder, molasses, is available in the required quantities.

2.17 Under the proposed production schedule (see Annex 2.6), 35,000 tonnes per year of the charcoal delivered to urban areas would have to be reprocessed into briquettes by 1992. The mission recommends that plans be made now for pilot production of these briquettes. Given the scale of this operation, and the need, in any case, for proper wholesaling and repackaging facilities, charcoal processing should be seen as an industry in its own right, possibly to include other higher value charcoal products.

2.18 A summary of the woodfuel resources to be delivered in the form of charcoal is provided in Table 2.5. The supply potential by 1992 is slightly more than the present estimated national consumption of charcoal. It is noteworthy that the projected 340,000 tonne long run annual supply is roughly 35% of the estimated 1992 demand for energy by households in Addis Ababa.

Agricultural Residues From State Farms

2.19 The collection and processing of agricultural residues to produce good quality household cooking fuels is unheard-of in Ethiopia and is uncommon elsewhere in Africa. However, fuel briquettes of coffee husk and groundnut shell are produced commercially in Kenya and Niger respectively; rice husk fuel briquettes are produced commercially in India and Thailand and, pelletized bagasse is well established at a major sugar mill in Hawaii. On Ethopian state farms wheat and barley straw, and corn and sorghum stover are burned in the fields as a means of disposal. Cotton stalks are also burnt-off both to sanitize the growing region of crop pathogens, and to clear the fields for replanting. Coffee cherry skin and husk residues for the most part rot and smoulder away behind decorticating mills scattered throughout the coffee producing provinces. Finally, there is considerable latent potential for producing surplus sugarcane bagasse in the rapidly growing sugar industry. The mission examined the general context of collection, high pressure briquetting and transport of these residues and established the quantities accessible and preliminary production costs for each resource. A brief review of the findings is provided in Chapter V. Table 2.6 provides an estimate of the quantities that could now be made available. The economic costs of these fuels delivered to Addis Ababa are provided in Table 2.10 below. A total of three-quarters of a million actual tonnes a year of agricultural residues is deemed accessible with appropriate management, and a total investment in harvesting equipment, briquetting presses and related facilities of about Birr 70 million. This is roughly equivalent to both the present day household energy use in Addis Ababa and the annual fuelwood production from a 100,000 ha plantation. The availability of each residue will grow substantially throughout the next decade though the target adopted here is to harvest the presently "accessible" resource by 1992. Even this will be a considerable achievement for it must be stressed that nowhere else in the world is there a crop residue recovery program geared directly to the production of fuel briquettes of the magnitude of the program here proposed. Despite the proven commercial nature of all the equipment involved, the management skill required to administer economically efficient residue recovery and the need for consumer acceptance increase the risks to be faced in this vitally important program.

Increased Supply of Petroleum Fuels and Electricity

2.20 Kerosene, LPG and electricity are all used to some extent for cooking in urban areas. For the petroleum fuels, supply is mostly limited to Addis Ababa and environs due either to a lack of distribution facilities or inadequate distribution incentives, or both. Electricity is used by upper income groups for cooking in Addis Ababa and other major cities with a public power supply in the central highlands, and those receiving heavily subsidized power from public grids serving Asmara, Asseb and Massawa. In the course of the mission's review of refinery management and expansion options (see Chapter IV), it was established that kerosene supply to households could be increased about fivefold, to 54,000 tonnes per year, and that in the mission's view, LPG production could grow about threefold to 12,000 tonnes per year without refinery expansion or conversion. The new supplies of kerosene and LPG would serve an additional 130,000 and 30,000 households, respectively. For comparison, there were about 300,000 households in Addis Ababa, and 85,000 in Asmara in 1982.

Table 2.5: WOODFUEL RESOURCES IN THE FORM OF CHARCOAL
('000 tonnes)

	1982		1987		1992	
	Earthen a/ or	Metal a/	Earthen or	Metal	Earthen or	Metal
Forest Logging Wastes	36	62	56	101	83	143
Sawmill Wastes (slabs only)	3	5	5	9	9	16
State Farms						
Bebeka	66	114	66	114	--	--
Other	17	17	17	17	17	17
Total	122	144	205	241	102	176
Quantities of Charcoal Briquettes Implied b/	24 or	40	29 or	48	21 or	35

a/ Kiln efficiencies applied: Earthen kilns: 15% in forest timber, 20% on savannah land timber; metal kilns, 26% and 30%, respectively. Only earthen kilns are used in savannah land operations.

b/ 20% fines for forest charcoal, 10% for savannah charcoal.

Source: Mission estimates.

2.21 Electricity can only be considered as an alternative cooking fuel where there is an existing public supply, and even then will only have some prospect of being economic in the short-term if the source is the EELPA ICS at current estimates of the long run marginal cost of power in that power system (see Table 2.10). This limits consideration of the option to the urban settlements of the central highlands, with a strong focus on Addis Ababa. Until 1987, the supply of hydropower is somewhat constrained by capacity limitations; however, an additional demand of 25 GWh per year for household cooking can be accomodated by that time, increasing to 39 GWh by 1992. (see Annex 3.2). This is enough to meet all the cooking energy requirements of some 80,000 households.

Table 2.6: ANNUAL AVAILABILITY OF CROP RESIDUE FULES FOR HOUSEHOLD COOKING IN THE SHORT- TO MEDIUM-TERM

Crop Residues	1982 Crop Production ('000 tonnes)	1982 Crop Residue ('000 tonnes)	Estimated Accessible Residue a/	Wood Equiv. b/ ('000 tonnes)
Coffee	250	450	150	191
Cereals on State Farms				
Wheat	112	210	105	147
Barley	4	6	3	4
Corn	97	266	187	226
Sorghum	32	48	24	29
Cotton				
on State Farms	58	253	239	334
Bagasse c/	146	58	43	60
Total		1,291	751	991

a/ Allowing for losses, residues left for soil production and fertilization, non-compatible processing, and prohibitive transport costs.

b/ Taking into account differences in net calorific value and the efficiency of present day cooking appliances using raw wood and dense dry residue briquettes.

c/ Applying 50 kg dry bagasse per tonne of cane harvested following upgrading of process energy efficiency, and subtracting 15,000 tonnes of bagasse committed to other uses.

Short Term Demand Options, 1983-92

2.22 The options for alleviating the shortfall of woodfuel supply by demand managment in the short- to medium-term appear confined to improving the efficiency of household cooking by increasing the efficiency of cooking stoves, introducing new stoves of high efficiency, and changing the cooking vessel. During the assessment mission, the efficiency of heat transfer was measured for wood stove types burning most fuels in common use. A special effort also was made to establish the efficiency of cooking injera by traditional and modern methods. These data and the related field observations, along with measurements of weight and moisture content of retailed traditional fuels, were used to define the cost of useful energy and the relative values of presently traded and prospective fuels for the household subsector.

Normal Cooking

2.23 Ethiopians cook meat and vegetable soup or stew (wat) dishes to eat with injera, as well as boil water, make coffee and the like, lighting a fire for these purposes several times a day. Many urban dwellers cook with both an open fire and a charcoal stove except when cooking injera. Table 2.7 presents the present and prospective efficiencies of Ethiopian cooking. The most significant findings are that there is consistently a 60-70% greater efficiency of fuel use with aluminum over traditional clay pots, and that the traditional charcoal stove can be modified very simply to achieve a 25% improvement in efficiency. The wick-type kerosene stoves in use are of comparable efficiency but, as expected, the kerosene pressure stove has a 10-30% efficiency advantage. The wick stoves retailed locally were found to be flimsy, short-lived and potentially unsafe, which tends to negate their moderately good efficiency. Since there are very few kerosene stoves in use or available for sale, any program of expanded kerosene use should be based on high quality wick stoves like the Nutan 2 of India, and pressure stoves; preferably the latter. The mission recommends the local production under license of quality stoves; promotion of more efficient kerosene stoves, and the implementation of tighter stove import standards. Aluminum pots (3.5 liter) currently retail for B12, whereas clay pots (4.0 liter) retail for B4.50 each. The difference in price almost certainly reflects high import duties, hence the prospect of very significant energy savings must be weighed against a probably minimal loss of revenue. There is a prima facie justification for heavily promoting the use of aluminum cooking pots, thus the mission recommends an early pilot program to examine consumer response and the implications of various pot pricing strategies.

2.24 In addition to modifying existing charcoal stove models, there is a possible role for the proven Upper Volta portable metal wood stove and a portable Lesotho-type dung stove. Therefore, the mission recommends cautious programs of trial and dissemination of these stoves in urban areas in the first instance. The context and mode of dissemination is discussed further below (see para 2.26). Due to an almost universal failure to achieve much vaunted savings through wide dissemenation of "improved" stoves in numerous countries, no attempt is made here to modify fuelwood production targets to account for anticipated reductions in per capita demand. It is encouraging to note, however, that considerable financial incentives exist for consumers to adopt the improvements or new stoves here identified. The simple payback on selected stoves or pots is indicated in Table 2.8 and ranges from two weeks to two months.

Injera Baking

2.25 Injera baking consumes about half of all household cooking fuels. Injera is cooked every two or three days in two to three hour sessions on a large clay plate called a "mtad" measuring about 60 cm wide and 2 cm thick. This plate usually rests on stones over an open fire, though in the northern regions the fire is partially enclosed with a clay wall (the "Tigrai type" injera stove). During the past decade electric injera cookers have become popular, particularly among upper income groups in urban areas. Here an electric heating coil is wound into a groove on the underside of the "mtad." There was a need to examine injera cooking closely not only because of its enormous impact on energy consumption in Ethiopia, but also because the government has ordered a crash program of electrifying injera cooking, demanding of the electric supply authority (EELPA) the production of 10,000 electric injera cookers per year. The results of the mission's investigations are provided in Table 2.9. To summarize, injera cooking with biomass fuels is even lower in efficiency than cooking with pots on open fires, though the northern style "Tigrai" stove is more than twice as efficient as the more common "open fire" injera cookers. There are, however, marked differences in fire management and fuels used which no doubt highlight the good performance of Tigrai cookers. Using the same, more volatile leafy fuels in the mission's own experimental design, and with no special fire management, fuel savings of 25% were achieved with the Tigrai type stove. Electric injera cookers are quite efficient by comparison, though it appears possible to achieve even higher energy efficiencies and to reduce the power rating from around 3 kW on average to 2 kW or less by using non-stick (teflon) aluminum plates with fully integrated heating coils (see Chapter III and para 2.26; vii). Besides the great merit of electric injera cooking, there is a need to promote the use of more efficient biomass-fired injera cookers.

Table 2.7: STOVE EFFICIENCY BY STOVE, FUEL AND COOKING VESSEL TYPE

Fuel Type	Stove Type	Ratio of Low a/ Power to High Power Efficiency	Percentage of Primary Heat Utilized (%)	
			Clay Pot	Aluminum Pot
A. Existing Stoves				
Firewood	Open fire	1.2	8	--
		0.7		13
Charcoal	Square metal	1.9	17	--
		1.5	--	15
	Round metal	0.9	14	--
		2.6	--	23
Kerosene	Daulat (wick)	--	--	35
	Chinese (wick)	--	--	42
	Swedish Primus (pressure)	--	--	46
Dung	Open fire	--	9	--
		1.1		16
Briquettes	Open fire	--		15*
* (estimate assuming about same behavior as dung)				
B. New Stoves				
Firewood (and briquettes)	Portable metal b/ (upper volta style)	--	--	28
Charcoal	Traditional stove	--	23	--
	High sided c/	--	--	30
Kerosene	Nutan-2 (Indian) (wick)	0.4	--	36
Briquettes	Modified Paolo type stove (Lesotho) d/	--	--	21
Dung	Modified e/	--	--	32

a/ The low/high power ratio indicates in which phase the stove is most efficient. Stoves with values greater than 1 have higher efficiency in the low power phase. Values less than 1 have higher efficiency in the high power phase.

b/ Stove recently well established in Upper Volta which is compatible with Ethiopian cooking methods. Not tested in Ethiopia but test efficiencies verified by mission.

c/ Simply adding a tubular sleeve to the traditional Ethiopian stove bringing the sides up around the pot.

d/ Briquettes obtained in the US for tests were extruded wood of very high density and difficult to light and burn without other materials in the fire.

e/ Dung burning proved very difficult to manage in this stove. These results are achieved with constant attention.

Table 2.8: COSTS AND BENEFITS OF IMPROVING STOVE EFFICIENCY

	Existing Stove Efficiency (PHV)	Laboratory Efficiency (PHV)	Efficiency to be Achieved in Practice	Cost of Existing Stove/Pots	Cost of Improved Stove/Pots	Payback at Present Market Prices a/
	(%)	(%)	(%)	(Birr)	(Birr)	(days)
Open Fire using aluminum pot compared with introduced metal stove	13	28	20	nil	10	61
Open Fire using clay pot compared with aluminum cooking pot	8	15	13	4.5	12 b/	18
Charcoal Stove using aluminum pot compared with high-sided, insulated sleeve and liner	23	35	30	5	8	13
Injera Cooking on open fire compared with a closed injera cooker	4-5	8-10	7	4	8	13-18

a/ 15 ec/kg wood and B1/kg charcoal. Consumption per family is 0.7 kg charcoal/day and for wood 5 kg/day average each for injera and pot-type stove cooking.

b/ Financial cost only. Economic cost is probably much less.

PHV = percentage of heat utilized.

Source: Testing and estimates by the mission.

The mission recommends a review of the prospects of success of heavy publicity favoring the use of Tigrai-type cookers as part of a package of cooking efficiency measures identified in Table 2.9.

Implementation of a Cooking Efficiency Program

2.26 The management of research, review and field trial activities, along with all government-sponsored stove marketing and promotion activities recommended here should be the responsibility of one agency: possibly a stove marketing organization. This organization should not itself undertake any stove design, testing or production, and it should attempt to contract out much of the market analysis and specific research and review work, retaining only the roles of coordination, analysis, policy development, and communications. All aid for stove work would be directed through this agency. Finally, it is desirable to have women playing a direct role in the management of the agency, including possibly the extensive network of women's organizations in dissemination.

Table 2.9: EFFICIENCY OF INJERA COOKERS

Energy Form	Injera Cooker Type	Cooking Time per Injera	Energy per Injera	Cooker Efficiency (PHV)
		(Minutes)	(MJ)	(%)
Biomass Fuels				
Twigs, leaves: sticks (1:3)	Open fire with "mtad" on stones, height 13 cm	5.6	12.3	4.3
Twigs, leaves: sticks (1:4)	Filipini stove: molded clay design fully enclosed with mtad inset and chimney, height 15 cm	13.1	11.1	4.8
Wood:	Tigrai stove: enclosed by clay walls with many small gaps in walls exhaust, height 14 cm	4.2	5.3	10.0
Twigs, leaves: sticks (1:3)	Experimental: like Tigrai with chimney, passive damper, height 12 cm	5.0	9.2	5.7
Electricity	Sample of models commonly marketed in Addis Ababa	3.0-4.0	0.9	60
	Mock-up of Aluminum injera cooker	not available		80

PHV = percentage of heat utilized.

Source: Mission testing and analysis.

Short-term Strategies

2.27 On the supply side, the energy sources that can be tapped in the short-term all have to enter the cash economy to generate financial returns justifying the required investment. Hence, they will be directed at urban markets and will benefit the rural areas indirectly by reducing the pressure there of urban household fuel demand. The economic merit of proceeding to mobilize the new or unutilized energy resources outlined above can be judged by comparing the economic cost of useful energy delivered from the available fuels. The relative impact of developing each resource can be judged by portraying the displacement effect of supply, in order of least cost, on the major target market in each strategic area: the northern and the southern region. This methodology has been applied more thoroughly to the southern region than to the northern region which the mission was unable to visit, and in respect of which it feels much less able to pass judgement. Comparative prices and present and future economic costs of existing and new household energy resources for the Addis Ababa target market are provided in Table 2.10. Dung is not included here as it is used minimally in Addis Ababa, and the comparison does not include injera cooking which is dealt with separately in Table 2.11.

Summary and Conclusions on Options for the Southern Region

2.28 The long-run economic costs of kerosene and electricity are comparable to one another on a useful energy basis and are slightly lower than those for LPG. If kerosene is used only in pressure stoves it remains cheaper than electricity even in the longer-term. All three are more expensive than the new short-term biomass energy sources proposed which, for normal cooking, are ranked in Table 2.8 in order of increasing cost, starting with charcoal. With the possible exception of bagasse, cost is a reasonable indication of the degree of difficulty of supply. The relevant observations and strategies that are implied can be summarized as follows:

(a) Peri-urban plantation fuelwood is cheaper than all other sources, verifying the priority for fuelwood development for longer term supplies. Since new supplies from this source will not be available this decade, this relative economy does not alter the need for proceeding to develop new sources for short-term supply.

(b) Charcoal produced in metal kilns from logging wastes and coffee residue briquettes are the lowest cost fuels. Pilot production of coffee residue briquettes and the commercial application of metal kilns should begin immediately.

(c) Cotton and cereal straw residues are estimated to be 20-25% more expensive, and production is more novel and complex. Their overall economy is good and the quantities are significant, warranting comprehensive pilot production along with coffee residues.

(d) Corn and sorghum stover, sawdust and bagasse residues are more difficult to access locally though all retain good economy in relation to the market price of wood and charcoal. Complexities of management and technological uncertainty, and hence, priority, should be resolved by immediate review followed by pilot production. The availability of resources for the energy sector in general will determine the rate at which this work proceeds, though with adequate funding, pilot production should begin in 1985.

(e) The impact of aluminum cooking pots on the efficiency of wood burning is very significant, reinforcing the view that market research is urgently required on consumer response, pricing and dissemination strategy.

(f) Consumer acceptance of more efficient new wood stoves, modified charcoal stoves, and primus kerosene stoves would not alter the supply side priorities: woody fuels simply become comparatively much cheaper. While trial production and dissemination of the innovations specified are strongly recommended, no impact of potential savings should be reflected yet in demand projections for supply side investment planning. Rather, careful monitoring and evaluation procedures should be established to record the impact of the recommended cooking efficiency program.

(g) For the rest of this decade at least, electric injera cooking will be cheaper than all biomass-fueled cookers (see Table 2.11) with the possible exception of the Tigrai injera cooker using residue briquettes and "new" charcoal sources. Firewood from new peri-urban plantations will be cheaper than all other fuels, but cannot be available in less than six years. Electric injera cookers using improved aluminum mtads appear to be the most economic.

A program of electrifying injera cooking is economically justified within the limits of power supply in the short-term with special emphasis to be placed on the development and dissemination of high-efficiency, low-power aluminum mtads. Given the high purchase costs of electric injera cookers (B250-B350), their appeal is limited to the middle and upper income groups, or about 20% of the urban population connected to the EELPA grid.

Table 2.10: COMPARATIVE COSTS OF SUPPLY OF HOUSEHOLD FUELS EXCLUDING INJERA COOKING IN THE SOUTHERN REGION URBAN AREAS USING ADDIS ABEBA AS THE REFERENCE MARKET
(Ethiopian Cents (ec) and Birr (B))

	Cost Per Unit Sold	Energy Value	¢/MJ	Conversion Efficiency (%)	Cost of Useful Energy ¢/MJ	New Quantity Accessible ('000 Actual Tonnes)
LIQUIFIED PETROLEUM						
Gas (Propane)						8
Official Price						
12.5 kg cylinders	1.20 B/kg	50 MJ/kg	2.60	45	5.78	
1.5 kg cylinders	1.50 B/kg		3.00	45	6.67	
Economic Cost	88.2 ec/liter	25.4 MJ/liter	3.47	45	7.72	
Long Run Cost (1995)	97.5 ec/liter		3.84	45	8.53	
KEROSENE						
Official Price	65.4 ec/liter	36.7 MJ/liter	1.78	36	4.95	44
Sample Market Price	85 ec/liter		2.32	36	6.44	
Economic Cost						
with wick stove	83.1 ec/liter		2.26	36	6.28	
with primus stove				45	5.02	
Long Run Cost (1995)						
- with wick stove	98.5 ec/liter		2.68	36	7.44	
- with primus stove		--		45	5.96	
ELECTRICITY						
(EELPA-ICS)						
Present Tariff (av)	15 ec/kWh	3.6 MJ/kWh	4.17	60	6.95	25 GWh
LRMC (minimum)	16 ec/kWh		4.44		7.40	
FIREWOOD						
Government	9.1 ec/kg	16.6 MJ/kg	0.55	8 a/	6.88	n/a
Supply (av)		(15% mcwb)		13	4.23	
Market Price	13.8-18.2 ec/kg		1.04 (av)	8 a/	13.00	
Economic cost from		15.4 MJ/kg		13	8.00	
peri-urban	B 23/m^3sv	(20% mcwb)				
plantations			0.27	8	2.90	
(Addis Ababa)	(450 kg/m^3bd)			13	2.08	
CHARCOAL						
Government supply	B0.39/kg in 40kg sacks	29 MJ/kg	1.34	23	5.81	
Sample Market prices	B1.00/kg (av)					
	(0.2-0.25kg lots)		3.45	23	12.83	
Economic cost						
(metal kilns)	B0.18/kg		0.61	23	2.65	
Economic cost						
(earth kilns)	B0.19/kg		0.67	23	2.91	
COFFEE RESIDUE						
Briquettes	B 66/te	15.8 MJ/kg	0.42	15	2.80	150
	in 40 kg sacks					
BAGASSE						
Briquettes	B90/te (est.)	17.3 MJ/kg	0.52	15	3.47	43
	in 40 kg sacks					
COTTON RESIDUE						
Briquettes	B92/te	17.3 MJ/te	0.52	15	3.47	239
	in 40 kg sacks					
CEREAL STRAW						
Briquettes	B93/te	17.4 MJ/kg	0.53	15	3.53	108
	in 40 kg sacks					
SAWDUST						
Briquettes	B98/te	17.7 MJ/kg	0.55	15	3.69	11
	in 40 kg sacks					
CEREAL STOVER						
Briquettes	B103/te	15.0 MJ/kg	0.68	15	4.53	211
	in 40 kg sacks					

a/ With clay cooking pots; mcwb = moisture content wet basis; bd = basic density; sv = solid volume; av = average; est = estimate.

Source: Mission estimates and field measurements.

Table 2.11: COSTS OF PRESENT AND PROSPECTIVE ENERGY FORMS FOR INJERA COOKING IN ADDIS ABABA (1983 dollars)

Energy Form and Cooking Mode	Cost Per Unit	¢/MJ	Conversion Efficiency (%) (PHV)	Cost of Useful Energy (¢/MJ)
Electricity--Present average tariff				
-- Existing Clay "mtad" cookers	15 ec/kWh	4.17	60	6.95
-- Potential Aluminum "mtad" cookers			80	5.21
Electricity--LRMC				
-- Existing Clay "mtad" cookers	16 ec/kWh	4.44	60	7.40
-- Potential Aluminum "mtad" cookers			80	5.55
Woodfuels				
-- Open Fire Cooker			4.3	
. Government Supply	9.14 ec/kg	0.55	--	12.79
. Market Price	16 ec/kg (av)	1.04	--	24.19
. Plantation Long-run economic cost	$B23/m^3$ (sv)	0.27	--	4.74
-- Tigrai Type Stove				
. Government Supply	9.14 ec/kg	0.55	--	10.0
. Market Price	16 ec/kg (av)	1.04	--	10.40
. Plantation Long-run economic cost: Peri-urban plantations	$B23/m^3$ (sv)	0.27	--	2.70
. Residue Briquettes	B90/te (av)	0.52	--	5.17
. Charcoal Long-run economic cost (metal kiln)	B5-30/30 kg sack	0.61	--	6.10

mcwb = moisture content wet basis
bd = basic density
sv = solid volume
av = average
PHV = percentage of heat utilized.

Source: Mission testing and analysis.

Potential Impact of Short-term Measures

Southern Region

2.29 The impact of the supply measures proposed here can be illustrated practically for the southern region by using Addis Ababa (population 1.3 million), with half of the southern urban population, as the target market into which all new fuels are delivered. An achievable production schedule for new biomass fuels, and a dynamic energy balance for Addis Ababa for 1983-92 also showing the expansion of supplies of LPG, kerosene and electricity for cooking, are provided in Annex 2.5 and 2.6 respectively. The production of new biomass sources for crop residue is based on harvesting the presently accessible resource (Table 2.4) by 1992; for forest residues, production is based on building up the capacity to harvest the 1992 resource after harvesting the vital Bubeka and related forest residue resources, some of which peak at 1987; and optimal management of the AfDB funded and the existing Addis Ababa fuelwood resources. Being optimistic, the result, which is summarized in Table 2.3, is that:

(a) new biomass fuel sources and expanded supplies of modern fuels exceed the demand for cooking fuels in Addis Ababa in 1992 by almost half a million tonnes of wood equivalent (see Annex 2.7 for wood equivalence);

(b) the deforestation of Addis Ababa's hinterland, now between 30,000 and 80,000 ha a year, 7/ is eliminated by 1988; and

(c) the total new household fuel supply is equivalent both to 60% of the 1992 deficit in the desired woodfuels supply to urban households in the southern region and to the annual production from a fuelwood plantation of about 170,000 ha.

Northern Region

2.30 In the northern region, since none of the new biomass fuels can be economically delivered there from the south-central agriculture and forestry regions, the only economic option in the short-term is to expand the supply of petroleum fuels. Table 2.12 shows that cooking with kerosene pressure stoves is 65% of the cost of the cheapest cooking method presently in use (open fire using aluminum pots). Without resorting to large scale imports of kerosene, the limit of supply to the north from the existing refinery is about 40,000 tonnes, allowing 14,000 tonnes for Addis Ababa and other southern region markets. The impact of this supply, as shown in Table 2.3, is to meet some 20% of the deficit in woodfuels supply in the north by 1992. The option to import more kerosene, with all the attendant problems of foreign exchange availability,

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7/ A hectare of savannah land normally has a stocking density of $30m^3$ (sv) ha but with thinning in Ethiopia, most is now only $10m^3$ (sv) ha. The estimated annual deforestation reflects this range.

distribution problems and product security, should be addressed immediately by a special study recommended by the mission to establish a comprehensive strategy to meet short-term household energy needs in the northern region. In the longer term, woodfuels are the most economic source of cooking fuels for the north despite arid growing conditions. Supply of substantial quantities of firewood could be available for new planting in the early to mid 1990s if the appropriate investments were to be made now (see para 2.32)

Medium- to Long-Term Strategies (1992-2012)

2.31 From the foregoing analysis it is evident that, for the longer-term, the least cost and most desirable method of meeting household energy needs for most of the population is to grow trees. Hence, a greatly increased program of afforestation is strongly recommended in the form of peri-urban plantations to meet the urban demand, and rural woodlots and agroforestry to meet the much larger rural demand. The scale of the planting operation implied (about 3.2 million ha) to meet the 1992 demand is so high that the mission cannot foresee it being implemented. Thus, both need-based and lower, more realistic or "achievable" programs of afforestation are here outlined, involving the equivalent of 1.12 million ha of planting during 1984-92. At the present rate of planting, only 120,000 ha of dedicated fuelwood planting would be established during the same period. The approximate cost of the expanded program would be about US$370 million. The manpower and training implications of these programs are dealt with in Chapter VIII. Work to achieve these longer-term supply side effects is of the utmost urgency, and should begin immediately. Aforementioned initiatives to achieve a short-term impact interact strongly with long-term fuelwood production targets and, together with the initiatives promoted below, should form part of a carefully integrated national program. Again, there is merit in addressing this problem in different ways in the two regions -- northern and southern -- though here a national program is outlined with reference only where relevant to unique aspects of the northern situation.

Peri-Urban Plantations

2.32 Ethiopia is unique in Africa in having developed peri-urban fuelwood plantations at the turn of the century. Although the majority have been planted in the last 20 years, there are about 20,000 ha of Eucalyptus globulus fuelwood plantations surrounding Addis Ababa and 60,000 ha in other peri-urban areas. Planting currently totals about 2,000 ha per year, though an AfDB funded project of 15,000 ha for Addis Ababa should plant 1,000 ha in 1984 and proceed at the rate of 3000 ha per year thereafter to completion. Smaller, 500-700 ha plantations for five other cities also are expected to begin in 1984.

Table 2.12: COMPARATIVE COST OF SUPPLY OF HOUSEHOLD FUELS TO THE NORTHERN REGION USING AMARA AS THE REFERENCE MARKET
Ethiopian cents (ec) and Birr (B)

	Cost Per Unit	Energy Value	¢/MJ	Conversion Efficiency	Cost of Useful Energy (¢/MJ)
ELECTRICITY					
(ERESA, ICS)					
Present Tariff	9ec/kWh	3.6MJ/kWh	2.50	60%	4.17
Economic Cost (SRMC)	31.5ec/kWh		8.75		14.58
KEROSENE					
Economic Cost	76.9ec/liter	36.7MJ/l	2.10	45%	4.67
Long Run Cost					
(1995)	92.3ec/liter		2.52		5.59
(Primus Stoves)					
LIQUIFIED PETROLEUM GAS					
Economic Cost	81.7ec/liter	25.4MJ/l	3.22	45%	7.15
Long Run Cost					
(1995)	91.3ec/liter		3.59		7.99
FIREWOOD					
(est. Long Run Cost)	B40-45/m^3				
Open Fire/					
Normal Cooking		15.4MJ/kg	0.49(av)		
- Clay Pot		as sold		8%	6.49
- Aluminum Pot		(20% mcwb)		13%	3.77
Portable Metal Stove				28%	1.75
Injera Cooking					
Tigrai Stove				10%	4.90
FIREWOOD-MARKET PRICES a/					
Open Fire	B167/te	17.7MJ/kg			
	(1980/81)	(10% mcwb)	0.94		
- Clay Pot				8%	11.79
- Aluminum Pot				13%	7.23
Injera Cooking				10%	8.80
- Portable Metal Stove				28%	3.14
CHARCOAL (est. LRMC)	B330/tonne		1.14		
Existing Stove		29MJ/kg		23%	4.96
Improved Stove				30%	3.80
CHARCOAL--MARKET					
PRICE a/	B840/tonne				
	(1980/81)				
Existing Stove			2.90	23%	12.59
Improved Stove				30%	9.67
DUNG (est.) MARKET					
PRICE b/	14.7ec/kg	14.8MJ/kg	0.99		
		(at 10% mcwb)			
Open Fire					
- Clay Pot				9%	11.00
- Aluminum Pot				15%	6.60
Improved Stoves					
using aluminum pots				30%	3.30

a/ Records of prices applying late 1980 and early 1981 from ENEC.
b/ Measured at Gondar market. Asmara was not visited by Mission.

Source: All stove efficiencies, except LPG stoves, as measured by mission. Other data are mission estimates.

mcwb = moisture content wet basis, bd = basic density, sv = solid volume, av = average.

Existing Addis Ababa Plantations

2.33 The productivity of these plantations was estimated to be 15-20 m^3/ha mean annual increment (mai) late last decade and in 1980 a survey found the average standing stock to be 118 m^3/ha, implying an acceptable five-eight year rotation. There is considerable evidence now that the rotation has declined to two-three years or less in many areas, with a high volume of 5-10 cm branch and entirely leafy shoot material flowing into the market. A survey by the mission and GOE officials of woodfuels inflow to Addis Ababa estimated that 170-190,000 tonnes of Eucalypt leaf and twig matter, about 25% of the total fuelwood supply, reaches the Addis market each year. This material is at least ten times higher in mineral nutrients than the heartwood of mature trees normally harvested. Its use as a fuel, and the dramatically shortened rotation, implies greatly decreased soil cover and fertility, fast declining yields (now 5-10 m^3/ha mai) and greater stump death. In addition, the high volatility of leafy fine firewood reduces cooking efficiency and increases overall demand (see Table 2.9). Dead stumps cover at least 1,000 ha and are interspersed with at least a further 5,000 ha. The mission recommends stump removal and replanting in totally dead areas, and enrichment planting in the remainder. Coppice management should be improved to increase productivity and reduce nutrient loss. Without these measures, the mission estimates that productivity will decline by 50% over the decade.

New Plantation Design and Management

2.34 Several aspects of proposed plantation design and management deserve review as part of a necessary diversification to upgrade biological and economic yields. First, the Ethiopian fuelwood crisis is so severe that efforts to achieve harvestable production earlier appear economically justified. Continual rotation lengths of four-five years may be achieved with heavier fertilization, good initial land preparation (ploughing) and close spacing. The mission estimates that the Addis Ababa fuelwood plantation, for example, could yield a 25% higher mai, and be harvested at year five, with a 10% reduction in the unit cost of production. Land requirements will be reduced accordingly. In addition, there must be a wider choice of species and provenances applied, with FAWCDA being constantly alert to the performance of high yielding candidates from its own and overseas plantations. Finally, the multiple role of peri-urban forestry in producing both fuel and timber for construction should be explicitly recognized as the plantation development program matures.

The Need For Peri-Urban Forestry

2.35 For Addis Ababa, if new biomass fuel sources (see Annexes 2.5 & 2.6) were not available, an additional some 120,000 ha (at 20 m^3/ha mai) of fuelwood plantations will be required by 1987 to meet the shortfall in household energy supply in 1992. However, the maximum achievable in addition to the existing AfDB project, is 16,000 ha by 1992. For the rest of Ethiopia a program has been developed based on existing forest cover and yield, allowing, as a simplification, no erosion to the existing productive base, and applying an estimate of plantation productivity based on available data, and the experience of FAWCDA and mission staff. Cost data reflect both recent experience and recent detailed cost estimates for a number of environments. Annex 2.8 provides estimates of peri-urban plantation needs by province using the mission's estimate of need of 2 kg air dry wood per capita per day, and excluding the needs of Addis Ababa. Annex 2.9 provides three sample silvicultural and cost models for typical ecosystems encountered: lowland (below 1,800 m), highland plateau (1,800-2,800 m) and erosion prone highlands (1,800-2,800 m). These cost models define direct cost only, whereas overall costs include infrastructure development and will be about 100% greater. The investment program outlined for peri-urban forestry is based on the higher cost, including infrastructure, of about B 1,760/ha (see para 2.42). These costs are comparable with those experienced in other African countries (US$800-1,200/ha) for industrial scale plantation with extensive infrastructure development. The long lead time for fuelwood development and the ever expanding need due to a rapidly growing population demand that a longer than ten-year perspective be taken both to review the impact of nearer-term investment and to gauge the nature and level of the ongoing commitment. To meet the 1992, 1997, and 2002 urban demand, an estimated cumulative plantation establishment of 387,000 ha, 545,000 ha, and 764,000 ha, respectively, has to be completed. It should be emphasized that the area required to meet the 1997 demand, using a five year rotation, must be planted by 1992, and so on. It follows, then, that the funds required to meet the need for peri-urban plantation development, including for Addis Ababa, are about B480 million, 1982-1993, and B670 million Birr, 1982-97, to meet the 1997 and 2002 demands, respectively. The four provinces of the northern zone use 63% of these funds for planting 60% of the specified area. Eritrea alone requires 39% of all peri-urban plantations and 41% of all investment in the program.

Achievable Peri-urban Plantation Program

2.36 The mission finds it inconceivable that peri-urban forests could be planted at the rate required to satisfy demand during the next decade. Rather, a more realistic, though optimistic, rate of planting has been proposed, bearing in mind the key constraints of land delineation and manpower development and training. Table 2.13 presents the planting program required to meet the estimated need, and that considered achievable under optimum conditions with a full GOE commitment. Even with the program for peri-urban forestry, the shortfall against need will be 467,000 ha in 1987, growing to 536,000 in 1992. Thereafter, the gap narrows, closing to 296,000 ha by 2002, eventually achieving a balance between 2010 and 2020. If the program of production and expanded supply from new and existing sources outlined above (para 2.8-2.21) is implemented, whereby about two million tonnes of wood equivalent are produced each year by 1992, the shortfall for the whole of the southern region in peri-urban forestry will be about 80,000 ha in addition to that now funded. The shortfall in the northern region remains 191,000 ha, compared with a requirement of 240,000 ha, once again highlighting its special problem (see Table 2.3).

Table 2.13: Need and Achievable Rate of Implementation for Energy Forestry

Year	Peri-Urban Plantations a/				Rural Forestry			
		Achievable Target				Achievable Target		
	Need (Accumulated) b/	Annual Performance	Accumulated Planting	Cumulative Deficiency	Need (Accumulated)	Annual Performance	Accumulated Planting	Cumulative Deficiency
				('000 ha)				
1982	335	2			2,006	10		
83		4	6			20	30	
84		6	12			40	70	
85		8	20			60	130	
86		10	30			80	210	
1987	512	15	45	467	2,344	100	310	2,034
88		20	65			110	410	
89		25	90			120	540	
90		30	120			130	670	
91		35	155			140	810	
1992	731	40	195	536	2,608	150	960	1,648
93		50	240			160	1,120	
94		60	300			170	1,290	
95		70	370			180	1,470	
96		80	450			180	1,650	
1997	1032	80	530	502	3,140	180	1,830	1,310
1998 to 2002	1226	80	930	296	4,074	180	2,730	1,344
to 2012					5,095	180	4,580	565

a/ Need includes requirement of Addis Ababa, but is not reduced to take account of the production of new biomass fuels (e.g. crop residue briquettes) or expanded LPG, kerosene or electricity supply.

b/ Indicates area to be established by that date to meet demands forecast five years hence, i.e., 512,000 ha are to be established by 1987 to meet the 1992 demand for woodfuel using a five year rotation.

State Farm Forestry

2.37 Special mention is warranted of the need to reforest state farms, the establishment of which has caused the same "urban shadow" of deforestation and fuelwood shortages as described for cities (see para 2.5). State farms are almost entirely void of tree cover as a result of wholesale clearing during their establishment. Apart from causing locally acute firewood shortages, the removal of this tree cover has allowed severely eroding and dessicating winds to lower productivity. In the mission's view, 10-15% of state farm areas, or 20-30,000 ha, should be afforested (between blocks, along roads and surrounding compounds). Higher yields resulting from increased soil moisture and crop production should more than repay the cost of establishing plantations and any reduction in crop land, quite apart from the value of the timber produced for fuel and construction. The area and cost of this program are covered within the overall peri-urban forestry program.

Rural Energy Forestry

2.38 The lead agencies in rural forestry are FAWCDA's department of Community Forestry and the Soil and Water Conservation Department (SWCD) of the Ministry of Agriculture. The former was created in 1980 to provide and service peasant association and school nurseries, demonstration plantations, and training facilities in rural forestry, including some dedicated fuelwood production. Table 2.14 illustrates the impressive start made by this department which in three years has raised over 50 million seedlings and established 45,000 ha of plantations. The SWCD activity is not aimed at woodfuel production, though this is an inevitable by-product so that in reality there is an overlap between FAWCDA community forestry and SWCD programs. In the past two years SWCD has also planted about 45,000 ha. The World Food Program (WFP) supports the SWCD activities and FAWCDA's community forestry department, with about two-thirds of WFP funds going to the former and one-third to the latter. However, the productivity of planting for soil protection is perhaps $5m^3$/ha mai or lower with at least 10 years to a possible harvest, and then with only limited permissible resource recovery. Thus, from a planning standpoint, the contribution from SWCD forests to woodfuel supply can be regarded as negligible. The same applies to the even more limited activities of the Relief and Rehabilitation Agency, a special agency responsible for resettlement which had a target for protective forestry of 4,000 ha in 1981/82.

Technical Performance and Requirement

2.39 By regional standards the start made by Ethiopia in all forms of rural forestry is very impressive. Regrettably, the need is far larger. To improve the efficiency and economic benefits of the required effort, several fundamental improvements should be made: emphasis on genuine agroforestry, careful selection of species and provenances, more optimal spacing, and better coppice management. It follows that this improvement can only arise through careful performance monitoring and field trials. Eucalypt species often compete with, rather than complement, crop production. The strong start made with Eucalypt woodlots should now be complemented by an aggressive agroforestry program selecting, testing, and promoting rapidly growing trees which fix nitrogen, which cycle mineral nutrients, and which do not have intolerably vigorous surface rooting. These trees are to be closely integrated with crop production in just the same way that existing slower growing Acacias do now. Considerable improvement in provenance and species selection is possible for woodlots, though this will go hand in hand with simple trial work, ample seedstocks, and adequate analysis and feedback, both to program managers and to field staff. The mission recommends the early establishment of simple experimental and recording procedures at the village level linked with the essential higher-level experimentation as part of a nationwide management information system for energy forestry.

The Need for Rural Energy Forestry Program

2.40 The same methodology that was applied to forecast the demand for urban forestry has been used to generate projections of the required rural forestry effort. The results are provided in Annex 2.10. To meet the 1992, 1997 and 2002 rural demand, the equivalent of 2.3 million ha, 2.6 million ha and 3.1 million ha would have to be in production, in 1987, 1992 and 1997, respectively, having been planted at least five years earlier. The cumulative matching expenditure by these latter dates is B211 million, B245 million and B283 million, respectively. These are direct costs only as they exclude labor and infrastructure requirements, manpower training and development, administrative salaries and wages and transportation. In the period 1982-97, 670 million man-days of labor would be required for program implementation. However, regardless of the availability of funds, it is quite inconceivable for planting to proceed at the required rate.

Achievable Rate of Rural Forestry Development

2.41 The key constraints on the rate of rural afforestation are current deficiencies in manpower training and development, program planning and management infrastructure. Nevertheless, if there were a truly strong national commitment to this program, the mission is optimistic that an order of magnitude increase in planting can be achieved. Referring back to Table 2.13, it is believed practical to budget on achieving a rate of 100,000 ha per year within five years and 150,000 ha per year within ten years, planting 960,000 ha by 1992 compared with a need at that time for 2.61 million ha. Extrapolated out, the achievable rate of planting does not catch up with demand until about 2020. At whatever level planting can be achieved, it is noteworthy that the northern region of four provinces requires just over half of the total projected afforestation.

Costs of Achievable Forestry Program

2.42 The cost data for rural afforestation provided in Annex 2.10 refer only to direct Peasant Association costs of nurseries and to the required man-days. A simple cost estimate is provided in Annex 2.11 for rural afforestation based on an allocation of overheads for an ultimate planting rate of 200,000 ha per year. Here, the costs compute to about B420 per ha (in 1983 Birr) or B403 million for the 1992 rural forestry target of 960,000 ha, plus peri-urban forestry at B1760/ha, half in direct costs and half for infrastructure, or B343 million. The total cost of the program is B746 million for the 1983-92 period. In this estimate peasant labor is costed at B1.00 per man-day on the basis that labor will have to be hired (using food as payment). If this labor is genuinely donated, the financial cost drops by B202 million to B544 million for the decade. In addition, the required manpower development and training, the remodeling and expansion of existing institutional capability, and the new buildings and hardware for training will cost about B21 million. These costs and those derived for the implementation of the short-term strategy are summarized below in Table 2.15. The total requirement is B152 million for direct investment in the measures which will have a significant impact during the 1987-92 period, including upgrading the Addis Ababa plantations (paras 2.30 and 2.31). It is assumed that the State Farms administration bears the infrastructure and manpower training cost of the crop residue program as part of their own expansion. The total cost of energy forestry for the decade is B767 million. However, it is noteworthy that in the five years 1992-97 during which time trees will be planted to meet the 2002 woodfuel demand, a further 1.2 million ha is required at an additional cost of almost B1 billion.

Table 2.14: FAWCDA COMMUNITY FORESTRY PRODUCTIVITY SINCE FORMATION

Year	Trained Farmer	Demonstration Nurseries	PA and School Nurseries	Seedlings Raised	Demonstration Plantations
	('000)			(millions)	('000 ha)
1980/81	10.64	30	74	1.2	14.0
1981/82	19.70	41	72	18.6	10.6
1982/83	20.00	225	67	32.0	20.0
	50.34	296	213	52.8	44.6

PA = peasant association.

Source: FAWCDA and Mission Estimates

Economic Justification of Energy Forestry

2.43 The program of expenditure on energy forestry which the mission believes to be achievable represents more than a tenfold increase over the present rate of energy forestry operations. This program implies a diversion of resources to fuelwood production alone far greater than ever applied to foresty as a whole in previous budgets, and it therefore must be supported by a sound economic rationale. Fuelwood produced from peri-urban plantations has already been shown in Table 2.10 to be the least-cost option for supplying household fuels in the longer term, being less than half the cost of all competitors besides coffee residues and charcoal from logging wastes. Another measure of the economy of the peri-urban program is the rate of return on investment, both financial and economic. The financial rate of return (FRR) will indicate how likely it is that smallholder entrepeneurs would find it attractive to participate in fuelwood production, and the economic rate of return will serve as an input to government decision making on investment priorities in the context of overall resource limitations. Firewood produced on the fringe of the large cities will be sold in competition both with firewood from the hinterland and with kerosene. Using the cost data of the AfDB Addis Ababa fuelwood plantations, which in the mission's view is 20% or so more expensive than will be future plantations, an FRR of 29% is achieved against the current average market price of firewood (Addis Ababa, Dire Dawa, Nazareth and Gondar prices), and a 20% and 23% ERR is achieved against the present and escalated (1.8% p.a.) real cost of kerosene, respectively.

Economics of Rural Forestry

2.44 The economics of rural afforestation are more complex and rest substantially on the perceived consequences of rural deforestation outlined in paras 2.4 and 2.5. Here a major quantifiable cost is the value of the fertilizer lost to agricultural production when dung is burnt as a fuel or, where there is no conceivable alternative fertilizer, the value of foregone crop production. In Ethiopia it has been possible to aquire, from a number of sources, sufficient data to make a first order estimate of these costs (a separate note is available). Using a conservative estimate of the economic cost of fertilizer (Diammonium Phosphate: DAP) at the farm gate of US$295/tonne (cf. government selling price in distribution centers of US$411/tonne), dung is valued at B45/tonne for its nitrogen and phosphorus content alone. However, the constraints to importing the quantity of fertilizer required to substitute for all dung burnt -- 490,000 tonnes of DAP costing US$114 million (CIF) -- must be recognized, along with an inability to distribute imported fertilizer to more than, say, 20-30% of peasant farmers. Applying data gathered on the pattern of subsistence agriculture in northern Shoa province, 8/ and with the use of appropriate fertilizer response curves drawn from Ethiopian data, incremental grain yields from the application of dung otherwise burned ranged in value from B130-190/ha, though higher values can be generated and justified.

8/ By the International Livestock Commission for Africa: ICLA.

Table 2.15: COSTS OF AN ACHIEVABLE HOUSEHOLD ENERGY PROGRAM

Source	Yearly Production by 1992	Total Investment During 1983-92
	('000 actual tonnes of fuel product)	(B million)
Short-term Measures		
Crop Residues	751	72.0
Charcoal	337	41.0
Improved Cooking Efficiency	n.a.	3.0
Addis Ababa Plantation Upgrading a/		
Added Fertilizer AfDB Project	598	9.4
Replant existing plantations	18	26.4
Subtotal		151.8
Medium to Long-term Measures	ha ('000)	
Peri-urban Plantations	195	403.0
Rural Energy Forestry	960	343.0
Manpower Training and Development	n.a.	21.0
Subtotal	1,155	767.0
Total for 1983-92:		918.8
Additional Costs to Meet Household Energy Needs of 2002	Additional Planting 1992-97 ('000 ha)	Total Investment 1992-97 (B million)
Peri-urban Plantations	335	590
Rural Energy Forestry	870	365
Total for 1992-97	1,205	955

a/ Additional wood yield forecast in air dry tonnes (25% mcwb), the same as tonnes of wood equivalent, up to and including 1992 over yields available from proposed AfDB project design and cutting program and no infill planting for existing plantations (see Annex 2.6).

Source: Mission estimates.

It should be clear that there are other economic benefits of using dung as a fertilizer and many benefits of afforestation per se that cannot readily be quantified. The data presented here imply an annual loss of grain production through the use of dung as a fuel of between 1 and 1.5 million tonnes, with an economic value of between B850-1275 billion. The estimated value of various uses of dung are as follows:

		Dung (B/tonne)
(a)	Value of dung based on the cost of production of the equivalent fuelwood through rural forestry (including labor inputs at B1/man-day) (10-15m^3/ha mai);	6-9
(b)	Value of dung (nitrogen and phosphorus content only) equated to farm gate costs of imported fertilizer;	45
(c)	Value of dung (N&P content only) equated to the minimum incremental production of Teff when applied as a fertilizer in typical peasant agricultural system.	128-189

These data indicate that the lowest value use of dung is as a fuel, justifying the investment in rural forestry to supply firewood to displace it for higher value uses. The ERR's for rural forestry at the lowest yields of 10m^3/ha mai, displacing dung for use as a fertilizer and assigning to it first its imported fertilizer equivalent value, then its low and high grain production equivalent value, are 35%, 59% and 70%, respectively. Even with a yield of 5m^3/ha mai, equating dung to imported fertilizer, the ERR is 23%. Clearly, investment in rural forestry is robust even in the very marginal arid areas and must be attributed high priority in the overall energy sector investment program.

Implementation of the Achievable Energy Forestry Program

Peri-urban Forestry

2.45 The institutional arrangements for implementing the proposed program of afforestation will vary between the peri-urban and rural components. The mission sees FAWCDA as the lead agency in peri-urban forestry in accordance with the existing government proclamation. FAWCDA has the base from which to develop the capability to implement this formidable industrialization of commercial fuelwood forestry. However, it is clear that to plant at the required rate, FAWCDA will have to limit its role beyond the plantation establishment phase to management advisory services and monitoring. Urban kebeles and, where relevant, rural peasant associations (PA), will have to be brought increasingly into day-to-day management of the maintenance, harvesting and marketing phases. In the long run, kebeles should also become the prime executing agencies. It is essential for there to be adequate incentives for Kebele and PA leadership to manage plantations for high sustained yield: unlike the situation of heavy overcutting for short-term gains now a feature of the management of the Addis Ababa plantations. The mission favors the allocation of plantation blocks to smallholder families under the general supervision of local authorities, and within guidelines established by FAWCDA, with appropriate stumpage fees paid to FAWCDA enabling it to profitably recover its investment and to reinvest quickly in new plantations.

2.46 FAWCDA will require a flexible and dynamic institutional arrangement in order to cope with the early development phase of the next decade when skilled manpower and infrastructure will certainly be limited. As over half of the plantations to be established will be about 500 ha and located near small towns, the option of establishing mobile extension and support units of well-trained staff supporting the local FAWCDA plantation manager (at least one technician per 500 ha) should be seriously considered. Plantations also could be designed and established in standard 500 ha packages tailored to the needs of particular regions, facilitating budgeting, procurement arrangements, and management information services.

Rural Energy Forestry

2.47 The implementation of this program must take full advantage of the existing and successful structures including both the regionalized political organization from province, through Awraja, Woreda, and PA's, and the administrative, public service vehicles of FAWCDA's Community Forestry Department and the Ministry of Agriculture's extension services. There are several options open to GOE though one essential element is to establish effective contact right down at the PA level, and through the "contact farmer", with individual peasants. This approach is fundamental because of the importance of genuine agroforestry, on the one hand to augment the supply of fuelwood and on the other hand to protect and revitalize agricultural productivity. Agroforestry involves forestry intimately interwoven with, rather than on the fringes of, crop production, hence it is appropriate that the concept be delivered through the familiar agency of the agriculture extension service. Nevertheless, FAWCDA could provide the subject specialist at say, the Woreda level, to ensure that advantage is taken of its existing community forestry expertise. FAWCDA would continue to deal with PA's or cooperatives concerning the design and establishment of fuel and timber woodlots for the community, and with the establishment of nurseries, training in woodlot management and the like. The Ministry of Agriculture can best incorporate agroforestry extension services by strengthening the basic structure proposed by the Banks Minimum Package Program, once again ensuring a simple and hopefully consistent line of advice to the contact farmers within PA's. The level at which an active interface between MOA and FAWCDA takes place, and the nature of the interaction required, must be clarified and agreed as a matter of priority. Details of the overall manpower training and development requirements of the achievable forestry program are provided in Chapter VIII.

Consequences of Failure to Act on Rural Afforestation

2.48 Two interlinked examples of the present direction of change serve to illustrate the dire consequences of inaction: deforestation in Gojam and the pattern of dung supply and demand in the populous grain producing regions. Gojam, a major grain producing province with 2.1 million people, presently has an estimated sustainable production of only

40% of the provincial demand for fuelwood, or a supply equivalent to the annual production of a forest of about 160,000 ha with 100 m^3/ha standing biomass. The mission calculated the impact of population growth on the available fuel sources if there is no further afforestation. From this forest resource base, and with the estimated cow dung supply and demand pattern provided in Annex 2.12, by the turn of the century Gojam will have no trees, no surplus dung, and merely old tree roots, brush and grass for fuel. This situation will be mirrored in Hararghe, Bale and so on across the middle belt of highland provinces all reaching more or less the situation of Eritrea today within 10 to 20 years. Equally alarming are the conclusions to be drawn by matching present supply and demand patterns for dung and crop residues (Annex 2.12) with the growth in household energy demand by province (Annex 2.13). Even assuming no reduction in the growing stock of trees, the present annual cow dung production accessible is entirely utilized in Bale, Goma Gofa and Wollo by 2000, and is exhausted within ten years in Hararghe, Gondar, Tigrai. In Wollega, Gojam and Sidamo, 50-70% utilization is implied, much like the situation now in Tigrai and Gondar. Nor is it realistic to forecast a significant increase in cattle population in most of these provinces. Therefore, substantially more than double the quantity of dung now burnt will be diverted away from crop and fodder production by the mid- to late-1990s. The indications are, quite simply, that the conditions now prevailing in the northern region will progressively appear in most of the populous central and western regions during the next 10-20 years.

2.49 In summary, the mission believes that over a period of 30 years it is possible to restore the supply and demand balance for rural energy, and to stabilize and rejuvenate agricultural productivity. The effort during that period is equivalent to reforesting 5% of the Ethiopian landscape. The required inputs of funds, manpower and other resources are large, but not prohibitive. To achieve these objectives the GOE must make an unparalled commitment to afforestation and biomass resource mobilization. The loss of soil, and the rate of deterioration in soil fertility, is now so great 9/ that there must be grave doubts as to whether declining rural productivity can be arrested. However, it is clear that if left for another decade, with only the present level of activity, the task may well become impossible.

2.50 In the event that the rate of afforestation proposed here is unmet, or that the production of the novel and apparently economic residue fuels prove infeasible, kerosene and LPG will become the next least cost option for much of the urban population. This option has serious balance of trade implications. For example, if half of the anticipated 1992 population of Addis Ababa were to switch to kerosene as a cooking fuel they would consume 140 million liters a year at an economic cost of US$56 million, excluding real price escalation.

9/ Soil erosion in the Ethiopian highlands is estimated to average 20 tonnes per hectare per year, exceeding one billion tonnes of soil loss each year. From a long time series of aerial photography, it has been estimated that about 1% of the surface area of Ethiopia's best soils are lost each year.

III. ELECTRICITY

3.1 Ethiopia has considerable power resources in the form of hydropower and natural gas and is in the process of exploring the potential for geothermal power. The main issues in the power sector center on the feasible level and source of future supply and, in turn, on the rate of growth in demand, the least cost program of power sector development and the related financing and pricing requirements. Decisions to be made on the future sources of power supply have significant implications for the development of other subsectors of the energy economy, making timely and comprehensive resource assessment and thorough power systems analysis of fundamental importance to overall energy sector investment planning.

Institutional Arrangements

3.2 Electricity is generated under the authority of the Ethiopia Electric Light and Power Authority (EELPA) which was formed in 1956 as an autonomous parastatal and since 1976 has been under the Ministry of Mines and Energy. While EELPA maintains overall responsibility throughout the country for public power generation, transmission and distribution, the supply of power to the northern region, including the major centers of Asmara and Massawa, is provided by its unconsolidated subsidiary, the Eritrea Region Electricity Supply Agency (ERESA). The only reason for this unconsolidated arrangement is to facilitate discrete accounting as ERESA consumers are heavily subsidized. Presently the tariff level in force in the ERESA supply region is similar to that in the main interconnected system (ICS) of the central highlands, even though the latter is supplied primarily by fairly low cost hydropower and the former is supplied from very expensive diesel and residual fuel oil-fired generation. Each of the EELPA and the ERESA supply regions are composed of an interconnected system and a series of satellite generation centers referred to as self-contained systems (SCS). With only one major exception, the Tis Abai hydropower plant at the outlet of Lake Tana which serves Bahir Dar, the SCS systems are supplied from diesel generators. In addition to public power supply systems, there are a host of captive generation systems within government and private enterprises as well as municipally-owned plants in many small towns and villages.

The Power System

3.3 The population of areas served by electricity was estimated in 1980 to be about 2.8 million, which is about 9% of the total population. There are approximately 290,000 households, or about 50% of the population connected with power supply within the supply areas. Average per capita consumption was 18 kWh/year in 1980/81 (21 kWh/year in 1981/82) which is extremely low even by regional standards. 10/ The distribution of installed capacity by type is indicated in Table 3.1. Of the 330 MW of generating capacity in public, quasi-public and private hands, 66% is hydro, 11% is oil-fired steam, and 23% is diesel engine generation. The main power plants are marked on the accompanying maps. The public systems account for 283 MW or close to 90% of total installed capacity. Electricity production so far has been concentrated in the central highlands of Ethiopia where consumption has grown steadily from 1961 to 1982 at an average annual rate of 9.0%. In the northern region, the available production data indicate a growth of 1.5% p.a. between 1971 and 1981. The much slower growth is explained mainly by the impact of military operations on the economy of the regional capital of Asmara. Power generation had fallen to one-fifth of the 1973 level by 1978 and was restored to the earlier peak only in 1982. Greatly increased oil-fired generation of power during the last four years has added substantially to the average cost of power production nationally. This recent growth has simply restored production levels achieved a decade ago. Table 3.2 also indicates that growth in publicly-generated power sales nationally in the 1977-81 post-revolutionary period of economic recovery was about 13% p.a. Of 1982 electricity consumption, 57% went to industry, 17% to government and commerce, and 26% to households (see Chapter I, Table 1.2)

3.4 The EELPA ICS generates about 73% of all public power supply and about three-quarters of this is used in Addis Ababa. A detailed analysis of recent trends in generation and sales for the EELPA ICS is provided in Table 3.3. Growth in sales was stagnant in 1981 but recovered again in 1982 due largely to interconnections with the SCS, commissioning of the first electric boiler loads and a spurt in domestic demand. The overall growth rate for the FY77-82 period was 9.4%, including interconnections. Understandably, the sectoral distribution of the sales within EELPA in 1982/3 was similar to the estimated distribution of sales nationally, with 60% to industry, 28% to households, and 12% to government, commerce and other categories.

3.5 Sales data for the EELPA SCS for 1977-82 are given in Table 3.4. The average annual growth rate for sales in the total system was 11.7%. By far the largest single load center in the SCS is at Bahir Dar, situated on the southern edge of Lake Tana at the source of the Blue Nile River (Tis Abai). The public supply system is obtained from the run-of-river Tis Abai power station which has a present installed capacity of 7.6 MW (two 3.8 MW units). A third unit of 3.8 MW is scheduled to be installed by 1984. In addition, a project to narrow the outlet from Lake Tana to the Tis Abai is scheduled to be completed in 1985 to regulate the outflow from the Lake to increase hydro power production from the Tis Abai station during the dry season. Present production capacity for the station is about 30 GWh/year and this will be increased to about 100

10/ Comparative per capita consumption data for 1980 for other countries in the region are (kWh/year): Kenya--92; Tanzania--44; Uganda--21; Malawi--64; Sudan--60.

GWh/year after 1985. The remaining sales in the SCS (about 63 GWh/year in 1982) are produced from a multitude (over 200) of small public and privately-owned diesel generators which average less than 300 kW in size. About 50% of SCS sales are to industrial consumers, about 30% are to domestic consumers and 20% to commercial establishments.

Table 3.1: INSTALLED CAPACITY FOR POWER GENERATION, 1981
(MW)

	Power Source			
	Hydropower	Steam	Diesel	Total
Public Systems				
EELPA				
- ICS	207.20	--	6.50	213.7
- SCS	10.07	--	20.14	30.2
Subtotal				
ERESA				
- ICS	--	15.00	26.2	41.2
- SCS	--	--	8.70	8.7
Private Generation				
Asseb Refinery	--	13.5	--	13.5
Sugar Corporation				
- Wonji	--	1.92	--	1.9
- Shoa	--	0.38	--	0.4
- Metahara	--	6.00	--	6.0
Nippon Mining	--	--	0.48	0.5
State Farms	--	--	4.78	4.8
112 Towns and Villages	--	--	9.38	9.4
Total	217.27	36.8	76.18	330.3

ICS = Interconnected system
SCS = Self contained system
Source: Acres-EELPA reports and energy assessment mission.

Table 3.2: PUBLICLY GENERATED POWER SALES IN ETHIOPIA, FY78-82
(GWh)

	1977/78	1978/79	1979/80	1980/81	1981/82	Growth (% p.a.)
EELPA						
ICS	318	358	402	414	485	10.6
SCS	68	77	79	75	93	--
Subtotal	386	435	481	489	578	9.7
ERESA						
ICS	15	53	67	76	79	14.2 a/
SCS	5	5	5	4	4	--
Subtotal	20	58	72	80	83	
Total	406	49	553	569	661	13.0

a/ 1978/79-1981/82
Source: EELPA.

Table 3.3: EELPA ICS SALES AND GENERATION FY77-82

Financial Year	Domestic (GWh)	Commercial (GWh)	Street Light & Agriculture (GWh)	Small Industry d/ (GWh)	Large Industry d/ (GWh)	Interconnected Centers (GWh)	Total Sales (GWh)	% Change	Generation (GWh)	Peak Demand (MW)	System Load Factor (%)	System Losses (% Sales)
1977	67.48	32.74	5.87	25.61	177.57	-	309.28	--	348.15	71.1	55.9	12.6
1978	77.71	32.66	6.17	26.77	175.15	-	318.46	+10.3	361.37	73.9	55.8	13.5
1979	89.23	36.71	11.65	29.46	189.31	1.65	358.00	+12.4	410.71	83.0	56.5	14.8
1980	99.20	36.66	6.46	29.71	219.99	9.85	401.87	+12.3	453.58	87.8	59.0	12.7
1981	107.82	37.05	4.39	30.00	219.36	15.02 a/	413.64	-0.8	478.44	90.0	60.7	15.7
	4.95	2.87	0.54	6.00	0.66	-	--	--	--	--	--	--
	112.77	39.92	4.93	36.00	220.02	--	413.64	+2.9				
1982	135.36	48.30	9.14	43.71	248.25 b/	--	484.76	+17.2	541.00	102.5	60.3	11.6
1982/1981	(+20.0%)	(+21.0%)	(+85.4%)	(+21.4%)	(+12.8%)		(+17.2%)		(+13.2%)	(+13.2%)		
1982 Imputed Category Losses (% Sales)	14.6	14.6	14.6	14.6	8.7	--	11.6					
1982 Imputed Category Load Factor (%)	50	55	55	60	70	--	60.3					
(Peak Load on Systems MW)	35.4	11.5	2.1	9.5	44.0	--	--	--	--	102.5		
Average Annual Growth Rate c/ (%) FY77-81 excluding interconnection	12.5	3.7	--	4.3	6.7	--	8.5	--	9.0	--		
FY77-82 including interconnection	14.4	7.5	--	10.7	7.4	--	9.4	--	9.4	--		

a/ Load Centers connected to ICS from FY79 onwards for FY79-FY82 comprise Assela, Dila, Shashamenie, Yirgalem, Yirga Chefe, Zewar.
b/ including 20.26 GWh boiler sales.
c/ computed from least-squares "best fit" curve for data.
d/ includes new industrial plants.

Source: EELPA and mission analysis.

Table 3.4: EELPA SCS SALES, FY77-82

FY	SCS Total a/	Interconnection	SCS Net
	(GWh)	(GWh)	(GWh)
1977	60.90	--	60.90
1978	68.22	--	68.22
1979	78.18	1.65	76.53
1980	88.83	9.85	78.98
1981	89.50	15.02	74.55
1982	109.70	16.68	93.02

a/ Before deducting sales to load centers interconnected with the ICS.

Source: EELPA.

3.6 Generation and sales data for ERESA for 1977-82 are provided in Table 3.5. The average annual growth rate in sales was 13.1%. Generation was estimated to be 95 GWh in FY82/83, of which 53% was from diesel and fuel oil-fired diesel engine generation sets and 47% from fuel oil-fired steam turbo-alternators. Average system losses are typical of small systems though some improvement should be achievable. The sectoral pattern of sales differs from the EELPA ICS only in respect of the domestic sector where artificially low tariffs encourage cooking and water heating with electricity. More economic means of serving both of these demands are available (see para 3.44). About 60% of ICS sales are to industrial consumers and 40% are to residential and commercial consumers.

Features of Present Demand

3.7 During the 1960s and early 1970s, the average annual growth in demand on the EELPA ICS was about 12%, but there was virtually zero growth due to the post-revolutionary disruption of the country between 1974 and 1976. The World Bank-financed Finchaa Hydropower Project of 100 MW was commissioned in 1973, yet by 1975/76 demand had not risen as expected. Hence, it was correctly perceived that there would be considerable excess capacity and energy available at very low cost for some years ahead. To take advantage of this unexpected surplus, EELPA promoted the use of electricity for both industrial steam raising and household cooking. As a first phase of a boiler electrification program, EELPA and the Ministry of Industry negotiated five-year contracts for the supply of power to electric boilers to take effect by 1980 at the latest. In all, there were 14 boiler installations planned with a total installed capacity of 68 MW, or about 40% of the total demand in 1984. Contracted tariffs ranged from 1.35 ec/kWh to 2.5 ec/kWh (0.65-1.21 US¢/kWh). By June of 1983, only two installations had been completed although all boilers had been purchased and several had been installed and were awaiting connection to power supply. Details of energy requirements, maximum demand and the current status of boiler installations are provided in Annex 3.1. By 1984, nine boilers were to be connected and all but one will be operating by mid-1985. Regrettably, the seven or so year delay in program implementation has meant that most of the benefits originally perceived will not materialize. Not only is peak demand rapidly approaching the power system firm supply capacity, but the long-run cost of electricity is much greater than has ever been considered (see Chapter VI). Therefore, the supply contracted for boiler consumption has a much higher opportunity cost than the tariff levels. Furthermore, recent GOE policy edicts require EELPA to generate substantial revenues and therefore the very low boiler tariffs will impose a financial burden on EELPA. In economic terms, considering only the energy costs of operation, electric boilers will incur economic costs of about B10 million per year in addition to the cost of fuel oil-fired boilers serving the same demand. Finally, there have been two major technical flaws in the design and procurement of electric boiler systems. First, the requirement for extensive water treatment was largely overlooked as was the need to provide adequate manpower training for the sophisticated management required for high quality water treatment. The equipment for effective water treatment is itself a major expense. Second, the boilers selected are not suitable for base-load operation since they have a very high rate of heat transfer per unit electrode area which makes them highly susceptible to scaling, even with low levels of water impurities. In all likelihood the boilers installed will have an economic working life of less than ten years.

Table 3.5: ERESA ICS AND SCS: SALES AND GENERATION, FY77-82

	ICS				SCS		
Year	Sales (GWh)	Generation (GWh)	Combined Demand (MW)	Losses (% Sales) b/	Sales (GWh)	Generation (GWh)	Losses (% Sales) b/
1977	45.1	49.0	--	8.6	--	--	--
1978	15.2	17.0	--	11.8	4.8	5.6	16.7
1979	52.6	63.7	11	21.1	4.6	6.3	37.0
1980	67.0	76.1	17.3	13.6	4.5	6.3	40.0
1981	76.3	86.8	18.5	13.8	4.3	5.8	35.0
1982	79.2 a/	92.2	19.7	16.4	4.2	5.6	33.3

a/ Estimated by mission.

b/ Believed to include considerable non-technical losses.

Source: EELPA.

3.8 For the above reasons, the mission considers that it would be uneconomic to continue the electric boiler program beyond its first phase, and that the only justification for continuing with the first phase is that the equipment already has been purchased and therefore constitutes a sunk cost. In view of the impending shortfall of system capacity on the EELPA ICS (Table 3.7), the mission considers that EELPA should invoke its contractual right to cease supplying power on concessional terms from 1985 onwards, and to charge thereafter an economic price for power supplied to electric boilers. The mission's analysis shows that electricity is a much costlier source of energy than fuel oil in terms of economic cost for boiler operation. Provided that market prices reflect economic costs, there would be a strong incentive to restore fuel oil in place of electricity as boiler fuel. Existing non-electric boilers should be kept in working condition for back-up operation when electric boilers break down or undergo maintenance and, eventually, for continuous use. Fortunately, in all plants except one, 11/ the existing non-electric boilers are still in place although expenditure on overhaul is required on some of them.

3.9 Electric cooking also has been heavily promoted inside and out of government as a means both of reducing fuelwood consumption and of utilizing "supposedly" cheap surplus hydropower. The program is focused on the EELPA ICS area, particularly in Addis Ababa. EELPA has contributed to this program since the 1970s through the manufacture and sale of electric cookers. EELPA estimates that the number of electric injera cookers in use at the end of 1982 was between 10,000 and 15,000, or about 3-5% of Addis Ababa households. Presently the market is supplied by both EELPA and private manufacturers. EELPA's present production capacity is about 2,000 cookers per year, although in the recent past actual production has been limited to about 1,000 cookers per year due to constraints on the supply of components. EELPA estimates that private manufacturers have a combined production capacity of between 2,000 and 3,000 cookers per year. Presently, the demand for electric injera cookers appears to exceed this supply capacity at market prices. 12/ EELPA is under direction from the government to produce 10,000 injera cookers per year to combat the fuelwood problem. Whereas up to now the Ministry of Industry appears to be doing very little in manufacturing electric cookers, EELPA is prepared to supply a substantial proportion of the market in order to set quality standards and to prevent private manufacturers from exploiting the present imbalance between demand and supply by raising prices to a market clearing level.

3.10 Injera cookers currently available draw a load of about 3 kW on average, and electric cooking pots are rated at 0.50 kW though few are in use. EELPA has developed a more efficient model of injera cooker which draws a load of 2.5 kW. This development will result in a significant

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11/ The exception is the United Oil and Soap plant in Addis Ababa. This boiler presently consumes 7,000-10,000 tonnes of fuelwood annually. Proposals for alternative fuels for this plant are given in Chapter V.

12/ Mid-1983 market prices in Addis Ababa: EELPA cooker -- B250; private manufacturers -- between B250 and B350.

reduction in maximum demand on the power system, and will provide some alleviation of the projected critical period for power system supply before the commissioning of the Malka Wakana hydropower station (see para 3.27). The extent of this alleviation depends upon growth in demand for these cookers, which is expected to be strong for at least the short-term, and the degree to which the use of these cookers can be timed to avoid daily peak demand periods on the power system.

3.11 The dominant market for electric cooking appliances is the middle and upper income group of urban dwellers, which is the only group that can afford the initial cost of an electric cooker. At present prices there is a substantial cost savings from using electricity which is a key factor in the strong demand for electric cookers. In economic terms, the choice between electricity and fuelwood depends upon a variety of factors and, in theory, fuelwood should be the cheaper energy form for injera cooking in the latter half of the 1980s and beyond. 13/ However, electric injera cooking is clean and convenient compared with open-fire injera cooking, which usually generates voluminous smoke from the volatile fine woody fuels used. In practice, it is likely that, at least among the upper income group, demand for electric cookers will remain strong (see recommendations regarding electric cooking in Chapter II).

Electricity Demand Forecasts

3.12 Power demand forecasts up to 2005 have been prepared by EELPA's consultants 14/ for both the EELPA and ERESA areas. The projections are based on a number of components including basic growth in the economy, new industrial development, industrial boiler electrification, domestic electric cooking appliances, extension of the interconnected system (ICS) and rural electrification. They explicity assumed that tariff levels would not be changed in real terms. The consultants concluded that these factors would result in a significant rate of increase in power demand, especially during the period 1982-87.

EELPA ICS Forecast Demand

3.13 Average forecast growth rates by the consultants for demand on the EELPA ICS are given as follows:

13/ The economic cost of energy for cooking at projected conversion efficiencies is: electricity -- 7.4 ec/MJ; fuelwood -- minimum 2.7 to 4.7 ec/MJ depending on cooking type (Table 2.11).

14/ Acres International Ltd., Canada.

	FY82-87	FY87-92	FY92-97	FY97-2002
Average Forecast Growth Rate (%/a)	19.2	8.6	6.3	5.6

The contribution of the demand components to the overall projected growth on the EELPA ICS is given in Table 3.6.

Table 3.6: EELPA-ICS: COMPONENTS OF CONSULTANTS' FORECAST DEMAND a/
(GWh)

Demand Category	FY80 (actual)	FY82	FY87	FY92 (projected)	FY97	FY2002
Domestic-General	119					
Commerce b/	51					
Small Industry	35					
Subtotal	205	229	321	450	632	886
Domestic						
Electric Injera Cookers and Pots c/		5	66	131	183	257
Large Industry						
Existing General	249	277	337	409	498	606
Boilers	0	59	342	582	821	1061
New Plants d/		16	177	245	292	349
New Interconnected Load Centers	—	25	223	402	586	797
Total Demand	454	610	1466	2219	3012	3956

a/ demand at generation stations.
b/ including street lighting and agricultural demands.
c/ included in Domestic General category for 1980.
d/ Included in Industrial Existing category for 1980.

Source: Acres "Power Planning Study" (October 1982).

3.14 The consultants' standard forecast is for 14.9% p.a. growth in capacity demand and 16.7% a year growth in energy demand between 1982 and 1989. The underlying growth rate in demand throughout the forecast period is projected to be 7% a year for domestic, commerce and small industries, and 7% a year for existing large industries. The abnormally high growth rates in the short- to medium-term are the result of demands from the special categories, namely industrial boiler electrification, new industrial loads, injera cookers and new load centers connected to the ICS. Both the consultants and the mission assumed that in the short term domestic demand would be inelastic. According to the consultants' forecast, demand will overtake available system power capability on the EELPA ICS in early 1984, and will exceed firm system energy generating capability in mid 1985, as demonstrated in Table 3.7.

3.15 Actual sales for the past two years on the EELPA ICS have been consistently below the consultant's forecast sales for this period, as shown below:

	FY80		FY81		FY82	
	MW	GWh	MW	GWh	MW	GWh
Consultant's Forecast Demand a/	88 b/	454 b/	104	499	128	610
Actual Demand	88	454	90	478	103	541
Ratio Actual to Forecast	1.00	1.00	0.87	0.96	0.80	0.89

a/ at generation station.
b/ actual demand for FY1980.
Source: EELPA

3.16 Furthermore, the mission considers that the consultant's forecast growth rates for demand for the EELPA ICS are unrealistically high, especially in the short-term. Therefore, the mission has prepared its own demand forecast that is lower than the consultant's by virtue of a lower base year demand (FY1982) and lower forecast growth rates. The rationale for this view is given in the following paragraphs which are then aggregated into the mission's forecast for total demand.

3.17 Future Electric Boiler and Cooker Demands. It is assumed here that the mission's recommendation to discontinue the electric boiler program will be accepted and implemented. This has a major effect on future demand, for in the present demand forecast boilers are an expanding load through 2000. In addition, in the early years the maximum supply contracted (and included in the consultant's forecast) overestimated the actual consumption. The mission's projected demand from electric boilers is therefore as follows:

	FY84	FY85	FY86	FY87	Beyond FY87
Maximum Demand a/	41	56	56	20	0
Energy Consumption (GWh/year)	137	179	179	80	0

a/ Unit coincidence factor for boiler maximum demands are assumed for these values and therefore this demand would be less according to the extent that the factor is less than unity.

Table 3.7: EELPA ICS: ACRES AND MISSION FORECASTS OF DEMAND AND GENERATION CAPABILITY, FY83-95

FY	Generating Capability		System Reserve a/	Available Capacity		-----Mission Forecast----- System Demand		Balance		-----Acres Forecast----- System Demand		Balance	
	(GWh)	(MW)	(MW)	(GWh)	(MW)	(GWh)	(MW)	(GWh)	(MW)	(GWh)	(MW)	(GWh)	(MW)
1983	1052	204	33	1052	171	618	126	434	45	732	152	320	19
84	1052	204	33	1052	171	735	164	317	7	920	192	132	-21
85	1052	204	33	1052	171	862	200	190	-19 e/	1126	233	-74	-62
86	1052	204	33	1052	171	877	213 d/	175	-42 d/	1329	280	-277	-109
87	1212 b/	264 b/	33	1212	231	934	196	278	35	1466	311	-254	-80
88	1760	(348.5/248.5/381.5) c/	35	1760	313.5	1052	213	708	100.5	1638	347	122	33.5
89	1760	381.5	40	1760	341.5	1145	232	615	109.5	1795	380	-35	-38.5
90	1760	381.5	40	1760	341.5	1241	250	519	71.5	1932	408	-172	-66.5
91	1760	381.5	40	1760	341.5	1342	270	418	71.5	2073	438	-313	-96.5
92	1760	381.5	40	1760	341.5	1453	292	307	49.5	2219	469	-459	-127.5
93	1760	381.5	40	1760	341.5	1566	315	194	26.5	2369	501	-609	-159.5
94	1760	381.5	40	1760	341.5	1687	340	73	1.5	2523	533	-763	-191.5
95	1760	381.5	40	1760	341.5	1791	362	-31	-20.5	2681	567	-921	-225.5

a/ Criteria is greater of 10% capability or largest single unit.

b/ Increase in capability (a) R. Amarti diversion + 176GWh/y from mid FY87 (b) Melka Wakana: 5 X 30MW units +560 GWh/y commissioned at 3 month intervals from mid FY87; 5.5MW/28GWh pa thermal plant retired end FY87.

c/ Finchaa extension (+33MW)-- penstock connection carried out during last stage of work in mid FY1988 once Malka Wakana is fully commissioned when there is sufficient surplus to close down Finchaa temporarily without incurring power shortages.

d/ Maximum demand could be lower--depends on rate of disconnection of boilers.

e/ Power shortages could be avoided by careful maintenance scheduling.

Source: Mission estimates.

3.18 For electric cookers the mission estimates that the size of the present potential market for electric injera cookers is about 50,000 households, corresponding in number roughly to those families in the main EELPA ICS supply area with monthly incomes exceeding B300 (1980 Birr) with a similar number of electric cooking pots. It is assumed that the supply of cookers will meet demand and that the electric injera unit demand increasingly will be supplied by 2.5 kW units instead of 3 kW units. The promising aluminum mtads the mission has tested and is promoting for further trial by EELPA (see Table 2.9) offer the possibility of further reductions in load.

3.19 EELPA's consultants estimated the probability distribution of cooking load on the power system from a general observation of preferred cooking times, from which they concluded that the contribution to the EELPA ICS peak demand from electric cooking appliances could be derived by using a system coincidence factor of 3.2% with the evening peak, which occurs at about 7:00 p.m. Most households only use their injera cookers during daylight hours to avoid overloading the local distribution supply equipment after dark by superimposing the cooking load on the lighting load. However, the daily load curve for the EELPA ICS has two weekday peak periods, with the higher peak occuring during early evening and a slightly lower peak occuring around midday, so that present cooking schedules will tend to coincide more with the midday peak demand period than with the evening peak. Growth in the use of electric cooking appliances will therefore tend to reduce the difference between the peaks and, possibly, reverse the ranking. In the absence of survey data on household cooking patterns, the mission considers 15% a more reasonable coincidence factor for electric cookers with system daily peak load period. The mission's projections for demand from electric cooking appliances, including maximum demands coincident with system peak periods, are given in Annex 3.2. Based on this survey, household power consumption for lighting and other appliances over and above cooking is expected to grow at about 7% a year.

3.20 Future Industrial and Commercial Demand. Within the manufacturing sector of industry, cement and textiles are responsible for 80% of new large industrial power demands of about 118 GWh per year by 1987. However, there is a substantial demand arising from the new sugar industry at Finchaa for which the opportunity for self-sufficiency through the year-round use of its potential seasonal bagasse surplus has been neglected. There will now be a load on the public power system of about 1 MW, with instantaneous back-up requirements of 4 MW, during the cane crushing season and about 4 MW peak outside of it for irrigation, housing, and workshops in the first phase of development, occasioning an annual demand of about 20 GWh unless the plant design and the pattern of demand internal to the industry (e.g., homes and villages) are changed. Both the design of the sugar mill and the associated housing neglect ready opportunities for improving energy efficiency. Apart from the greater cost of operation implied, the Finchaa power demand arises at just the time that capacity constraints on the EELPA ICS are most critical. The mission therefore recommends an urgent design review with the objective of maximizing the supplies of bagasse and achieving year-round self-sufficiency and complete autonomy from EELPA. Even including the Finchaa project, a load demand growth of only 4% p.a. is estimated for existing industry due to an already high level of plant capacity utilization. Growth in the commercial sector is less restricted with new hotels, office blocks and general urban infrastructure expansion expected to create a demand growth of 7% p.a., slightly in excess of the projected urban population growth rate of 6.5% p.a.

3.21 Interconnection. Throughout the 1970s there were no major extensions to the EELPA ICS. However, EELPA connected six isolated load centers to the ICS between 1979 and 1982, and EELPA now has an ambitious program for extending the EELPA ICS to new load centers in the SCS and for village electrification. The rationale for this program is the need to reduce consumption of imported oil, to alleviate fuelwood shortages for households, and to promote development away from conurbations by providing power for industries, commerce and community centers. The main ICS transmission network consists of a radial system centered on Addis Ababa, based on 230, 130 and 66 kV lines. A regional 66 kV network is presently being constructed in the Lake Tana area to serve load centers with hydropower from the Tis Abai station. The major transmission projects being planned are a 230-kV line between the Finchaa power station and Bahir Dar, and a 230-kV line between Melkassa and Dire Dawa. EELPA has a long-term objective of interconnecting the EELPA and ERESA ICSs, and the two 230-kV projects can be viewed as components of an eventual national transmission system. The economic justification for extending the transmission system has to be carried out case by case. However, the ultimate constraint on the rate of extension will probably be availability of resources. The mission has adopted a lower rate of investment in transmission extension than planned by EELPA that is in line with lower and more realistic estimates of likely resource availability. Nevertheless, the mission forecast shows an incremental load (excluding system losses) from interconnected centers on the ICS of 20 MW/83 GWh/year in 1990 and 46 MW/204 GWh/year in 1995.

Mission's Demand Forecast

3.22 By aggregating the estimated growth projections for each of the key determinants of future power demand, the mission's revised forecast is for energy and power demand to grow at 8.5% p.a. as opposed to the 15-17% growth rate projected by EELPA and consultants. Nevetheless, under the mission's forecast, per capita power consumption will be about 40 kWh per year by 1992. The comparison made between these data in Table 3.7 indicates that under the mission's forecast the capacity constraint is much less severe and appears first in 1985, two years later than under the consultant's forecast, and that no energy deficit arises prior to 1987 providing there is no substantial delay in commissioning the Malka Wakana scheme. Furthermore, the level of the capacity deficit in 1985 and 1986 is below the capacity of electric boilers installed by that time and will disappear if the government adopts the mission's firm recommendation to relegate electric boilers to back-up status. Once again, the importance of maintaining and, where necessary, rehabilitating the existing oil and wood-fired boiler capacity is emphasized.

Medium-Term Supply Options

3.23 There are only two projects to augment power supply in the medium term that have been funded and are currently under construction. These projects are the US$29 million Amarti-Finchaa diversion, providing an additional 176 GWh a year through the existing Finchaa Power Station, and the Soviet-funded and contracted Malka Wakana Hydropower Plant of 152 MW and 560 GWh average annual energy production, located 250 km south of Addis Ababa on the Wabe Shebelle River. The Amarti-Finchaa diversion is scheduled to be completed by mid-1987 and the Malka Wakana Station also by mid-1987 (first of four 38 MW units). As capacity availability is the earliest and most severe constraint to power supply, the consultant's demand forecast suggests that investments in new capacity are required immediately to alleviate the impending shortfall. EELPA and its consultants have foreseen this capacity being available from two main sources: the now unused Aba Samuel hydropower plant and the addition of a fourth 34 MW unit in the Finchaa power house for which some provision was made at the time of construction.

3.24 The Aba Samuel scheme could be rehabilitated as a 6 MW plant for about B13 million by mid-1985, or it could be upgraded to up to 36 MW at a cost of about B56 million for completion late in 1986 at the earliest. In the former case the benefit is minimal and would make little difference to system capacity constraints. In the latter case, the plant only could be used for peak period supply due to limitations on storage capacity; consultants 15/ to EELPA also have expressed reservations about the feasibility of obtaining as much as 36 MW output since the high discharge rates involved in rapid loading could cause hydraulic problems. The consultants consider that such problems could be avoided only with a lower installed capacity of about 21 MW.

3.25 The addition of a fourth turbo-generating unit to Finchaa Power Station also was originally proposed as a means of alleviating power shortages before commissioning the Malka Wakana Station. However, the station would have to be shut down completely for at least a month so that a wye junction could be fitted at the bottom of the penstock to provide a feeder to the new unit. Such a shutdown would involve removing about 50% of system capacity (100 MW out of 204 MW) and thus would create massive power shortages with an unacceptable degree of disruption to the national economy. In fact, the earliest that the new unit could be commissioned is presently in early 1987, and therefore it would not alleviate the situation before the scheduled commissioning date of Malka Wakana. However, the proposal does have merit in the context of longer-term planning as a means of rectifying the present imbalance between capacity and energy constraints, which requires new capacity to be added to the system about 1-1/2 years in advance of the need for additional

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15/ Lahmeyer International "Review Report on Feasibility Study for Aba Samuel HPP Rehabilitation/Redevelopment" (May 1983).

energy capability. Rectification of this balance would thus allow investment in the next major hydropower scheme to be postponed by 1-1/2 years. Furthermore, immediately after the commissioning of Malka Wakana, there will be sufficient surplus in system capability over system demand to allow a shutdown of the Finchaa station to occur without precipitating power shortages. The mission recommends that EELPA investigate the economic justification for installing the fourth unit at Finchaa station in such a manner.

3.26 The Malka Wakana project is the key to short- and medium-term planning for the EELPA ICS. At full commissioning, the project will add 75% additional capacity and 55% additional energy to the existing system hydro capability. According to the mission's demand forecast, the addition of this relatively large increment will meet the increase in demand for six years. However, as with any major hydroelectric project, there are risks of serious delays in completing the project. EELPA is not involved in programming project implementation; this is being handled by a high level Ethiopian Committee appointed by the Government. 16/

3.27 There are a number of options for covering the risk of a serious delay to the Melka Wakana Project. EELPA have favored proceeding with preparation of the Gibe Daka project (para 3.33) to minimize the implementation period if a decision to proceed quickly was required. This strategy only makes sense if there is a serious possibility that the Malka Wakana project will not be completed, and at this stage there is no justification for such a view. Furthermore, the Gibe Daka project does not form part of the least-cost program, and a hasty commitment to the project runs the reverse risk of simultaneous investment in two large projects when only one is required. For example, if both the Malka Wakana and Gibe Daka projects were to be commissioned around 1990, this would add 300 MW/1300 GWh per year to system capability, equivalent to additions of 150% and 130% to system capacity and energy. In the mission's view, this outcome would constitute a massive uneconomic investment.

3.28 A strategy is required which involves a minimum of additional investment during the next few years over that for the Malka Wakana project and which also is consistent with long-term planning. The mission recommends that such a strategy be prepared as a matter of urgency and envisages that it will be based on demand management (paras 2.29 to 3.32) as a means of coping with a delay in the commissioning of Malka Wakana of up to one year, and on other options for increasing supply capability for a longer delay. One option is the construction of Tis Abai II power station (30 MW) at the same time as the proposed 230 kV line between Finchaa and Bahir Dar to interconnect this station with the EELPA ICS. Another option is interconnection of the Ethiopian and Sudanese main systems

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16/ This arrangement reflects GOE existing policy of funding major capital projects from the central government resources and handing over the assets to the operating utility on completion.

through a transmission linkage between Finchaa and Rosieres. This option has the long-term (post 1990) attraction of taking advantage of surplus Ethiopian hydro power (after commissioning of the Malka Wakana project and subsequently other projects) to displace expensive thermal power in the Blue Nile grid in and around Khartoum and to take advantage of non-coincidence of system peak load periods. In the medium-term (to 1990), 340 MW (300 MW thermal, 40 MW hydro) are scheduled to be installed in the Blue Nile Grid based on the need to meet system demand during the season of low Blue Nile flow (March-May) in a projected dry year. Thus, there will be considerable underutilized thermal generating capacity in the system. Advancing the timing of interconnection of the two systems to 1988 would provide the Ethiopian system with back-up capacity to cover the risk of delay to Malka Wakana. The mission recommends that the investigation of both options be given top priority.

Demand Management Options

3.29 The conclusion of the preceeding paragraphs is that a vital option realistically available to alleviate short-term power and energy constraints is demand management. Electric boilers will continue to have only short-term application and electric cooking will be accessible just to middle and upper income groups, nevertheless making a significant contribution to household energy supply. Demand management measures which are justified are (a) achieving greater efficiency of electric cookers; (b) correcting power factor distortions; (c) reducing transmission and distribution losses; and (d) conducting a thorough review of the potential for solar water heating. The first of these measures is implicit in the mission's revised demand forecast which assumes a reduction from 3 kW to at most 2.5 kW maximum demand for each electric injera cooker.

3.30 The mission's tests of aluminum "mtads" show that energy savings of 35% are achievable over clay "mtads" due to greater plate conductivity. The mission has received advice from cookware manufacturers that a non-stick aluminum "mtad" without electric fittings could be produced in bulk in the US for US$15-17. A sealed unit with aluminum "mtad," resistance coils, thermostat and switchgear would cost at the most B100 and would yield a reduction in load of at least 0.5 kW. The cost of saving 1 kW in peak system demand by this means would amount to about B1,335 at a coincidence factor for cooking demand with system peak demand of 0.15 and if the whole cost of the unit was written off against this saving. In fact, the incremental cost of a unit with an aluminum "mtad" over a unit with a clay "mtad" would be much less than B100 and thus, the cost of saving one kW in peak system demand would be much less than B1,335. In contrast, the investment required to install one kW of hydroelectric power is about B2,000. The mission recommends that EELPA pursue the development of non-stick aluminum "mtads" with demonstration units placed in households and by adopting this design for units manufactured by itself. EELPA also should consider making available sealed aluminum "mtads," possibly initially at a subsidized price so they are competitive with existing units, to private manufacturers of cookers to achieve an early and major impact on the average demand and efficiency of electric cookers.

3.31 Power factors of 0.6-0.8 are common in large Ethiopian industrial establishments and are as low as 0.5 in small industrial plants due to the proportion of the plant load comprised by motors. Such low factors cause gross underutilization of existing power system capacity and losses of power throughout the transmission and distribution system. While power factor correction would not directly benefit the industries concerned unless the tariff structure provided incentives, it would ease EELPA's capacity constraint. The mission estimates that 2 to 3 MVA could be saved by installing power factor correction equipment and by enforcing strict financial penalties for individual plant power factors below 0.95. The data in Table 3.3 and 3.4 indicate that losses, defined as the difference between power generation and power sales, are substantial and, in the case of ERESA, quite serious. The relative contributions of technical inefficiency and failures in consumer billing are not known, though it should be possible to contain technical losses to 10% of generation. Hence, a detailed review of the causes of inefficiency is recommended, together with a program of action to implement improvements, focusing particularly on the short-term impact, such as power factor correction.

3.32 Solar water heating is likely to be economic in all hotels, hostels and hospitals now using electric water heating. Payback periods of four to six years are likely in economic terms in industrial and commercial applications in the EELPA system. A major opportunity exists to install solar water heaters in several thousand high quality homes in Addis Ababa. Retrofitting of adequate solar water heating to existing electric storage heaters appears to be feasible with paybacks of four to five years. The mission recommends that a review be made of the benefits of installing these systems for households and of recovering the installation costs through monthly billing over an extended period. Appropriate upward revision of tariffs (para 6.11) should provide the financial incentive to introduce these installations.

Long-Term Supply Options

Hydroelectric Power

3.33 According to the EELPA-Acres standard forecast, the next major hydroelectric scheme following Malka Wakana is required by late 1989 (Table 3.7). According to the mission's forecast, this scheme would not be required until 1994. The difference in timing is significant for planning options. Planning is sufficiently advanced at present on only one scheme at Gibe Daka (150 MW/735 GWh/y), to achieve a commissioning date of 1990. The detailed design of the Gibe Daka scheme, at an estimated unit cost of US$1260/kW including associated transmission, is now underway with aid funding from the Italian Government. However, the Gibe Daka scheme is not the least-cost option identified by EELPA's consultants. 17/ The most promising hydropower schemes are available in the Aleltu, Upper Beles and Halele Werabesa River basins, and through the

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17/ Acres "Power Planning Study," October 1982.

Chemoga Yeda diversion scheme. These options need to be compared on an equal basis with the currently proposed Gibe Daka (formerly Gilgel Gibe) scheme. The estimated capacity and average energy production from these schemes are given in Table 3.8. The most promising of these alternatives are those whose development can take place in stages with increments that are compatible with the growth in power demand. For example, the hydro potential of the Aleltu River system could be developed with four units ranging from 120 MW to 190 MW, and the Chemoga Yeda diversion in two stages of 210 MW and 100 MW each. Preliminary estimates for the development of these cascade-type resources are US$900-1100/kW including associated transmission. The mission estimates that the long-run marginal cost of power from an optimized development program is about 16ec/kWh sold.18/ Pre-feasibility survey work is required at both these sites to confirm the feasibility of these options. Under the consultant's demand forecast there is insufficient time to carry out such work, whereas under the mission's forecast there is adequate time. The mission recommends that survey work for at least one and preferably both of these options be started as soon as possible to develop a range of planning options, to be followed by feasibility studies.

3.34 Beyond the early 1990s, Ethiopia has a wealth of options for developing domestic resources for power production. EELPA's consultants consider that the total hydroelectric potential of the country is in the range of 15,000 to 30,000 MW. Although a proportion of this potential would be uneconomic to develop, nevertheless there exists potential of many times the present level of demand and that could be developed relatively cheaply by world standards. The topography of the region permits good regulation of hydro resources to be obtained at low cost. The hydro projects described in the preceeding paragraph are the most attractive of many options presently identified. Ethiopia therefore possesses potential greatly in excess of foreseeable domestic requirements and is also surrounded by countries which are relatively poorly endowed with energy resources. The scope for developing power potential for export is an attractive long-term possibility which should be explored at political and technical levels.

Export Options

3.35 As noted above, Ethiopia has extensive low cost indigenous hydropower potential, and is much more favorably endowed than its neighbouring countries who are having to increase their importation of hydrocarbons to support development of their power systems. The most promising opportunities for realizing mutually beneficial developments are with Sudan and Djibouti.

3.36 The interconnection of the EELPA ICS with the Blue Nile Grid is one option for development with Sudan that already has been discussed in

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18/ The mission has estimated the average incremental cost of power as a measure of the long run marginal cost.

connection with a strategy for covering the risk of delay in commissioning the Malka Wakana project (para. 3.28). The option capitalizes on the sunk investment in transmission capacity between Roseires and Khartoum and the low output sent from Roseires to Khartoum during the Blue Nile River dry season (at least six months per year), so that exports of power from Ethiopia would be predominantly during this season. EELPA's consultants (Acres) estimated the cost of the transmission link between Finchaa and Roseires to be about US$66 million (1982 prices). Given the mutual benefits to Sudan and Ethiopia discussed in para. 3.28, the mission recommends this option be investigated as a matter of priority.

Table 3.8: PRODUCTION CAPABILITY OF POTENTIAL HYDROPOWER PROJECTS

Project	Installed Capacity (MW)	Average Energy (GWh/y)
1. Malka Wakana	150	560
2. Gibe Daka	150-300	735
3. Chemoga Yeda		
Stage I	210	935
Stage II	100	420
Total Chemoga Yeda I & II	310	1355
4. Aleltu		
Stage I	120	525
Stage II	190	830
Stage III	160	700
Stage IV	140	610
	610	2665
Stages V & VI	160	725
Total Aleltu	770	3390
5. Upper Beles	245	1100
6. Halele Werabesa		
I	55	245
II	300	1180
Total H. Werabesa	355	1425

Source: Acres: "Power Planning Study" (October 1982).

3.37 The development of hydro potential in Ethiopia for exporting firm power to Sudan is a long term option. Under this scenario, the option of developing a major hydro scheme in the Lake Tana region becomes attractive as part of a strategy to supply hydropower to the northern regions of Ethiopia (ERESA systems), since the transmission distance to the northern region would be substantially less than would be the case with development of a site north of Addis Ababa (Aleltu, Chemoga). Economies of scale also could be obtained from developing a hydro site if the development were sized to supply a substantial load in Sudan as well as the relatively small load of the ERESA ICS. Suitable sites have been identified on the Upper Beles River (245 MW/1100 GWh per year) and the Rahad River (585 MW/2565 GWh per year).

3.38 Interconnection with Djibouti could be realized by either a transmission line from Dire Dawa or by a line from Kombolcha to serve both Djibouti and Assab. Acres judged the extension from Kombolcha to be a better option. On the basis of supplying 105 GWh/year of off-peak energy to Djibouti by 1995, Acres concluded that the value of fuel savings to Djibouti would be about three times the annualized cost of transmission and generation supply from Ethiopia. Therefore, the mission recommends that this option be considered seriously once the availability of hydro energy in Ethiopia becomes assured.

Natural Gas

3.39 Natural gas must be seriously considered as a power source for the 1990s and for early next century. Very preliminary analysis by the mission indicates an economic cost of about 15ec/kWh sold for the known Ogaden Desert gas resource, which is comparable to the long-run cost of power from hydroelectric resources. 19/ This estimate is derived by weighing the entire cost of additional field development, an 800 km pipeline, and a gas turbine farm in Addis Ababa against the incremental market for power from 1994 onwards. The incremental usable power produced in the early years of a gas project would be small and some of the gas delivery capacity could be used to supply the substantial market for gas in industry, fertilizer production and transportation in the Addis Ababa area. Some of the gas delivery costs could thus be allocated against non-power uses. The required steps in resource evaluation to enable a fair comparison to be made between natural gas and hydropower are outlined in Chapter IV. The mission recommends that the required program of work, including a preliminary gas market analysis and confirmatory drilling, be started as quickly as possible to fit in with the timing of further investigations of major hydropower resources in the process of determining a least cost power development plan.

Geothermal Power

3.40 The present work program of geothermal exploration is described in Chapter V. This Rift Valley resource is part of the same system that is being tapped in Kenya with technical and financial assistance from the

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19/ Mission estimate of 16 ec/kWh.

Bank. Geothermal power is often developed in unit sizes ranging from 15-30 MW with units in commercial operation of up to 55 MW. At the time of the mission two dry holes had been drilled in the Lakes area south of Addis Ababa. Shortly after the mission's fieldwork potentially commercial steam flows were tapped. The economic cost of developing geothermal power, based on the Bank's experience, is generally in the range of US$2,000-2,500 per kW installed, which is about double the estimated cost for prospective hydropower in Ethiopia for the equivalent firm capacity. Preliminary analysis suggests special circumstances would have to apply for there to be a significant role for geothermal in the EELPA ICS generation expansion program, such as the relative ease of financing smaller increments to available installed capacity, or the expedience of "infilling" between large and lumpy hydropower supply increments. However, there are many factors which influence the delivered cost of geothermal power, including steam quality and maintenance costs, drilling costs and proximity to the grid and, depending on local circumstances, the cost per kWh delivered could easily range across present estimates of the long run marginal cost of power for the EELPA ICS. The GOE, with the assistance of the EEC and UNDP, is committed to explore geothermal resources and to undertake a feasibility study on the viability of a 30-MW geothermal power plant near Langano in the Lakes district where drilling activities are in progress, and in Corbetti, near Awasa, and Abaya, where detailed technical studies are underway. The mission believes that the prospects for producing geothermal power competitively with hydropower or natural gas are yet to be demonstrated, and endorses the Government's endeavors to undertake a detailed evaluation of the economic cost of geothermal power production. The mission also recommends that the economic viability of this power source be evaluated in the context of the least cost power system development for the EELPA ICS. Similarly, it is appropriate to use the above economic analyses as the basis for determining the likely prospects for economically producing power from other potential geothermal resources in order to determine the priority for allocating resources available for further geothermal or other energy resource exploration, such as in the north where further evaluation of geothermal resources in the Tendamo and Eritrea region are required to determine the prospect of supplying power to the ERESA system in the medium- to long-term.

EELPA SCS Forecast Sales

3.41 Forecast sales on the EELPA SCS to 1995 are given in Table 3.9. The underlying growth rates derived by Acres are 10%/year for 1982-87, 8.5% a year for 1987-92, and 7% a year for 1992 onwards. The remaining load on the SCS after interconnection with the ICS is forecast to decline slowly. By 1995, nearly 70% of the load from the present day SCS is forecast to be interconnected with the ICS, which represents a substantial impact on efforts to reduce oil-based power generation.

ERESA ICS and SCS Forecast Demand

3.42 Forecast sales and demand for the ERESA ICS and SCS are provided in Table 3.10. Sales on the ICS are projected by EELPA's consultants to grow at an average annual rate of 12.4% a year for the 1982-95 period. Peak demand is projected to roughly treble during this period, implying an aggressive program of generation expansion. Growth of sales in the ERESA SCS is expected to be 20% per year in the short-term, mainly due to taking up suppressed demand.

Table 3.9: EELPA SCS FORECAST SALES, FY83-95
(GWh)

FY	FY82 SC	Interconnection to ICS	SCS Net
1982	93	--	93
1983	102	--	102
1984	113	--	113
1985	124	9	115
1986	136	19	117
1987	150	32	118
1988	163	46	117
1989	179	63	116
1990	197	83	114
1991	216	106	110
1992	238	133	105
1993	255	161	94
1994	272	190	82
1995	292	204	88

Source: Mission estimates.

Future Supply and Demand Management Options for ERESA

3.43 According to EELPA's present investment program, a transmission link between the EELPA ICS and ERESA ICS is planned for the early 1990s. The mission considers that the interconnection of the two ICSs would not be an economic undertaking in this time-scale, although in the longer term it may be desirable. Without a firm, proven geothermal resource, the range of options is narrowed in the medium-term to expanded use of heavy fuel oil in slow- to medium- speed diesel engines and to imported coal. In the Bank's recent experience, imported coal is not a competitive primary energy source with imported heavy fuel oil for generation unit sizes of less than 20 or 30 MW. For the foreseeable future, capacity additions to the ERESA ICS should be in 5 to 10 MW units for optimum generation efficiency and security, and therefore heavy fuel oil engines will be the least-cost source of power.

3.44 The installed capacity by type and location of engine for the ERESA ICS is provided in Annex 3.3. The total effective capacity is

41.2 MW, of which 15 MW is in steam plants and 26.2 MW is in diesel generators, and there is a further 10 MW yet to be commissioned in 5 MW diesel engines that will use heavy fuel oil. Diesel-fired engines produced 46 GWh or 51% of total generation in 1981/82. Replacement of the steam plant by diesel generators is justified from fuel savings alone. A complete conversion to fuel oil-fired diesel engines would require investment in a further 15 MW (3 X 5 MW) of diesel capacity, plus the necessary fuel oil heating and cleaning equipment to convert the existing 5-MW diesel engines into an entirely fuel oil-fired mode. The mission estimates that the conversion would effectively replace about 12.8 million liters of diesel with 3.1 million liters of fuel oil after allowing for much improved efficiency in fuel oil consumption. 20/

Table 3.10: ERESA ICS AND SCS: FORECAST SALES AND DEMAND c/

	ICS			SCS		
FY	Sales a/	Generation b/	Combined Peak Demand b/	Sales c/	Generation d/	Combined Peak Demand d/
	(GWh)	(GWh)	(MW)	(GWh)	(GWh)	(MW)
1983	85.8	98.7	20.1	5.0	6.5	2.1
84	92.9	106.9	21.8	6.0	7.8	2.5
85	100.6	115.8	23.6	7.2	9.3	3.0
86	108.9	125.4	25.5	8.6	11.2	3.6
87	118.0	135.8	27.7	10.4	13.4	4.3
88	137.5	158.2	32.3			
89	160.2	184.3	37.6	Subsequent demand on SCS from existing		
90	186.6	214.7	43.8	SCS load centers will decline due to		
91	217.4	250.2	51.0	interconnection; however, assuming		
92	253.2	291.4	59.4	that diesel sets are moved to new load		
93	275.2	316.8	64.6	centers, the total SCS demand will		
94	299.2	344.4	70.2	remain at about a constant level.		
95	325.2	374.3	76.3			

a/ Acres projected growth (including interconnections) for ICS -- 1982-87: 8.3%/y; 1987-92: 16.5%/y; 1992-97: 8.7%/y.
b/ Assuming system losses of 15% on sales; 56% SLF on ICS.
c/ Acres projected growth 1982-87: 19.8%/y (no interconnections).
d/ Assuming system losses of 30% on sales; 35% SLF on SCS.
Source: Mission estimates.

20/ In effect, with an increase from 20% to 35% conversion efficiency for fuel oil, present fuel oil consumption drops from 19,870 to 11,420 te. At 35% efficiency, 12,800 liters of diesel are replaced by 11,350 te of fuel oil. Thus, 22,770 te fuel oil replaces 19,870 te fuel oil plus 12,800 liters of diesel in the present power system.

For a capital outlay of about B16 million, economic cost annual savings of B6 million will result, giving a simple payback period of less than three years. The mission believes that heavy fuel oil diesel engine generation is the least cost option for the ERESA system and strongly recommends that EELPA review this conclusion by more detailed analysis.

Demand Management in the ERESA ICS

3.45 The marginal cost of producing power in the ERESA ICS is estimated by consultants to EELPA 21/ to be 36 and 55 ec/kWh (17-27 US¢/kWh) sold off-peak and peak for low voltage supply, respectively and similarly, 34 and 46 ec/kWh for high voltage industrial supply. Thus, the cost of meeting increases in demand are high and make the need for demand management a high priority. The mission has identified projects described in the following paragraphs both for electricity conservation and for substitution of electricity within the ERESA ICS by the cheaper energy sources. The mission recommends that the efficiency of supply and use of power in the ERESA area be specifically examined to identify measures to minimize the cost of energy utilization.

3.46 Domestic Loads. In the ERESA ICS supply zone, upper income households commonly cook and heat water with electricity. The cost of cooking with electricity is more than twice the cost of cooking with kerosene (see Table 2.10). The mission recommends (Chapter II) that households in Asmara and other major cities of the north now using electricity be strongly encouraged, by appropriate power tariffs and publicity, to switch to kerosene for cooking. Some 8,500 homes have electric water heaters installed. It will be possible to supply hot water needs with solar collectors for about one-third of the economic cost of electrical heating. ERESA should participate actively in this program by financing the installation of solar panels and arranging for repayment on commercial terms by monthly billing. With payments spread over a decade, consumers would experience a substantial reduction in the financial costs of water heating at the present tariff and a much greater reduction if electricity tariffs are raised to reflect the cost of supply, which again underlines the importance of charging for electricity at the full economic cost of production. Electrical backup should be neither necessary nor permitted.

3.47 Commercial and Industrial Loads. In the ERESA area, transmission losses are high and can be reduced, perhaps to about 10%. A program of loss analysis and reduction should be mounted in combination with power factor correction enforcement for large industrial loads. The use of high efficiency sodium vapor lamps should be considered for street and other public lighting. Inappropriate and inefficient use of electricity has been observed in large industrial plants such as in glass manufacture where electricity is used for a portion of the required heating.

21/ Coopers & Lybrand Associates: "Tariff Study and Asset Revaluation" Final Report, August 1983.

Detailed energy audits and least-cost analyses should be undertaken for each of the major power consumers in the ERESA system.

Small-scale Alternative Power Sources

3.48 Many isolated load centers are too small and/or too distant from the nearest part of the ICS for interconnection to be economically justified. There are well-defined opportunities for using mini-hydropower resources and some small prospect of wood-fired power generation which may economically displace diesel-fired generation. Feasibility studies for two small hydropower plants on the Hoha and Sor Rivers have been completed by a UNDP team under a program for technical assistance. The Sor River scheme is 4 MW, with an estimated final cost including transmission of B26 million, and it would displace diesel generation at the towns of Mettu, Gambella and Dembidollo. The Hoha River scheme is 650 kW, with an estimated cost of B2.54 million, and it would replace diesel power at the town of Asosa. Both schemes would supply power for about 28 US¢/kWh based on the load forecast adopted. The economic rates of return computed are 12-16% and are critically dependant on the demand forecasts which must consequently be verified before commitment is made to implement. EELPA have included seven other mini-hydro schemes in their investment program.

3.49 Wood-fired power options are confined to state farms both in the forest to the southeast of Jimma at Bubeka and in the savannah land grain growing regions. A small wood- and waste-fired steam plant should be investigated for supply to the new coffee plantations, sawmill and environs of Bubeka, which soon will constitute a substantial load (Chapter II). Literally hundreds of thousands of tonnes of wood-waste from clearing operations are burnt in this region annually. Cogeneration of steam for crop processing and power in several hundred kilowatt plants should be investigated as a substitute for diesel generation. There is also the prospect of using agricultural residue briquette-fired gasifiers for diesel power generation on those state farms that begin to produce fuel briquettes for the urban household market. This option is discussed in Chapter V, though it is not considered to be significant in the short-term.

Financing Power Sector Investment

3.50 Considerable investments will be required in the power sector to meet forecast demand. EELPA's programs for investing in both generation and transmission capacity will be a major component of public sector investment. EELPA have prepared an investment program for both the EELPA and ERESA systems for the period 1984-93 in which total expenditure is about B3 billion (US$1.5 billion in 1983 prices). This program is based on installing capacity to meet the Acres demand forecast, and the generation component alone totals about B2 billion. The investment program therefore exceeds the system requirements according to the mission's forecast. Availability of funds will be a major consideration in determining the rate of investment, particularly in transmission projects.

3.51 The mission has prepared an alternative investment program for the period 1984 to 1995 in which total expenditure is about B2 billion in 1983 prices, of which the generation component is about B1.2 billion. This program is based on the mission's demand forecast, and is set out in Table 3.11. The program recognizes the importance of extending the transmission system by retaining most of EELPA's transmission projects. The program also includes nine mini-hydro schemes designed to replace diesel generators in isolated load centers.

Table 3.11: SUMMARY OF PROJECTED INVESTMENT IN THE ETHIOPIAN POWER SECTOR
(B million 1983 prices)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Generation													
EELPA ICS	73	126	126	101	--	48	95	119	142	71	60	60	1022
EELPA SCS	20	22	26	21	9	9	9	2	2	2	2	2	126
ERESA ICS & SCS	26	--	1	--	1	--	1	--	1	--	1	--	31
Subtotal	119	148	153	122	10	57	105	121	145	73	63	62	1179
Transmission & Distribution													
230 kV/132 kV	58	67	47	50	22	30	31	23	--	--	--	--	328
66 kV/45 kV	2	--	--	--	19	35	19	13	9	5	5	5	112
Substation Expansion	--	--	17	32	24	11	7	7	5	5	5	5	118
Distribution Expansion a/	12	12	12	12	12	12	12	12	12	12	12	12	144
Subtotal	72	79	76	94	77	88	69	55	26	22	22	22	702
Infrastructure Subtotal	11	24	26	24	9	2	2	2	2	2	2	2	108
Total	202	251	256	240	96	147	176	178	173	97	87	86	1989

a/ Includes village electricity.

Source: Annex 3.4.

By retaining most of EELPA's transmission projects, the main cost reduction occurs in generation where commissioning of the Gibe Daka project is delayed by four years and that of the subsequent hydroelectric station is also delayed by four years. In other respects this program is based on minimum investments required, in the sense that no expenditure is included for interconnecting the EELPA ICS and the ERESA ICS, a major regional transmission system in the Eritrea/Tigrai area, gas or geothermal power development, or for developing generation and transmission capacity for power exports. The feasibility of such developments has yet to be established either technically or economically, although after 1990 this situation could change.

3.52 The most important issue concerning the means of financing the investment program is the means of local financing. About 65% of the program is composed of direct foreign exchange expenditure, and the inclusion of indirect foreign exchange costs increases this proportion to about 75%. It is reasonable to assume that this proportion can be funded almost entirely from foreign sources, but the difficulties of mobilizing these funds are considerable. The requirement for local financing thus will be about 25% or B500 million in 1983 prices.

3.53 In the past, it has been GOE policy to fund capital expenditure from the national budget and to makeover the assets to EELPA as a grant. In return, EELPA has not been required to fund capital expenditure or debt service from internal resources, which has been a strong factor in preventing the implementation of tariff increases. It appears that the present capital work-in-progress, including the Malka Wakana project, will be treated in this manner. However, GOE has decided to change its policy for future capital investments and will require EELPA to become self-financing. This change also will have implications for tariff levels and structure, particularly the subsidization of the EELPA SCS and ERESA systems. At present, EELPA receives a subsidy from the government for this purpose, although there is some uncertainty about the amount of this subsidy before it is actually paid. EELPA recently has commissioned a tariff study, the conclusions of which are discussed in Chapter VII.

IV. PETROLEUM

4.1 Imported petroleum products comprise only 6.5% of total final energy consumption, yet their current annual cost of about B400 million is more than half the value of imports (see Table 1.2). Inland consumption of petroleum products now exceeds 600,000 toe, or 13,000 bbl/per day, having grown at 7.6% p.a. between FY77/78 and FY81/82 (see Table 1.1) compared with a growth in GDP of 4.1% during the same period. The current sectoral end use of petroleum products is described in Chapter I. Transport uses about 70% of petroleum product consumption and diesel oil dominates the product mix, providing about half of all petroleum energy consumed.

4.2 The key issues in the petroleum sector are concerned with reducing the cost of supply and delivery to the main central highlands market, and with efficient exploration and development of known or prospective petroleum resources. As the benefits to flow from satisfactory resolution of these issues will not be experienced for five years or more, the mission also gave high priority to a review of the prospects, in the short-term, for increasing the efficiency of petroleum fuel use.

Pattern of Supply

4.3 Ethiopia imports both crude oil and refined petroleum products. Crude oil is refined at the country's only refinery located at the Red Sea port of Asseb, and refined products are imported to make up the deficit between demand and refinery production. The 800,000 tpy refinery is owned by the GOE and is operated by the Ethiopian Petroleum Corporation (EPC). Since the middle of 1980, the EPC has procured its crude oil on a contract basis from the USSR. The refinery design is such that fuel oil production can range from 32-55%, depending on the crude oil supplied. The crude oil currently in use yields 43% fuel oil, hence 60-70% of fuel oil production is exported at about 70% of the price per tonne of imported crude. Actual petroleum product imports and exports for 1978 through 1982 are provided in Table 4.1.

Imports

4.4 During the period of post-revolution economic growth, the amount of imported refined products to supplement refinery production has grown considerably, being moderated only by, in 1981, an increase in refinery capacity from 650,000 to 800,000 tpy of crude input. Imports of refined products as a proportion of retained petroleum imports rose from 14% in 1978 to 22% in 1982, peaking at 37% in 1979.

Petroleum Distribution

4.5 The distribution and marketing of petroleum products in Ethiopia is handled by four major oil companies: AGIP, Total, Mobil, and

Shell. The EPC delivers products by pipeline to the oil company storage in the vicinity of the refinery, and from there the bulk of the products are transported by road (mostly by Natracor, the national road transport agency of the Government) to demand centers in the central highlands. However, some products are moved by coastal vessel and the Djibouti-Addis Ababa railway to Dire Dawa and central highlands markets, and coastal vessels also supply product to the port of Massawa and distribution inland from there is by road. The companies retail the product through a national network of service stations and wholesale it in bulk to major consumers. The EPC also imports refined product to make up the deficit between refinery production and demand, allowing the oil companies to import product only at its discretion.

Table 4.1: PETROLEUM PRODUCT IMPORTS AND EXPORTS, 1978-82

	1978	1979	1980	1981	1982	US$ per Unit
	('000 metric tonnes specified product)					CIF,1982
						(per bbl)
Crude Oil	611.4	612.4	633.1	684.0	773.3	$30.63
Refined Products						(per tonne)
Avgas	9.0	16.1	8.3	6.9	8.1	$679.00
Jet. A-1	7.4	15.8	2.1	6.0	4.2	$332.55
Special Jetfuel (TS-1)	36.0	14.0	20.0	12.7	47.3	$388.76
Gasoline (regular)	2.7	41.2	21.4	10.6	9.0	$337.30
Diesel	10.1	137.9	135.9	88.7	87.3	$307.85
Kerosene	0.5	0.4	0.5	--	--	$307.85
Total Imports	674.10	837.8	821.3	805.9	929.2	
Exports						(US$/tonne)
Fuel Oil	196.6	222.6	160.9	168.1	211.4	$153.40

Note: Net imports do not match consumption on an annual basis. Some products are shipped irregularly, giving rise to highly variable stock inventories.

Source: Ethiopian Petroleum Corporation.

Alternative Supply Options

4.6 The refinery was built in 1967 with Soviet technology and technical assistance. Presently, the refinery is operated and overhauled with the assistance of 20 Soviet technicians and skilled workers. Many of the existing facilities are obsolescent and corroded. Key problems include an internal loss and consumption of fuel oil and other hydrocarbons of 8% to 9% of crude oil throughput; heavy boiler tube corrosion and low boiler thermal efficiency. The mission analyzed five of the most plausible options for reducing the cost of supply, including closing down the refinery and relying entirely on imported refined products.

4.7 The five cases examined in the mission's preliminary economic analysis of supply options were as follows:

Case 1: Business as Usual

Run the refinery as at present, continuing to make up the difference between refinery production and market demand with imported refined product and to export surpluses of fuel oil.

Case 2: Conservation Only

Improve refinery efficiency and implement energy conservation measures without increasing capacity. Import the refined product deficit and export surplus fuel oil.

Case 3: Conservation and Debottlenecking

Increase refining capacity from 0.8 to one million tpy in addition to the measures taken in Case 2.

Case 4: Conservation, Debottlenecking and Secondary Conversion

In addition to Case 3, install thermal cracking and hydrotreating facilities to increase distillate production at the expense of fuel oil.

Case 5: Import Only

Close down the refinery and import the entire refined product requirement at the best open market prices possible.

In the more detailed analyses that should be undertaken before commitment to a stance on the future pattern of petroleum product supply, the options to process spiked crude and to expand the refinery beyond one million tonnes of annual throughput capacity also should be examined along with options for achieving economies of scale in the transportation, handling and storage of crude and refined products.

4.8 The nature and level of investment required in each of these cases iS provided in Annex 4.1. Oil price projections are based on the Bank's own estimates and the investment costs are derived from recent Bank projects on design work in this field. In each case the refined product not produced by the refinery under the level of upgrading concerned is imported at the then estimated real cost (CIF).

4.9 The results of these analyses are provided below in the form of the present value of the stream of net costs at 10% and 15% discount rates and the economic rate of return (ERR) on the incremental investment in the refinery should continued operation (Case 1) be the base case, or should it be, instead, closing down the refinery altogether (Case 5).

	Investment Cost (US$ million)	PV of Net Cost at 10% Discount Rate (US$ million)	PV of Net Cost at 15% Discount Rate (US$ million)	ERR for Incremental Investment	ERR Overall
Case 1	nil	1900	1593	base case	--
Case 2	22	1861	1578	32	9%
Case 3	25	1866	1573	28	7%
Case 4	67	1579	1501	35	26%
Case 5	nil	1859	1557	--	base case

4.10 The ERR for investment in secondary conversion is attractive though the analysis is clearly sensitive both to the long-run costs of oil (here assumed to reach US$38/bbl in real terms by 1995), the final cost of modifications, and the future demand for refined petroleum products. The mission therefore recommends a detailed inspection of the refinery facilities followed by engineering and economic studies to determine more accurately the cost basis for comparing these and other options, and to determine the final cost and practicality of refinery expansion and upgrading.

Product Transportation

4.11 A key issue in the petroleum sector is the cost of transporting petroleum products from the refinery and point of import at sea level to the main market of Addis Ababa some 870 km away and at 3,000 meters elevation in the central highlands. By the present method of road transport, one tonne of diesel is used for every 18 to 24 tonnes of petroleum product transported, making the energy cost of petroleum transport a significant factor in the choice of transport mode and a significant portion of total diesel consumption. GOE is considering a number of alternatives including a pipeline for refined products from Asseb to Addis Ababa, a railway line from Asseb to Addis Ababa, and a combination of barge and rail transport between Asseb and Addis Ababa via Djibouti using the existing rail track. The mission regards the Asseb-Addis Ababa railway line as a very long-term prospect to be considered in the much wider context of the transport sector as a whole. The existing Djibouti-Addis Ababa railway is now quite incapable of carrying more than a small proportion of the specified load. Preliminary estimates indicate a requirement for at least several trains per day, each pulling 15 rail tanks (180 tonnes per train). Currently two combined passenger and goods trains use the line. To carry a significant additional load the line would have to be duplicated in places and greatly improved to accommodate bigger trains. These investments must also be considered in the context of an entire transport sector strategy, though major new investments in additional line and rolling stock are unlikely to be made this decade. Nevertheless, rail transportation is generally much less energy intensive than road transport per tonne kilometer and the results of the EEC-funded prefeasibility study on the future of the present railway should provide guidance as to the longer term prospects of an expanded and competitive railway system.

4.12 Therefore, the mission has made a preliminary analysis of only two options: continued use of road transport and the construction of a white product pipeline from Asseb to Addis Ababa. The mission's analyses have been supported by a considerable body of data gathered during the course of the mission from Natracor, the Ministry of Transport, and various private truckers and truck dealers. In reviewing this data it became clear that marked differences exist between the energy efficiency and overall economy of operation of different classes of vehicle within the national trucking fleet in general, and the tanker fleet in particular. For this reason, two classes of truck transportation, 24 tonne and 36 tonne net carrying capacity, have been analyzed as separate cases in comparison with the product pipeline. There do appear to be significant differences in the longevity and maintenance costs per tonne kilometer between certain makes and models, though the most important observation is that there are very large differences in fuel consumption per ton km, with large (i.e. 40 tonne capacity) tankers consuming much less fuel per tonne of product carried between Asseb and Addis Ababa. In respect of the pipeline, besides the usual industrial indices, the mission had the benefit of recent cost data from detailed analysis of an identical facility in South Yemen.

Specific Variables

4.13 The pipeline case analyzed is for a 10-inch line 860 km long with a maximum throughput of 25,000 barrels per day. Taking account of the difficult terrain, the financial cost of the pipeline is estimated to be about US$160 million, plus about US$31 million for pump stations, and US$26 million for ancillaries. The total economic cost of the pipeline is about B565 million in 1983 Birr. For the road transport option, the key variables assumed are provided in Annex 4.2. All cases are compared on the basis of investment beginning in 1984 with product volumes of 416,000 tonnes moved along this corridor in 1987 and growing to 750,000 tonnes per year at the end of the period.

Table 4.2: LEAST-COST OPTION

Transport Mode	Present Value of Net at 10% Discount Rate	Economic Rate of Return on Pipeline Investment
	(US$ million)	(%)
Medium Capacity Trucks	756	23.5
Large Capacity Trucks		
High Cost	586	16.5
Moderate Cost	475	11.0
Pipeline	447	base case

Note: Working papers provided to the GOE.

4.14 As the present fleet is comprised of medium-size 24 tonne tankers, the most expensive option is to continue the present mode of product transportation. From Table 4.2 it is clear that the ASSAB-Addis Ababa pipeline is the least-cost and most economical means of petroleum transport inland. In the event that the GOE decides to delay the implementation of the pipeline project, the lower-cost large vehicle case is a reasonable representation of future road transport costs, assuming the investment is made to alter the composition of the fleet, and that the recommended axle loading limits are not exceeded. However, a much more detailed review of the substantial investment involved should be made not only in the context of energy sector priorities, but also taking account of overall transport needs and options. Therefore, the mission recommends that the National Road Transport Study proposed as part of the Bank's Second Road Sector Project due to start in early 1984 address this question in greater depth. In the short term, there is a need to review the truck procurement guidelines to ensure that optimal economy is achieved in ongoing road transporation of petroleum products (see para. 4.30).

Petroleum Exploration and Production Prospects

4.15 In this component of the petroleum subsector, the main issue is the focus and extent of the existing petroleum exploration activity. The Bank is already actively supporting an expansion of petroleum exploration activities in Ethiopia. An IDA credit of US$7 million recently has been approved for petroleum exploration and promotion activities arising from the expenditure of US$400,000 on project preparation during which a considerable resource potential was defined. Another important issue in this subsector at this time is the future role of natural gas in the national energy economy. In support of the existing IDA credit agreement between the Bank and the GOE, the mission sought to outline the potential market for natural gas and the best way to proceed with a detailed evaluation.

Previous Petroleum Exploration

4.16 International oil companies began exploring for petroleum in the Ogaden Desert and Red Sea areas more than 30 years ago. These efforts pointed to large deposits of gas but not oil. In 1975, Tennaco confirmed a resource of about 1.3 TCF from one well, Calub-1, in the Ogaden Desert, and Mobil had a gas blowout from a well drilled in a salt formation in the Red Sea, although because neither market nor local conditions were conducive to further development at the time both fields were abandoned and the resource was never fully proven.

4.17 Presently, two prospective sedimentary basins are being subjected to some level of exploratory activity. The Bank project provides for additional seismic work in the Red Sea basin, and a joint Soviet-Ethiopian exploration program (SPEE) is in progress in the Ogaden Desert. Until 1983, Chevron Oil Company had been gathering geophysical data on the Gambela Promontary in the far southwest, just over the border from their oil find in Sudan. SPEE is the most significant of the current activities. It is three years old and covers 10,000 km^2 in the Ogaden Desert region near the Tenneco discovery. The agreement provides for the collection of 1,200 line km of seismic data and for drilling four wells with the objective of finding oil at relatively shallow depths. The first well was drilled on the Shilalo structure to a depth of 2,900 m and was abandoned as a gas well, and the second is to be drilled on the Hilala structure where, from the first and only well sunk, a significant oil show was recorded.

Production of the Ogaden Gas

4.18 The "known" resource of 1.3 TCF is not large enough for export but is very substantial in comparison to the local demand for modern energy forms. The primary market for natural gas is for power production as a direct competitor with hydropower. In addition, natural gas could displace fuel oil in the cement and textile industries, diesel in road and rail transportation in compressed form, and LPG in larger commercial applications. Furthermore, the National Chemical Corporation has recently established a good case for a 200,000 tonne per year urea industry which could become economic with the use of local natural gas. There is already a provision for a detailed gas utilization study in the IDA credit for petroleum exploration and development so the mission did not attempt to develop more than a preliminary overview of the prospective market. At this stage, it is more important to establish whether or not there is any prospect of economically competitive production and delivery of natural gas from a resource 800 km from the major market of Addis Ababa.

4.19 An indication of economic potential can be gained by assuming that the only market for natural gas is in power production. If the entire costs of the required further drilling of the pipeline and of a receiving facility and gas-turbine farm are weighed against the incremental market for power from 1994 onwards, the present value unit cost of electricity from gas is estimated to be roughly 7 US¢/kWh. The pipeline in the case analyzed is 20 inches in diameter and 800 km long, with an average throughput of 220 MMCFD, and the estimated financial cost of construction is US$300 million. For the first few years of the assumed 20-year project life the pipeline is used at less than one-third of its capacity and by year 20, less than half of the estimated gas resource of 1.3 TCF is utilized. As there exists an excellent prospect of serving additional markets during the first 15 years, substantially lowering the average cost of supply, the mission concludes that the prospects for the economic development of natural gas are good and should be vigorously pursued. Gas might be delivered for as little as US$3.00/MMBtu (full economic cost) at the rate of production for power supply, which is about 40% of the cost of fuel oil in Addis Ababa. A potential gas market (for cement and fertilizer) also results in Dire Dawa some 550 km from Calub 1 in the general direction of Addis Adaba, and there may be some minor demand in the Ogaden region much closer to the resource. There also have been natural gas shows in the north of Ethiopia offshore in the Red Sea. Further seismic work is proceeding as part of a new evaluation of the potential of this resource which, if confirmed, would have to be considered as another option for supplying power to that region.

Immediate Requirements for Evaluating Gas Supply

4.20 An important next step in evaluating local utilization of natural gas is to confirm the size of the resource. One well is not a sufficient basis for expending very large sums on market analysis, hence the mission recommends that, as soon as possible, at least one additional well, suited for production if justified, be drilled on the Calub structure near Calub-1. In parallel, a preliminary gas market analysis costing US$100-150,000 should be undertaken to confirm and rank the foreseen end uses, and to set terms of reference for detailed study if, and when, justified. GOE should make every effort to arrange drilling of the proposed Calub-2 within existing petroleum exploration agreements and work programs.

Petroleum Conservation and Substitution

4.21 There is considerable scope for both increased fuel economy and interfuel substitution in the industrial and transport sectors. New energy sources for industry include agricultural residues and direct solar heating. In the transport sector the only alternative fuel available in the short-term is ethanol (see para. 5.18) which will substitute directly for gasoline and, at the same time, expand to a comparable degree the supply of diesel from the Asseb refinery. In the longer-term there is the prospect of natural gas, in the form of CNG or LNG, as a substitute for both diesel and gasoline.

Improving Energy Economy in Industry

4.22 The key areas for energy savings are improved combustion control and heat recovery. 22/ Apart from the sugar industry, none of the boilers or furnaces inspected by the mission had combustion monitoring equipment, and combustion control was quite poor. Fuel savings of 10% can be achieved through both the provision of appropriate equipment and operator training at relatively little cost. Improving boiler water treatment is in the same category and should be included as part of a training program the mission recommends for energy efficiency.

4.23 Heat recovery systems offer important savings for the textile, glass, steel and cement industries. In the textile industry, a 12% savings of energy use should be achieved by extracting heat from effluent from the finishing sections of the mill. Installation of ceramic or stainless steel heat exchangers to extract otherwise wasted energy from furnace flue gases should save 25% of current energy use, and useful energy can be recovered by recycling clinker cooler air for raw mill drying in the cement industry. The mission recommends that prefeasibility studies be commissioned immediately to cost and rank these measures as part of a program of investment in energy conservation.

Interfuel Substitution in Industry

4.24 Substitution of fuel oil by bagasse and cereal straw bales or pellets in the cement industry and some boilers appears practical and economic. It is now common for cement plants to provide a proportion of their energy from waste materials (e.g., rice husks, household refuse, tires) co-fired with oil or coal. In Ethiopia, fluidized bed combustion of agricultural residues is recommended for the new Mugher plant near Addis Ababa, and for the proposed Dire Dawa plant. Displacement of as much as 50% of fuel-oil normally required should be possible if the burnt gases are fired into the low temperature end of the kiln. The existing sugar industry at Shoa and Wonji can, with certain investments, generate 35-40,000 tonnes of bagasse surplus to their annual need, which is more than the amount required, and they are ideally located to serve this market. The wood-fired boilers of the United Oil and Soap factory must be refurbished in any case as back up to, and eventual replacement of, new electric boilers installed there, and at minimal additional expense they also can be made to fire baled or briquetted crop residues. Finally, solar water heating is economic in at least three major hotels and seven tanneries. The preliminary design and costing of these installations should be included in the national solar water heating review project later recommended (see para. 5.20).

22/ A long and varied list of plant-specific prospects for energy conservation was compiled and made available to the GOE, and included improved insulation, repairs to combustion equipment and the like in the textile, brewing, glass, iron and steel and other industries.

Fuel Oil Viscosity

4.25 The viscosity of the fuel oil sold to industry is kept very low (600 sec-SSU) by blending in kerosene at the refinery. In all, 3,000 tonnes of kerosene are consumed in this way. On the one hand, with minor investment most industrial plants could burn higher viscosity fuel oil (1,200-1,400 sec) and on the other hand the EPC claims to be able to easily produce and handle higher viscosity. At least 2,000 tonnes of higher value kerosene per year can be saved for use in the household sector in this way. In the longer-term, much more viscous fuel oil (3,500 sec) could be used in the cement industry, providing fuel handling facilities are designed accordingly, leading to further enhanced economic benefits.

4.26 The costs and benefits of the measures proposed to increase the efficiency of petroleum fuel use and interfuel substitution in the industrial sector are summarized in Table 4.2. The overall savings possible within the next five years are of the order of 22,000 tonnes or 20% of the present petroleum use in industry, mostly in the form of fuel oil. The return on investment is uniformly high with a simple payback averaging just over one a year. The total capital requirement of about B12 million is modest when compared with current energy sector investment and should be accorded a high priority. The Ministry of Industry should be charged with the responsibility of defining and scheduling the required investments on a plant-by-plant basis to facilitate early implementation.

Table 4.3: SUMMARY OF FUEL ECONOMY OF SUBSTITUTION MEASURES IN INDUSTRY

	Annual Fuel Oil Savings (tonnes)	Approximate Investment Required (B '000)	Value of the Annual Fuel Savings Resulting a/ (B '000)
Combustion Control and Heat Recovery	3,900	4,000	2,800
Firing Agricultural Residues	15,000	5,000	4-6,000
Solar Water Heating	1,400	2,500	850
Firing Heavier Fuel Oil (kerosene)	2,000	200	840
Total	22,300	11,700	8,490-10,490

a/ This is not a measure of economic performance of these interfuel substitution measures. Additional information is required to establish the economic rate of return of these investment prospects.

Source: Mission estimates.

Transport Energy Efficiency

4.27 The mission's efforts here focussed on the truck and bus fleet which between them are responsible for more than half of all diesel consumption. Fuel use is excessive in both the public and private bus fleets because of overloading, insufficient maintenance, and continued use of old vehicles. Fuel efficiency in the trucking fleet is also very low by international standards. In both cases, one aspect of the problem is insufficient vehicles whereby routine maintenance has ceased and there is widespread, premature aging of all components of the drive-train. Efforts to improve vehicle maintenance facilities will achieve relatively low returns until the fleet is adequately expanded. Possibly US$20-30 million for additional vehicles is required to achieve the reserve capacity required to facilitate routine maintenance. This investment should be placed in the context of the much larger investment proposal arising out of the Bank-supported transport sector study recently completed. Since the savings forecast from the specific fuel economy measures promoted here are to some extent predicated on routine maintenance, investment planning for the road transport fleet should explicitly recognize these linkages.

Specific Measures

4.28 In the short-term, proven low maintenance requirements, especially for diesel pumps, should become a prime element of procurement policy. There is an urgent need for an investment of B4.5 million in modern workshop equipment and diesel pump testing facilities for the Government's bus fleet and, similarly, B6 million for its truck fleet. Overall, annual savings of about 6,000 tonnes of diesel, or about B6.0 million, will be achieved, quite apart from savings resulting from reduced wear and so on. Savings of this kind already are being achieved in certain private trucking fleets in Ethiopia which have the benefit of properly programmed servicing, and of diesel testing equipment. Trucks and tankers deployed continuously on the Addis Ababa-Asseb truck route, which is a good quality highway, should be fitted with turbo-charged engines. The fuel savings foreseen from this conversion are about 8,000 tonnes per year, valued at B6 million, for an incremental investment of B16 million. In the process of undertaking the vital once-off fleet expansion program here provided, and in routine vehicle replacement and fleet expansion, truck size should be minimized for the particular road environment and cargo concerned, and driver having reoriented to the efficient management of larger, more sophisticated vehicles.

Management Information Systems

4.29 It is evident from the detailed review of cost data for the trucking fleet compiled during the analysis of the Addis Ababa-Asseb petroleum products pipeline that much can be learned from systematic and concise monitoring of individual vehicle performance. Large differences between vehicle make and model are apparent in respect of maintenance history, fuel economy, down-time, and longevity, all of which are important in comparitive cost analyses. Not only is the fuel economy of vehicular transport important in the overall energy economy, but transportation is a vital and costly component in the supply of all wood fuels which, in all respects, dwarf the other energy forms in use. The mission strongly advises a comprehensive transport management information system be established to recover and compare on an equal footing all relevant data on the classes, makes and models as an input both to transport energy management and to overall procurement policy.

V. OTHER ENERGY SOURCES

5.1 There is little doubt that some economic justification can be found for a great many energy sources new to the Ethiopian energy economy. However, the mission has attempted to confine its deliberations to the key issues agreed with the GOE and to review in depth only those energy sources which may make a significant contribution to the energy economy in the foreseeable future. Accordingly, energy sources such as solar electricity and wind power, which are seen as having only limited applications, have not been examined further and, from field observation, it has become clear, too, that biogas and producer gas power production do not yet warrant detailed analysis. The energy sources examined in detail here are crop residues of various kinds and ethanol, with some consideration of geothermal and coal resources and biomass gasification.

Crop Residues

5.2 The rationale and potential for exploiting for fuel surplus lignocellulosic fuels of low opportunity cost is provided in Chapter II as part of the evaluation of a short-term strategy for augmenting household energy supply. In the discussion below, the distinction must be drawn from the outset between crop residues produced on peasant farms and those produced on huge state farms and arising from the coffee and sugar industries. The former already are used as fuels and have equal or higher value as fertilizers, soil conditioners and stock-feed. There is rarely sufficient straw produced to adequately feed cattle, let alone to serve other purposes (see schema paras 2.4 and 2.5). Therefore, the use of these crop residues as household fuels is, for the most part, undesirable, and the prime objective of the household energy strategy outlined is to displace these residues and animal dung to higher value uses. On the state farms and for the specified cash crops, vast quantities of residues are left on the fields, or at processing sites, where they are either burnt or rot away. The removal of at least 750,000 tpy (330,000 toe) of this combustible residue is possible at negligible opportunity costs, and preliminary estimates indicate that the materials can be briquetted and transported several hundred kilometers to be delivered at costs competitive with firewood and other traditional fuels. The specific circumstances are outlined briefly below.

State Farm Crop Residue Resources

5.3 The residues concerned here are those of the wheat, barley, maize, sorghum and cotton crops. The estimated quantities of residues generated in the 1980-81 cropping season are provided in Table 5.1. Cotton, maize and wheat residues comprise 95% of the total. Resource estimates are made by first determining total residue production (stalk, leaves, flowering parts) using harvest indices 23/ agreed with state farm agronomists and then half of this amount is allocated as an accessible resource, provided the residue left in the field is in the range of 500-1,000 kg/ha. Higher or lower collection rates are applied to adjust to this residual where necessary. The intention here is to leave sufficient crop organic matter to sustain soil structure and prevent serious erosion. The residues now remaining are mostly burnt off prior to replanting, voiding any significant soil protection. Indeed, in the case of cotton it is desirable to burn off old plants to limit the transmission of crop pathogens from one region to the next. Rather than being an agent of depletion, the rational collection of crop residue can form part of an integrated management strategy to maximize economic returns and to stabilize long-term productivity.

Table 5.1: ACTUAL CROP AND ESTIMATED RESIDUE PRODUCTION BY REGION FOR STATE FARMS, 1980-81
('000 tonnes)

	Cotton		Wheat		Barley		Sorghum		Maize		Total
Location	Bale	Residue	Grain	Residue	Grain	Residue	Grain	Residue	Grain	Residue	Residue
South	7	37	112	105	4	3	--	--	43	80	225
North	--	--	--	--	--	--	7	7	2	3	10
West	--	--	--	--	--		18	16	51	101	117
Awash	51	202	--	--	--	--	1	1	1	3	206
		239		105		3		24		187	558

Source: Mission estimates.

5.4 Harvesting and Processing. The basic techniques for harvesting and processing this resource vary from crop to crop. For cereal straw and stover some form of baling is required in the field during the two- to three-month harvest to allow for easy transport to, and storage at, the processing center on each farm. Baled material is then retrieved from straw, finely ground, and briquetted at an even rate all year round. All of these crop residues are naturally dry (10-15% mcwb) by the time of baling and can be briquetted or pelleted under very high pressure in heavy duty motorized steel presses without the use of a binder. Transport to market is conveniently handled in bulk or bags, as the briquettes have bulk densities of 600-800 kg/m^3. Investment is required in additional tractor and trailer capacity, baling equipment, and in briquetting facilities. Cotton stalk collection is done without baling and consequently the whole of the residue could be processed to briquettes during the harvest season.

23/ Harvest index here is the proportion which the grain or bole makes of the total above ground biomass yield measured at a constant common moisture content.

5.5 Problems. State farm operations currently have poor productivity and financial performance and are plagued with poor quality farm equipment and insufficient maintenance staff and facilities. Long delays in receiving spare parts on order simply compound these problems so it is not unusual to have 100% overcapacity in tractors just to have sufficient numbers operational at any time. Obviously, harvesting residues adds from one to several more mechanized field processes, and increases the maintenance burden. A major effort is being made by the Ministry of State Farms to upgrade mechanical skill and equipment operator training, and the results of this effort must be experienced before scaling up mechanized farm operations. There also should be considerable attention given to the choice of technology based on energy efficiency, maintenance experience and durability; evaluating life cycle rather than first costs. Very substantial maintenance and reserve capacity allowances have been made in reviewing the economy of residue collection to reflect the present day operational environment. However, the capacity to manage additional operations, regardless of cost, is currently limited, and would have to be improved before full scale harvesting and processing of fuel value residues could proceed.

5.6 Costs of Production. A summary of the mission's preliminary estimate of the costs of crop residue briquette production and delivery is provided in Table 5.2. Costs are fairly evenly distributed between field collection, densification and transport, with the delivered cost averaging about US$50 per tonne. The single most important cost of production is energy in the form of electricity to operate briquetting presses and, to a lesser extent, in the form of diesel to fuel farm machinery. Where only diesel power generation exists, and power is US$0.35/kWh, energy costs comprise 35-40% of the total. Where hydropower is available, energy costs fall below 20% of total costs (detailed cost data are provided separately). It is worth noting, however, that the net energy ratio for the briquette fuel cycle is about 20:1, i.e., about 20 times more primary energy is obtained than is used, including transportation to the urban market.

5.7 Future of the Resource. From the plans provided to the mission by the Ministry of State Farms, the area under cereal production is to expand from 173,000 ha in 1982 to 243,000 ha in 1993. The area planted to cotton is to expand from 31,000 ha to 98,000 ha over the same period. Although expansion planned by area is significant, planners hope to achieve the greatest benefits from increasing yields. The data provided in Table 5.3 indicate that a 330% and 530% increase in grain and cotton yields, respectively, is expected by 1993. The fuel production targeted for 1992 is based on the collection of approximately half of the residue available in 1981. In fact, with moderate growth in state farms, the mission's projections of crop residue briquette production will be between only one-eighth and one-fourth of the resource available in 1992. However, the value of this production will be about US$19 million at this farm gate, incorporating an attractive rate of return on investment, as well as offering a valuable source of high quality energy for on-farm processing (heat and steam-raising and power production) in the longer term.

Table 5.2: SUMMARY OF ESTIMATED COSTS OF CROP RESIDUE BRIQUETTE PRODUCTION AND DELIVERY (US$/tonne)

Residue	Field Collection and Storage	Densification and Packing Handling	Transportation to Market (330 km)	Total
Wheat & Barley Straw	14.40	16.30	16.00	46.80
Corn & Sorghum Stover	25.40	16.40	16.00	57.80
Cotton Stalk	10.50	17.90	16.00	44.40
Average Cost	16.70	17.90	16.00	44.40
%	33	34	33	100

Source: Mission analyses (available to the government).

Table 5.3: ACTUAL AND PROPOSED PRODUCTION OF SELECTED CEREALS AND COTTON ON STATE FARMS OVER 1982-93

Crop	1981 Actual	1983 (Estimate)	1985	1988	1993
			---------- Projected ---------- ('000 tonnes Grain or Bole)		
Cereals					
Barley	4	5	19	25	36
Wheat	112	154	148	206	326
Maize	147	171	195	311	491
Sorghum	26	31	23	47	97
Total	289	361	385	589	950
Cotton	58	79	83	114	308

Note: Residue production will be roughly proportional to grain and cotton yields.

Source: Ministry of State Farms.

5.8 Scheduling Production. The rate of exploitation of this resource is dependent on the success of the early trial work recommended in Chapter II (para 2.19), and is constrained by the factors identified in 5.5 above. Four criteria are used for selecting state farms for the first phase of operations: proximity to the market, high yield, EELPA ICS supply, and good management record. The production schedule outlined in Annex 2.6 provides for only 20,000 tonnes of cereal stover briquettes and 40,000 tonnes each of cereal straw and cotton residues by 1987, rising sharply thereafter. By starting early pilot production at the prime locations, there is a period of five years during which operational and maintenance skills, and farm management practive can be upgraded on the less successful farms before being burdened with residue collection and briquetting.

Coffee Residues

5.9 Coffee is a major crop in Ethiopia, with total production in the range of 200-250,000 tonnes of green bean per year. Currently all but about 13,000 tonnes of this production is as unwashed beans. In the production of unwashed coffee the entire coffee cherry is sundried and carried to a centralized decorticating station where the dry skin, pulp, and husk is removed from the bean and dumped. Dry pulp residue is roughly 1.7 times the weight of the green bean. When removed from the bean at the cleaning stations it is very dry (10-12% mcwb) and quite often spontaneously ignites with the heat generated by fermentation deep down in rotting piles from previous years. Some 150,000 tonnes a year of this residue are now available at 55 processing centers which are mostly small towns scattered through the main coffee producing provinces of Kaffa, Sidamo, Wollega, and Illabador. Although the coffee industry is expected to expand greatly during the next decade the production of fuel briquettes here targeted is based on the residues available in 1982.

5.10 Washed Coffee. There is a premium for washed coffee in the world market, so the GOE plans to expand washed coffee production to 26,000 tonnes by 1988. In the washed coffee process, the cherry is processed fresh, leaving very wet pulp residues and a dried green bean with the husk or parchment still attached. The wet pulp is discarded into water-courses, causing considerable pollution, and the husk is removed at one final cleaning station in Addis Ababa. At present, some 2,600 tonnes per year of the excellent fuel value residue is available there, expanding to 5,200 te per year by 1988. The wet pulp also may be processed to a dry fuel though the mission did not find this yet to be an attractive option, except perhaps in combination with pollution control measures.

5.11 Process and Costs. It is proposed that fuel briquettes be produced from the dry coffee pulp residue in parallel with seasonal decortication. Production units of 2,500-7,000 te briquettes per year are envisaged, matching the size of the cleaning stations. Briquetting presses would have to be sized to process the flow of residue literally blown out the back of decorticating mills. Fortunately, many of the larger processing centers are connected with the EELPA grid, for otherwise electricity costs exceed half the total cost of production. A sample cost analysis for producing coffee residue briquettes is provided in Table 5.3. The majority of the processing centers are between 330 km and 450 km from Addis Ababa, hence, transportation is about 50% of the delivered cost of the product. Even so, coffee residue briquettes are much cheaper than cereal or cotton crop residues due to the absence of a field collection phase in production.

5.12 Development Strategy. Coffee residue fuels are among the cheapest available, being competitive even with fuelwood production in some areas, and their production should be given high priority. The mission recommends that a pilot briquetting press be installed as soon as possible at the Addis Ababa washed coffee cleaning depot to process the husks removed; that dry pulp residues are delivered for trial briquetting to establish design parameters for the first pilot briquetting plant at a decorticating mill; and that a preliminary selection be made of the most suitable processing site for the first commercial production. The mission supports the GOE's program to amalgamate old small mills into one large station in each processing center, as this provides the opportunity to develop a fully integrated coffee cleaning and residue briquetting operation offering considerable economies of scale.

Table 5.4: COST SUMMARY FOR BRIQUETTING AND TRANSPORTING COFFEE RESIDUES a/

	Briquetting	Bagging	Transport b/ (US$)	Financial Cost	FE	Economic Cost	%
Capital Charges	4.60	2.40	3.10	10.10	76%	12.80	30
Fuel and Power	3.70		3.70	7.40	50%	8.60	26
Maintenance	1.40		4.10	5.50	75%	6.90	21
Labor	1.20	1.00	2.90	5.10	c/	4.40	14
Total	10.90	3.40	13.80	28.10		32.70	100

a/ Per tonne in 6,000 tonne/yr units.
b/ From 365 km (reference of town of Dila in Sidamo) to Addis Ababa.
c/ About 75% skilled and 25% unskilled at 0.5 shadow value.

Source: Mission Annexes Report (available to the Government).

Bagasse

5.13 The Ethiopian sugar industry produced 146,000 tonnes of sugar in 1982 from their Metahara, Shoa and Wonji plantations, located 110-350 km from Addis Ababa. A new industry is being developed at Finchaa about 300 km west of Addis Ababa which will produce 83,000 te (4,000 tonnes of cane per day: TCD) in the first stage, to be completed by 1986 and 125,000 te (6,000 TCD) after the second phase of development early in the

1990s. The Metahara plantation and mill was expanded from 3,000 TCD to 5,000 TCD by 1982, and the addition of a further 2,500 TCD of capacity at Shoa will be completed during 1984. None of the present mills or the new and expanded mills are designed to maximize bagasse production through energy efficient operation, yet the new Shoa and Finchaa mills for which plant is soon to be procured could become, at a small marginal cost, major bagasse producers. Bagasse fibre dried and densified in bale, pellet or briquette form is an excellent fuel from a well proven process. A study recently commissioned by the Bank showed that sugar mills of similar design to those in Ethiopia could produce bagasse surpluses of 15-40 kg oven dry (kgod) per wet tonne of cane produced and that with varying levels of investment including the installation of higher pressure boilers, efficient turbines, flue gas heat recovery and improved pan evaporation designs, these surpluses could increase to 50-75 kg per tonne of cane.

5.14 The present production of surplus bagasse is 9,600 tonnes per year (50% mcwb) and will grow soon to nearly 16,000 te per year concentrated entirely at the Wonji-Shoa mill complex. Much of this surplus will be used to displace fuelwood in lime-burning nearby. However, the mill's management has acquired valuable experience in baling and storing surplus bagasse. The present and potential bagasse surplusses are outlined in Table 5.5. With appropriate investments, bagasse surpluses could be increased tenfold, creating a valuable fuel supply to industry, households, or in the case of the Finchaa sugar industry, a high degree of year-round self-sufficiency in power. In order to take advantage of this potential, the government must intervene in the procurement processes for both the Shoa factory expansion and the new Finchaa mill to allow for relatively small design changes to the relevant steam raising, power production, and process heat components now specified to operate well below optimum energy efficiency. Although the mission identified specific fuel saving measures in all factories, and in the Finchaa design, it is desirable to have the engineering contract managers in each case systematically upgrade and review specifications. If this is not done immediately, the opportunity to generate large bagasse surpluses will be foregone for the next 15-20 years. The estimates of future supply applied in Chapter II anticipate the availability of about one-third of the potential here cited. The costs of bagasse fuel briquette production will vary greatly, increasing with the level of bagasse surplus envisaged, and with the existing factory and process design. The costs should fall in the range of B50 to B70 per dry tonne ex-factory. Here, an average cost of B90 per tonne delivered has been assumed in all comparative analyses.

5.15 Cane field residues represent an even larger energy resource than potential surplus bagasse where they are not used for animal feed, such as in Wonji and Shoa, and possibly Finchaa. The fuelwood supply problem is so acute that this resource should be regarded seriously. Much of the dry leaf matter is burnt off prior to harvest and the green tops and leaves are left in the fields. The government is encouraged to review local means for collecting and processing this residue without disrupting sugar production.

Table 5.5: BAGASSE SURPLUS POTENTIAL OF THE ETHIOPIAN SUGAR INDUSTRY

Sugar Mill	Cane Throughput 1987	Sugar Production 1982	Sugar Production 1987	Bagasse Surplus Present	Bagasse Surplus Planned	Bagasse Surplus Potential
	(tonnes of cane per day)	('000 tonnes)		('000 oven dry tonnes)		
Shoa						
Line 1.	1,650	43	43	--	7.9	17
Line 2.	2,500	--	65		Combined	26
Wonji	1,420	38	38	4.8	--	15
Metahara	5,500	65	140	--	--	56
Finchaa	4,000	--	83	--	3.9	36
Total	14,570	146	300	4.8	11.8	150

Table 5.6: COMPARATIVE ECONOMIC COST OF INDUSTRIAL BOILER FUELS, ADDIS ABABA (US$)

	LRMC per Unit	Energy Value	Price Per Unit Energy	Conversion Efficiency	Economic Costs per Unit of Delivered Energy
	(US$)		US¢/MJ	(%)	(US¢/MJ)
Fuel Oil (incl. shadow value)	$337/te	42.5 MJ/kg	0.79	78	1.01
Electricity					
Large boiler (>1MW)	7.0 US¢	3.6 MJ/kWh	1.94	98	1.98
Small boiler (<1MW)	per kWh			90	2.16
Cereal Straw Bales	$45/te	17.4 MJ/kg	0.26	65	0.40
Cereal Straw Briquettes	$47.76/te	17.4 MJ/kg	0.27	70	0.39
Cereal Stover Briquettes	$57.76/te	15.0 MJ/kg	0.39	70	0.56
Cotton Stover Briquettes	$44.43/te	17.3 MJ/kg	0.25	70	0.36
Coffee Residue Briquettes	$32.72	15.8 MJ/kg	0.21	70	0.30
Bagasse Briquettes	$43.50	16.6 MJ/kg	0.26	70	0.37

Note: Boiler capital and operating costs for new combustion equipment and fuel-handling systems for baled straw and briquetted residues will be 40% and 25% higher, respectively, than for oil-fired boilers. However, the overall costs of residue fuel combustion will remain less than half of those for fuel oil, and the return on incremental investment would be high.

Source: Mission estimates.

The Market for Crop Residues

5.16 The household use of briquetted residues has been discussed and compared with other options in Chapter II, and has been found to have great economic and strategic promise in the short to medium term. Tests by the mission on the use of these briquettes in stoves have shown that, used alone, and unless they are in small pieces, they are difficult to light. Once well lit, they burn extremely hot and slowly. If they were to be used as a sole fuel source, the briquettes would have to be produced as wafers instead: a process already commercially available. However, in practice, these fuels would be used in combination with other raw woody fuels and with charcoal, where they would be ideal for sustaining a slow hot fire for the simmering phase of Ethiopian cooking, and the lighting difficulties could be eliminated or minimized.

5.17 Industrial Market. In Chapter IV, reference was made to the potential use of crop residues in the cement industry and at the Akaki Oil Mill. Residue briquettes are excellent boiler fuels and in practice it is likely that they will be used both as industrial and as household fuels. For the cement industry application and for some boilers, baled rather than briquetted residue can be accepted, thereby eliminating the capital intensive briquetting phase. The costs of baled residue delivered to the urban market would be about the same as for briquettes due to the low bulk density of the bales and the great distances for transportation. Comparative estimates on fuel costs for industrial applications are provided in Table 5.5. These preliminary data indicate that briquetted or baled crop residues will be less than 40% of the energy cost of a fuel oil-fired boiler and 20% or less of the energy cost of electric boiler operation. Apart from the obvious implications for future industrial energy use, it is important for the GOE to ensure that the new boilers acquired for any of its existing industries in back-up to electric boilers, or for future industries, should be multi-fuel package boilers able to accept fuel oil, residue briquettes and natural gas. The mission strongly recommends that measures to ensure this are taken.

Ethanol

5.18 The GOE has plans for a US$11 million, 20 million liter per year ethanol distillery at Shoa, using surplus molasses from Shoa, Wonji and Metahara and a US$8 million, 14 million liter per year distillery for Finchaa producing about 7 million liters in the first phase of development. The required molasses feedstock of 72,000 tonnes will be available from the 1985 sugar industry, surplus to bakers yeast and potable alcohol production which between them consume 20,000 tonnes. Surplus molasses is now dumped on roads and in rivers. The likely long run molasses market price is US$71.50/te FOB New Orleans, and provides for no better than break even with the economic cost of transport to the port of Asseb some 800-1200 km from the point of production. The mission reviewed the capital and operating costs for a 20-25 million liter per year ethanol plant at the Wonji-Shoa plantation complex and found the likely costs of production to be between 18-20 US¢ per liter compared with the present border price for gasoline at Addis Ababa of about 30US¢/liter. The economic internal rate of return on the Wonji-Shoa investment is estimated to be about 39% at the investment cost of US$0.56 million per million liters per year of firm capacity. Doubling this capital cost will still yield over 20% ERR. The strength of this investment is based on the low opportunity cost of feedstock, the great distance of the market from the point of petroleum production or delivery, and the availability of steam and power at very low cost from the sugar mills. Despite the smaller size, the Finchaa distillery should show a similar economy. Ethanol fuels also offer greater benefits for combustion in normal petroleum engines at high elevation as they counteract the natural leaning of the fuel. A blend of 20% ethanol and regular gasoline will be both possible and desirable. Hence, the mission supports the proposed investment in ethanol production, providing that steps are taken immediately to avoid a number of possibly crippling constraints.

Constraints to Using Ethanol Fuel

5.19 Fuel handling systems in vehicles and fuel depots, and fuel storage tanks at every point in the distribution system to the point of end-use must be both ethanol tolerant and water free to ensure optimum operating economy with ethanol fuels. Casual observations made by the mission in the field point towards significant levels of moisture in service station fuel tanks in the central highlands region. At 1-2% water, phase separation between ethanol and gasoline will occur, rendering the fuel unusable. Similarly, all vehicles imported from now on, and those now in use and still operating in 1986, will have to be checked for fuel system material sensitive to ethanol attack. The cost of replacement is negligible for new vehicles but the disruption caused by faulty operation could be significant. Finally, adequate arrangements will have to be made regarding pricing, transport, blending and storage facilities for ethanol with the local oil companies before any commitment is made to distillery construction.

Solar Water Heating

5.20 There are economic applications for solar energy to displace electric water heating in as many as 8,500 households in Asmara, and probably as many again in Addis Ababa. An additional but unquantified domestic market exists in the major towns and cities now supplied with electricity. In reviewing industrial energy use, markets were found for solar water heating for tanneries and hotels, hospitals, and the like across Ethiopia. The economics of solar water heating have been discussed briefly in Chapters III and IV. There are potential benefits in local production of solar equipment providing the market is large enough to effectively amortize the costs of establishing manufacturing facilities locally. The mission supports the intent of the ENEC investment proposals for solar collectors and recommends an immediate review of the national market to define the feasibility and, if viable, the size and nature of local production facilities. If a sizeable long-term market exists the GOE should examine the prospect of a joint venture with an overseas company to establish local production of solar collectors and to impart the necessary skills to design and service complex industrial and commercial installations.

Other Energy Forms

Coal-Lignite

5.21 Lignite has been found in more than ten areas in Ethiopia. The major deposits are in Wollega, Gondar, Eritrea, and Sidamo. Recent evaluation of the Wollega and Gondar resource revealed poor quality discontinuous and deep deposits interbedded with thick basaltic flows. Further exploration is now in progress in Eritrea and Sidamo. Estimates of the total resource range as high as 20 million tonnes though the data base is minimal and the costs of production have not been carefully studied. It is noteworthy that deposits tend to occur in the more deforested energy-poor regions. Low quality lignite has been used in some countries, after suitable processing, both for power production and for household fuels. ENEC has recognized that even very small low quantity deposits (100,000 tonnes plus) could prove economic to exploit in the short- to medium-term, and a thorough resource evaluation is clearly required. The mission strongly recommends upgrading the level, and increasing the scope, of the GOE's resource inventory now in progress, with particular emphasis on the likely economics and proximity of potential markets. Subject to confirmation of an appropriate resource, a detailed anlaysis should proceed on the economy of producing lignite briquettes for the household and small industry market.

Geothermal

5.22 The high enthalpy geothermal potential of Ethiopia has been estimated at up to 4,000 MW, higher than any so far identified in Africa. The first project to reach the exploratory drilling stage was at Aluto in the Lake district sector of the Rift Valley, 140 km from Addis Ababa. There appear to be good prospects of potentially commercial steam flows following early drilling and additional wells were planned in this region. An evaluation is now required of the economics of power production from this resource (see para 3.40). US$20 million were provided for this exploratory drilling by the Commission of European Communities (CEC), the UNDP, and the GOE. Additional wells will be drilled at Corbetti Caldera and the Lake Abaya area, and in Tendaho in the Afar region in the near future. Furthermore, the Bank has financed under the Petroleum Exploration Promotion Project a pre-feasibility study of geothermal energy production in the Fantale-Dofan area in the middle Awash Valley. Complimentary economic studies are included under that project to establish the contribution that this resource might make to the energy economy of Ethiopia.

Biomass Gas Sources

5.23 The GOE is considering proposals for an ambitious biogas program comprising the installation of 27,500 2m^3 digestors over the next decade. The mission examined both the social and biological environment in which it is intended to place these digestors and a pilot plant at an agricultural training college at Awassa. First, it is clear that to generate and maintain a digestor, considerable changes are necessary in a peasant family's daily activity schedule and, second, the required capital outlay in materials (cement, piping, gas-holder, stoves, lights and other fixtures) of B500-1,000 is well beyond most rural peasants. However, the most important constraint is the daily requirement for about 25 liters of water to dilute the required daily cow dung input of 15 kg fresh weight for a 2 m^3 digestor serving a family of five. It is widely reported that only 6% of the population has regular access to a reliable water supply. In the rural areas, fetching water over long distances in clay pots of 10-15 liters capacity is a costly daily ritual. The mission believes that the program of agroforestry and rural woodlot development should be given much higher priority than a biogas program, and that the installation of digestors should be justified on a strict economic basis after carefully assessing the true cost and availability of all required inputs. It is likely that these will only be feasible at a limited number of locations and will have a very small impact on the overall energy needs of the rural sector.

Power Gasification

5.24 There is a prima facie case for a pilot program of producer gas power generation on state farms which become involved in the residue briquetting program. These state farms are the only locations where good quality gasifier feedstock and significant diesel power generation are found together. However, in the short term there are a number of constraints offsetting the benefits that might result from displacing diesel power generation. In the first instance it will be up to five years before residue briquettes are produced on many state farms, should that option prove viable. Second, the power systems on state farms are almost all operating intermittently, not only being limited to 12-14 hours per day but also stopping and starting several times during the day. This makes the economic operation of gasifiers quite difficult due to both the much closer management requirement to bed down and recover the gas producer for each operating period, and due to the considerably reduced proportion of gas in the fuel mix that would result. State farms are currently burdened with numerous mechanical and other maintenance problems and in the short-term it will be difficult enough expanding operations to produce residue briquettes let alone imposing power gasification technologies. The mission recommends that this program be put in abeyance pending a successful crop residue briquetting program.

VI. ENERGY PRICING

6.1 This chapter deals with several aspects of energy pricing of concern to energy management and planning. The first is the relationship between economic costs of supply and fixed or market prices for the most commonly traded fuels. Second, there is consideration of the financial as well as the social and economic determinants of price levels and price structures, and third, there is the interpretation of trends of market prices with respect to implications for future energy planning. A considerable volume of comparative data has been presented in Chapters II and IV on prices and costs of present and prospective energy forms. Here the discussion is focused on present day prices, pricing practices, and the implication of the existing price structure within the electric power, petroleum, and biomass fuel subsectors.

Woodfuels

6.2 Hard reliable data on woodfuel prices are difficult to obtain. In Ethiopia the conventions for measuring retail prices of these fuels appear to have changed over the decade from volume to weight and back again. Volume measurements are inherently inaccurate, hence the government is advised to standardize price monitoring procedures on the basis of weight wherever possible, and to specify the size of the parcel measured in each case. The mission weighed and established the fuel value of wood, charcoal and dung in many locations during fieldwork and observed huge variability in marketing practices, and in firewood quality, from one marketplace to another. The mission's own data have been added to existing data to make up a time series for wood and charcoal prices for Addis Ababa extending from 1970 to 1983. Nominal retail prices have been converted into real prices using the Addis Ababa retail price indexes as shown in Table 6.1. In real terms the price of firewood has risen from about B17 per tonne to B55 per tonne over the last 13 years, equivalent to 9.2% per year, with the bulk of the growth occurring in the past decade. Similarly, the real price of charcoal, which now retails for over B1,000 per tonne in small lots, has risen at 6.7% p.a. The sharpest price increases occurred between 1974 and 1978 when prices for both commodities doubled in real terms and increased fourfold in nominal terms. These data provide sound evidence of the growing scarcity of woodfuels and, in turn, of the deforestation crisis in the urban hinterlands.

6.3 Regional Data. The need to consider separating the unique situation of the northern region is stressed in Chapter II. The only apparently reliable data comparing woodfuel prices during the same period are for the last quarter of 1980. These data are provided in Table 6.2, verifying the even more extreme situation of the northern region and in particular, Asmara and Mekele, the provincial capitals of Eritrea and Tigrai, respectively.

6.4 Government Woodfuel Prices. The GOE supplies the Addis Ababa woodfuels market with charcoal and fuelwood through retail depots operated by the Fuelwood and Charcoal Marketing Company (FCMC) of FAWCDA (see para 7.14). FAWCDA proposes the retail prices for its products on the basis of its own costs of supply and the requirement of profitability for the FCMC.

Table 6.1: WOODFUEL PRICES IN ADDIS ABABA, 1970-83

Year	Retail Market Prices		Movement in Price	Real Price	
	Firewood	Charcoal	Index Unitized at 1970	Firewood	Charcoal
	(Birr per metric tonne) a/			(Birr per metric tonne)	
1970	16.94	163	1.000	17.94	163
1971	17.60	169	1.005	17.50	168
1972	18.77	180	0.944	19.88	191
1973	19.92	191	1.028	19.38	186
1974	28.33	272	1.117	25.36	244
1975	38.79	431	1.190	32.60	362
1976	49.08	458	1.529	32.08	300
1977	76.38	553	1.784	42.81	310
1978	81.27	768	2.039	39.86	377
1979	105.75	914	2.366	44.70	386
1980	101.92	1036	2.472	41.23	419
1981	131.40	1010	2.624	50.08	384
1982	no data	no data	2.770	no data	no data
1983 a/ (first half) b/	160.00	1136 (to June only) c/	2.895	55.27	392

a/ Standard conversion applied to compute cubic meter stacked to metric tonnes assumes 600 kg/m^3 basic density with a mixture of Acacia and Eucalypt sp.; 0.6 solid volume is stacked volume, and 25% mcwb (av). Charcoal sacks are assumed to average 45 kg.

b/ Mission measurements of lowest level of retail sale i.e., for charcoal 0.2-0.25 kg lots; for wood 1-2 kg lots.

c/ Assuming 4.5% half yearly increase in retail price index for 1983.

Sources: Statistical Bulletin of Ethiopia, ENEC and mission records.

Table 6.2: COMPARATIVE PRICES OF WOODFUELS IN ETHIOPIA; LAST QUARTER OF 1980

Province	City	Firewood	Charcoal
		(Birr per tonne)	
Shoa	Addis Ababa	94	670
	Nazareth	74	330
Harrarghe	Dire Dawa	73	310
	Harrar	83	330
Wollo	Dessie	67	440
Eritrea	Asmara	167	840
	Asseb	125	780
Tigrai	Mekele	204	none available
Gondar	Gondar	46	380

Source: ENEC and mission estimates.

The comparison between government and market prices for firewood and charcoal is provided in Table 2.8 of Chapter II. Government prices are about 40-55% and 60% of the open market prices for charcoal and wood respectively, depending on the size of parcel sold. One objective of the government is to significantly lower the average market price but thus far has been unable to achieve this end, partly because of a lack of customer orientation in its marketing (restrictive pack sizes, opening hours, poor quality, rationing, etc.) and partly because it is supplying only a small part of the market. FCMC now supplies less than 10% of the charcoal and about 20% of the firewood demand of the Addis Ababa market. Financially its prices appear sound, ensuring the FCMC a margin of at least 15% over its total costs of operation. From an economic standpoint it is important to know whether the full resource costs of harvesting the logging and forest clearing residues are covered within the consumer price. In this case, the resource costs are reasonably represented by the costs of replenishing the wood resource through re-establishing an equivalent standing biomass in the form of plantations, though this is a narrow site-specific determination, for elsewhere there may be higher value crops than reforestation. By allocating the relevant plantation development cost data to the timber and energy products concerned, a crude estimate is obtained of the resource cost of about B4.30 per solid cubic meter or B6.40 per tonne of fuelwood. For charcoal produced by traditional methods the resource cost computes to B59 per tonne and the economic costs of production and delivery become B190 per tonne. Furthermore, the long-run cost of fuelwood will be approximated by the cost of production from the most expensive peri-urban plantation development in the central highlands which is about B23 per m^3 or B41 per tonne (20% mcwb) delivered. Since the government selling price for woodfuels exceeds both the economic costs of present supply and the long run costs of production and supply, the main consideration should be whether it serves the desired financial objectives. In the more commercial urban components of the woodfuel production program outlined in Chapter II, here envisaged, the government can opt either to fund FAWCDA directly from the budget to undertake peri-urban plantation development or, preferably, it can allow FAWCDA to generate sufficient cash generation from its sales to become substantially self-financing in the longer-term. The point in the supply chain (i.e., ex-forest, wholesale level, retail level) at which an interface is established for cost and capital recovery should be carefully reviewed, as the mission does not see an ongoing role for FAWCDA as a retailer of woodfuels (see Chapter VIII).

Petroleum Pricing

6.5 Petroleum prices are proposed by an ad hoc committee established by the Government, and the final decisions are made by the Council of Ministries. The Ministry of Internal Trade is responsible for implementation of agreed prices. Prices have recently adjusted from levels set in April 1981. The government policy is to peg prices to import parity in an attempt to make its refinery operations profitable. For reasons outlined in Chapter IV, the present state of the refinery obstructs fulfillment of this objective. In addition, there are deliberate cross-subsidies attempted which in 1982 caused a net overall subsidy to the refinery of B5.63 million. However, the notion of import parity pricing disregards the cost of foreign exchange and is, in effect, just an attempt to have receipts balance with direct costs. The "import parity" buildup applied by the EPC to achieve a price C.I.F. Asseb is shown in Annex 6.1. The buildup of retail price from the posting ex-refinery is provided in Annex 6.2 accompanied by the transport cost formula applied. Differences in the 1982 import parity and the ex-refinery postings illustrate the pattern of subsidy and cross-subsidy applied (e¢/liter):

Comparison of Estimated Parity Petroleum Prices with Ex-Refinery Postings

	Kerosene	Regular Gasoline	Diesel	Fuel Oil
Import Parity	68.3	60.6	64.5	46.8
Ex-refinery Postings	67.8	88.5	52.8	38.5

Source: EPC, Mission estimates.

6.6 The economic cost of supply and the current retail price in Addis Ababa for each of these products and for LPG is provided in Table 6.3. Retail prices in four other main towns are provided in Annex 6.2. It is evident that gasoline and fuel oil are the only products priced in excess of economic costs (with the shadow pricing of foreign exchange) and that very substantial underpricing applies to kerosene and LPG. Although diesel is priced only 7% below the level of economic costs, it is nevertheless an important "subsidy" due to the large volume of product concerned, the need to improve energy efficiency in road transport, and the mechanism for providing road-funding revenue that is being foregone. The small penalty on fuel oil is of little consequence and can be regarded as both a revenue raising measure and an added incentive for boiler efficiency and interfuel substitution. The gasoline market is already highly regulated both by rationing to private and public vehicles, and by limiting the importation of spark ignition engine vehicles. While there is no economic rationale for such a high price, the measure can be justified as a luxury tax. There is a need, however, to ensure that high prices for gasoline, and comparatively very low prices for diesel, do not work against a full and economic use of locally produced ethanol which cannot be blended with gasoline at greater than 20% by volume without additional investment in vehicle fuel systems. Gasoline can readily be used in light commercial vehicles now using diesel in order to expand its market.

Table 6.3: ECONOMIC COST AND RETAIL PRICES OF PETROLEUM PRODUCTS IN ADDIS ABABA, 1983

	Economic Cost a/ (ec/liter)	Retail Price	Difference
Gasoline (regular)	80.3	117.4	+46%
Diesel	82.7	78.0	-7%
Kerosene	83.1	65.4	-27%
Liquified Petroleum Gas	88.2	67.8	-30%
Fuel Oil	55.8	59.9	+7%

a/ The estimated product costs, CIF, and the relevant component of inland transport costs are included at the shadow value for foreign exchange of 1.3 times the official exchange rate. Other costs included are part handling, distribution handling, and marketing charges.

Source: EPC and mission estimates as per Annex 6.3.

The Case for Increased Prices

6.7 Kerosene and LPG are well below the cost of firewood and charcoal as cooking fuels in most urban areas even when priced at full economic cost (see Table 2.8). Moreover, the economy of kerosene use can be improved by making available more efficient stoves. Both petroleum fuels offer greater convenience than their biomass counterparts for normal cooking, adding further to their attraction. Finally, the propensity of higher income households to use kerosene and LPG means that, at present price levels for various fuels, lower income groups in the cash economy tend to pay more per unit of cooking energy. The mission therefore recommends removing the subsidy on these household petroleum fuels and, in accordance with the proposed short-term strategy for household energy supply, concentrating instead on investments in production, delivery and end-use facilities to make them widely available on the market. The case for increasing the diesel price rests, on the one hand, with the need and the potential to improve efficiency of use and, on the other hand, with the importance of the measure in raising revenue for high priority energy sector investments, and road maintenance, which in turn has a favorable impact on fuel economy. Most of the diesel is used in road transportation where small-fleet or single vehicle owner-operators contract to Natracor for business. The mission has observed that the operations of this component of the fleet tend to be more sensitive to energy costs and that with increased prices, improved fuel economy is likely, not only through better operation of existing trucks and buses, but through the added inducement to purchase more fuel efficient vehicles in the future (see Chapter IV). Finally, the revenue base in Ethiopia is narrow and the vast majority of expenditures required for the rural forestry program is in local currency. The greater portion of the would-be beneficiaries of rural aforestation, the rural peasantry, have negligible contact with modern fuels and would be unaffected by the price increases proposed, whereas stabilizing and stimulating peasant agriculture is fundamental to modern sector development, and the surpluses generated from higher petroleum fuel prices would contribute to this end. It is therefore recommended that prices for petroleum fuel products reflect their economic costs, in particular, that kerosene and LPG prices be adjusted upwards as soon as possible.

Electricity Pricing

6.8 Present Tariffs. The present electricity tariffs in Ethiopia have been in force since October 1978 for the EELPA ICS and SCS and since April 1974 for the ERESA systems. The value of tariff levels by 1982 had decreased by 26% for the EELPA system and 60% for the ERESA system in real terms since the date of the last adjustment (according to the Retail Price Index in Addis Ababa). The cost of power production in the thermal systems of the EELPA SCS and ERESA ICS and SCS has increased by a greater amount than the Retail Price Index due to increases in the cost of imported petroleum products during these periods. Although production costs on the EELPA ICS have not been directly affected by petroleum price increases since the system is supplied almost entirely from hydroelectric stations, the cost of meeting increases in demand beyond the capacity of existing hydroelectric installations will have increased substantially since 1978. Therefore, tariff levels need to be reviewed.

6.9 The present tariff structure for all the power systems is based on a declining block rate, whereby the marginal unit costs less than the initial unit purchased, and does not incorporate time-of-day factors. Such a structure is promotional and reflects a situation in which there exists substantial excess hydroelectric capacity, as was the case on the EELPA ICS during the mid to late 1970s. However, this situation is not likely to remain for long according to demand forecasts (Chapter III), and therefore this structure is inappropriate for the future. The declining block structure was never appropriate for the thermal-based systems. Between consumer categories, the tariff levels for high voltage supply to industrial consumers are low relative to the levels for other categories even with allowance for lower system losses at high voltage supply. Tariff levels on the EELPA SCS and ERESA ICS are about 25% higher than on EELPA ICS, even though costs of supply relatively are much higher. The tariff levels on the ERESA SCS are nearly three times as high as on the EELPA ICS, which is a more accurate reflection of relative supply costs. Average tariff yields for the power systems are given in Table 6.4.

6.10 Economic Costs. The economic costs of supplying long-run increases in demand for power have been estimated recently by consultants 24/ for EELPA. These estimates are summarized in Table 6.5. The

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24/ Coopers & Lybrand Associates "Tariff Study and Asset Revaluation" -- Final Report (August 1983).

consultants have differentiated between daily peak and off-peak demand periods since new investment will be determined by the need for additional capacity before the need for additional energy capability. The consultant's estimated economic costs are compared to the existing tariff schedule in Table 6.6. For the EELPA ICS, there is little difference between the existing tariff and economic costs. However, the economic costs of supplying the thermal-based systems are about three times as high as the present tariff levels for the EELPA SCS and ERESA ICS, and about twice the level for the ERESA SCS. This comparison shows starkly the present degree of heavy subsidization of consumers in the three small systems.

Table 6.4: Average Electricity Tariff Yields
(Eth cents/kWh sold)

Consumer Category	EELPA in FY81 ICS	SCS	Total	ERESA in FY82 ICS	SCS	Total
Domestic	14.99	18.31	15.55]			
Commercial	15.17	20.39	16.44]	18.80		
Street Lighting	11.00	15.00	12.93	15.00		
Small Industries	16.20	20.03	17.62]			
Low Voltage Large Ind.	12.43	16.52	12.82]	10.05		
High Voltage Large Ind.	8.26	7.50	8.19	-	-	-
Agriculture	7.82	8.82	7.84	-	-	-
Average Revenue	12.00	14.92	12.52	14.19	32.87	14.40

Source: EELPA

6.11 The adoption of tariff levels established according to economic costs of supply would introduce a huge differential between tariffs on the EELPA ICS and other systems. GOE is sensitive to the social issues and considerations of equity that would be involved, as well as to the effects that large tariff increases could have on its overall policy for prices and wages. The consultants computed a tariff schedule based on uniform rates for each consumer category throughout the country. The uniform tariff level is about 50% higher than the economic cost of supplying the EELPA ICS alone, and is between one third and one half of the tariff levels for the other systems under separate tariffs. Thus, price distortions under a uniform tariff would be considerable, and the mission strongly recommends against adopting this policy. However, the mission recognizes the difficulties in changing tariffs immediately to a structure that reflects economic costs. Such a change could be introduced in stages over a few years.

Table 6.5: ECONOMIC COSTS OF POWER SUPPLY a/

	EELPA ICS	EELPA SCS c/	ERESA ICS	ERESA SCS
Long Run Marginal Capacity Costs (Birr/kW pa)				
Generation	232	106	157	324
Transmission/HV Dist.	30	10	20	10
LV Distribution	51	51	51	51
Long Run Marginal Energy Costs (Birr/kWh)	0.050	0.3757	0.3254	0.3588
Peak b/ Economic Costs				
(Birr/kWh) - HV	0.332	-	0.445	-
- LV	0.477	0.695	0.554	0.968
Off Peak Economic Costs				
(Birr/kWh) - HV	0.054	-	0.342	-
- LV	0.059	0.437	0.363	0.417

HV and LV: High Voltage and Low Voltage.

a/ Evaluation based on Shadow Foreign Exchange Rate = 1.33 x official rate; 10% discount rate; Shadow Wage Rate for Unskilled Labor = 0.5 x financial rate.

b/ Monday - Saturday 6:30 p.m. - 9:30 p.m.

c/ Excluding Bahir Dar region which is treated as part of EELPA ICS.

Source: Coopers & Lybrand Associates: "Tariff Study and Asset Revaluation", Final Report (August 1983).

Nevertheless, tariff levels should cover at least variable costs, which are largely composed of fuel costs in the thermal-based systems, and accordingly the mission recommends that tariff levels on the EELPA SCS and ERESA systems be raised immediately to at least an average rate of 35e¢/kWh, with planned regular increases to the level of full economic costs over the short-term. 25/

6.12 Financial Requirements. The consultants also examined the tariff levels that would be required to meet certain financial objectives, namely that revenue should cover all operating costs and yield a certain return on revalued assets 26/ or generate funds to finance 25% of

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25/ The long run marginal energy costs (Table 6.5). Ideally, the tariff level should reflect specific variable costs of each system, but a uniform rate for the thermal-based systems may be more acceptable.

26/ Under IBRD Loan 596-ET (1969) for the Finchaa Project, EELPA was required to comply with a 7% rate of return on non-revalued assets.

capital investment. The self-financing condition generally dominates the other conditions with the large investment program required. The computed tariff levels required to meet the stated objectives are about 29% higher than marginal cost tariffs if applied across all the power systems. However, the levels for consumer related charges on the EELPA ICS would be 49% higher than marginal cost tariffs if the incremental burden of the financing requirement was carried by this system alone. The consultants have formulated their recommended tariff levels according to the latter financial requirements. The consultants also have incorporated an allowance for anticipated inflation between 1983 and the time of implementing the tariff increase (7%), and a further increase (13%) to allow for a three year interval between the next increase and the subsequent increase. The consultant's proposed financial tariffs also are shown in Table 6.6. The recommended tariff structure is according to economic costs.

6.13 The consultants have based their estimates of tariff levels on EELPA's optimistic capital investment program, which amounts to about B3 billion for 1984-93 in 1983 prices. It is unlikely that this level of resources could be made available for power sector investment. The consultants used a demand projection based on the optimistic forecast growth rate in demand for the EELPA ICS derived by EELPA's engineering consultants (Acres). The investment program required to meet the Bank's demand forecast (Chapter III) is substantially lower than the program used by the consultants, and it should be possible to gather the financial resources to meet this projected demand. The consultants tested the sensitivity of their proposals to the lower demand/investment scenario, and they concluded that EELPA's position would be only slightly better in this case, and this would not warrant a significantly lower financial tariff than the one they propose.

6.14 Implementation Strategy. The consultants have recommended tariff levels in their financial analysis on the assumption of a three year interval between tariff increases according to projected rates of inflation, since EELPA consider it unrealistic to assume that tariffs will be allowed to increase at more frequent intervals. Nevertheless, in economic terms a policy of relatively frequent and minor tariff increases is more sensible than occasional large increases, since it permits the supply agency to monitor demand more accurately and thereby adjust its investment program to match demand more closely, and it results in a less dramatic impact on customers at the time of the increase.

6.15 The projected existence of substantial surplus hydro generating capacity following the commissioning of the Malka Wakana project (Chapter III) raises the issue of pricing according to short run marginal costs. According to the Bank's demand forecast, there will be a surplus of about 700 GWh/y and 100 MW in 1988 which will decline steadily to zero by 1994. There will be an opportunity to offer a low tariff for electric boiler use provided that it is clearly understood by all parties that this facility only lasts while sufficient surplus capacity is available, and that it is not taken to be the signal for extending the boiler electrification program. The particular circumstances which would justify this policy are that electric boilers are already installed so that the investments are sunk costs, and that non-electric boilers are maintained in working condition in the same plants so that the electric boilers can be disconnected when the surplus capacity is reduced. Under these conditions, the demand from electric boilers is not relevant for system planning purposes and, therefore, it has not been included in the Bank's forecast. The economic benefit from this facility would be savings in fuel oil costs, and the electricity tariff for this special category should be set to provide an incentive to switch over to using electric boilers on the basis that capital investment is a sunk cost. The tariff should not be set sufficiently low to justify the investment in new electric boilers, due to the short-term nature of the surplus power and the long-run marginal cost of power supply which makes electric boilers less economic than alternatives. The mission considers that a tariff of about 5.5e cents/kWh in 1983 prices would give the correct signal to consumers.

6.16 A particular feature of the domestic market for electricity in the main urban centers is the existence of "meter landlords" who are consumers that unofficially supply power from the public supply system from their own metered connections. EELPA estimate that tens of thousands of consumers are supplied through these landlords. This system is open to abuse by the landlords through exploitation of a local monopolistic position by charging rates that are much higher than EELPA's tariffs. However, there is no recorded information on the on-selling rates, so it is not possible to reliably assess the extent of such abuse. In contrast, the meter landlords perform a useful service by reducing distribution and billing costs, and by making electricity affordable to many consumers who cannot afford EELPA's connection charges. To prevent excessive abuses, EELPA should impose a ceiling on the rate that meter landlords could charge by making individual connections more affordable, for example, by offering long-term credit for connection charges and by treating the cost of meters as an overall distribution cost rather than charging this to the cost of individual connections.

6.17 The possibility of introducing a "lifeline" rate for the first few kWh of monthly domestic consumption is examined by the consultants in response to GOE's desire to provide cheap electricity to the poorest consumers. There are strong economic arguments against such a rate, for example: (a) it will involve a heavy subsidy to cover thermal energy costs outside the main ICS, and also since consumption by these consumers is predominantly from lighting and thus coincides with the period of system peak demand, and as a result advances the timing for investment in new capacity in all systems; and (b) it could stimulate a surge in demand for new domestic connections from consumers presently served by meter landlords which would be costly to satisfy and could well be beyond EELPA's capacity to service. The èconomic advantage of a "lifeline" rate lies in the social benefits to the poor section of the community. The consultant's propose a compromise in which the first 7 kWh of monthly consumption would be free, but there would be a minimum charge equal to the service charge. The monthly consumption limit would only allow the use of about 60 watts of lighting for about 4 hours per evening. On balance, the mission is sympathetic to the need for making electricity available to the poorest section of the community but considers that there are better ways of achieving this than the consultant's proposals. Therefore, the mission recommends that alternative approaches be considered.

6.18 The mission does not consider that the case for increasing tariffs arises in any way from inefficiencies in EELPA's operations. There is scope inevitably for improvements, but the case for tariff increases rests on the economic costs of meeting increases in demand, and not on present operating practices. The Mission notes, however, that there is scope for improvements in operating efficiency, such as the maximization of hydroelectric energy output on the main ICS, and reduction in fuel utilization in isolated diesel stations.

6.19 Summary. The discussion on electricity pricing can be summarized as follows:

(a) Tariffs on the EELPA SCS and ERESA ICS are about 25%, and those in the ERESA SCS about three times higher than tariffs on the EELPA ICS.

(b) Economic costs of supply on the hydro-based EELPA ICS differ little from the present tariff level, whereas they are about three times EELPA SCS and ERESA ICS, and twice ERESA SCS, tariff levels.

(c) The mission concludes that:

- the present tendency towards uniform national tariffs is leading to severe distortions in energy pricing and to economic inefficiency.

- the declining block tariff structure now in place is inappropriate because of its promotional nature in the face of impending capacity constraints and because it does not accurately reflect the distribution of costs.

- the GOE's intent to make EELPA financially autonomous is correct and hence EELPA's financial requirements should be a key determinant of the level of tariffs on the EELPA ICS.

(d) Thus, the mission recommends that:

Table 6.6: COMPARISON OF EXISTING AND PROPOSED TARIFFS a/ b/

Consumer Category	EELPA ICS Existing Tariff	EELPA ICS Proposed New Tariff: Economic f/	EELPA ICS Proposed New Tariff: Financial g/		EELPA SCS Existing Tariff	EELPA SCS Proposed New Tariff h/		ERESA ICS Existing Tariff	ERESA ICS Proposed New Tariff h/		ERESA SCS Existing Tariff	ERESA SCS Proposed New Tariff h/
Domestic (Birr/kWh)												
First 25 kWh/month	0.15]				0.15]		Lighting	0.24]		Lighting	0.37 c/]	
Next 26 to 100 kWh/m	0.17]				0.18]		Power, First					
							500 kWh/m	0.19]		Power	0.25 c/]	0.608
Remainder	0.12]	0.159	0.271		0.13]	0.608	(Massawa	0.17)]	0.542			
Off-Peak	0.09]				0.13]		Remainder	0.15]				
Commercial (Birr/kWh)												
First 50 kWh/month	0.15]				0.19]			(as for]			(as	
Next 250 kWh/month	0.18]	0.150	0.271		0.22]	0.608		domestic)]	0.542		above)	0.608
Remainder	0.13]				0.18]							
Street Lighting (Birr/kWh)												
All consumption	0.11	0.145	0.262		0.15	0.618			0.428		0.37	0.618
Small Industrial (Birr/kWh)												
First 1000 kWh/month	0.20				0.24			(see				
Next 2000 kWh/month	0.15				0.19			below)				
Remainder	0.10				0.14							
Peak		0.474 d/	0.863			0.913			0.661			0.913
Off-Peak		0.059 d/	0.107			0.526			0.441			0.526
Low Voltage Large Industrial												
Maximum Demand Charge: First 50 kW	12				10			10				
(Birr/kWh/month) Next 200 kW	10											
Remainder	8				8							
Energy Charge: First 200 kWh/kW	0.09			First 10000 kWh/month	0.13/kWh		First 100000 kWh/m	0.09			(as	
(Birr/month) Next 200 kWh/kW	0.08			Next 10000 kWh/month	0.12/kWh		Remainder	0.06			above)	
Remainder	0.07			Remainder	0.11/kWh							
(Birr/kWh) Peak		0.477 d/	0.863			0.913			0.661			0.913
Off-Peak		0.059 d/	0.107			0.526			0.441			0.526
High Voltage Large Industrial												
Maximum Demand Charge: First 200 kW	10											
(Birr/kW/month) Next 800 kW	8											
Remainder	6											
Energy Charge: First 200 kWh/kW	0.075											
(Birr/month) Next 200 kWh/kW	0.06											
Remainder	0.05											
(Birr/kWh) Peak		0.332 e/	0.601			-			0.541			
Off-Peak		0.054 e/	0.098			-			0.415			

a/ Proposed tariffs by Coopers & Lybrand in Tariff Study (August 1983).
b/ Service charges, minimum charges and power factor penalty clauses are additional to these tariffs.
c/ Tariffs vary considerably between ERESA SCS towns.
d/ Average tariff 0.097 Birr/kWh.
e/ Average tariff 0.088 Birr/kWh.
f/ At mid-1983 prices
g/ Required rates to meet rate of return on assets and self-financing criteria, with allowances for a three-year interval between tariff increases.
h/ Based on marginal economic costs in mid-1983 prices with allowances (22%) for a three-year interval between tariff increases.

- the level of tariff on the thermal-based ERESA ICS and SCS, and the EELPA SCS be increased immediately to the level of direct costs per unit, implying about a 250% increase, and be further increased to the level of full costs within several years.

- that tariff levels on the EELPA ICS be increased by 30-40%, both to provide revenue for power system development and to balance somewhat the sharp tariff increase required on the smaller systems.

- that the flat tariff structure be applied with some time-of-day metering imposed on larger industrial consumers.

The highest priority in the short-term is to increase tariff levels because of important conservation and interfuel substitution measures that are dependent on correct economic pricing, and because of the urgent need to establish investment funds to finance the required power system expansion.

VII. INVESTMENT, MANPOWER AND INSTITUTIONAL REQUIREMENTS

7.1 This chapter covers the means by which policies, plans and investment programs recommended elsewhere in the report can be refined and implemented. The GOE has recently drafted a preliminary ten-year investment plan which will need further refining and priority setting. The mission's findings hopefully complement this preparatory phase, which should culminate in a final set of energy sector policies and plans sometime in 1984. The mission also reviewed the institutional arrangements necessary for efficient planning and resource allocation in the energy sector, as well as manpower training and development needs.

Energy Sector Investment

History and Plans

7.2 Since 1973, investment in the energy sector has been minimal. Total capital investment in the past three years has ranged from 9-12% of GDP, and investment that can be construed as directly relating to energy has been barely 5% of that. The main reason for such a low commitment of funds to the energy sector is that, since the commissioning of the Finchaa hydropower project in 1973, there has until now been no need to invest heavily in power generation expansion in the main EELPA ICS. Similarly, the commitment of funds to energy forestry has greatly lagged the awareness of need for investment. Recent and proposed energy sector investment levels are identified in Table 7.1. The level of commitment to the energy sector is greatly influenced by the mission's somewhat arbitrary definition of energy forestry, which by name was not to begin substantially until 1984. The data on future GOE plans for energy sector investment are unofficial and tentative, representing the sum of investments proposed by each energy-related government agency to the Central Planning and Supreme Council rather than an approved program of expenditure. It does reflect, however, the interests of the administration and reveals a heavy bias towards modern sector energy supply through investment in power and petroleum. The proposals advanced to the CPSC for energy amount to about B12 million for 1983/84-92/93 and may be compared with the total cost of proposals made of B42 billion, and with the CPSC proposed target for public expenditure for the decade of B32 billion. Hence, energy sector investment proposals are 28% of the total, and 37% of the proposed investment ceiling. Given less optimistic assumptions concerning GDP growth (4% vs. 7.5%) and likely investment levels (given major constraints on both domestic and foreign capital mobilization), it is the mission's view that total public sector investment is unlikely to exceed B20 billion (US$10 billion) for the decade and hence the funds available to the energy sector will be substantially reduced from the levels proposed, perhaps being of the order of three to four billion Birr, or about 40% of the expenditures now proposed to the CPSC, and 15-20% of the likely total domestic investment. The mission's estimate of investment requirements by subsector add up to a total that is within this range (Table 7.2).

Future Investment

7.3 A review of previous chapters indicates that the main requirements for future investment are to meet the needs for electric power, to greatly expand household fuel supplies, and to explore, develop, and improve the economy and efficiency of existing petroleum supply. The bulk of the capital required is for electric power generation and transmission. However, the growth in power demand, and in turn, the demand for investment capital in the power sector, is closely related to the investments in new industrial capacity which constitute 30% of the new power demand now forecast. Similarly, household power demand is somewhat influenced by the rate of interconnection, and hence by investments made in transmission and distribution during the period.

Table 7.1: Average Annual Investment by Energy Subsector
(Birr million)

	Historical (1979/80-1981/82)	Budget for (1982/83)	Preliminary 10-Year Plan (1983/4-1992/3)	Likely Scenario (1983-92/3)	(Percent)
Electric Power	32.1	42.5	528	182	51
Petroleum	12.6	9.2	126	85	22
Energy Forestry a/	27.0	36.0	75	77	21
Other	2.1	1.5	106	20	6
Total	73.8	89.2	835	364	
% of Total Public Investment b/	4.8	5.6	28	15-20	100

a/ Based on assumption that 25% of industrial plantations, 50% of protective plantations and 10% of community forestry is fuelwood investment, all at an average of 81,000/ha. Fuelwood plantation development per se begins in 1984.

b/ The 1983/84-1992/93 GDP growth rate implicity assumed is 4% average. Total capital investment as a proportion of GDP begins at 13% and rises to 20%.

Source: CPSC, ENEC and mission estimates.

It is clear, then, that the demand for power can be managed according to the rate at which new industrial, commercial, and residential loads are committed and that investment in power supply becomes very much a question of what the country can afford and of what is economically justifiable. This situation is rather different from that of household energy where for rural areas, and for low-income urban dwellers, an increased supply of cooking fuels is a basic need: even a matter of survival. In addition, the dynamic interplay between afforestation and agricultural production here demonstrated makes investment in rural energy supply fundamental to the well-being of the rural sector and essential to sustained social and economic development. These factors should be taken into account in setting priorities as well as the fact that prospective returns on rural woodlots and agroforestry are as high as 80% when the non-fuel benefits of trees are taken into account; this is higher than the returns anticipated from any other energy sector investment besides some small projects in industrial energy conservation.

7.4 The question of priority aside, the rate at which funds can be disbursed is an important determinant of the respective level of investment in power and petroleum supply, as well as in rural forestry, particularly in the short-term. EELPA and the EPC could, within the decade, identify and manage through to the commissioning stage major capital-intensive investment in virtual enclave projects such as pipelines, refineries and hydropower stations, disbursing two or three billion Birr in the process. However, the institutions, manpower and infrastructure do not yet exist to disburse funds at the same rate in forestry -- ranging from clumps of trees on peasant farms to 20,000 ha plantation blocks across the whole of Ethiopia. Recognizing this, the mission has had to draw a distinction between a "need" to invest about two billion Birr and a "capacity" to disburse, at best, 800 million Birr in afforestation in the next decade. In summary, the overall level of investment in the energy sector in Ethiopia is a function, on the one hand, of economic growth, the rate of private and public saving and the level of foreign assistance, and on the other hand, of the capacity of the administration and a much constrained private sector to cope with the required rate of growth. There is also a need for energy sector investment to be allocated a much greater share of public sector investment than ever before, and to recognize explicitly in determining this proportion the contribution to GDP to flow from stabilizing rural productivity. The mission believes it reasonable that energy sector investment should comprise up to 20% of total public sector investment. The relative priority of investment within the energy sector is a function of the pattern of future growth by subsector; the rational mix of energy forms to meet demand; and the rate at which it is possible, taking account of short term constraints on implementation capacity, to disburse funds in priority areas. The mission accords highest priority to investment in the supply of household energy of all kinds and in particular to rural agroforestry.

7.5 The mission's estimates of energy sector investment requirements during the decade are of the order of B360 million per year (average), or approximately B3.6 billion for the 1983/4-1992/3 period, with an estimated foreign exchange component of about 60%, or US$1 billion. More than half of the total will be in the power sector and about one-fifth in various forms of energy forestry. The mission's estimates are about half those of the EELPA ten-year plan proposals for power development but accord well with proposals for forestry investment by the respective agencies. Of course, with the exception of power, investments are heavily geared to the last years of the decade as the investment program gains momentum. A year-by-year schedule of investments by energy subsector is provided in Appendix 7.1. The single most important observation is that, despite the scale of the energy forestry program -- to plant 1.2 million ha in ten years -- it does not impose an intolerable financial burden, consuming only about 4% of the funds estimated to be available for public sector investment. A summary of the key investments foreseen by priority class is provided in Table 7.2.

Table 7.2: MAJOR NEW INVESTMENTS BY PRIORITY CLASS

Project or Program	Estimated Cost (million 1983 Birr)
High Priority	
Short-term (1983-86)	
Household Fuels	
Rural Energy Forestry and Housing	364
Peri-urban Forestry	403
Charcoal, crop residues and cooking efficiency	152
Addis Ababa plantation upgrading	36
Power Sector	
Finchaa Hydropower Generation (for 1988/9)	47
Diesel Displacement (small hydro, and at Asmara by fuel oil)	54
Transmission, Phase I	174
Petroleum	
Natural gas reserve confirmation (CALUB 2/3)	17
Conservation and Interfuel substitution	38
Longer-term (1987-92)	
Power Sector	
Next major project (Tis Abai, Gibe Daka, Aleltu, Chemoga Yeda, Natural gas)	695
Transmission, Phase II	200
Diesel Displacement (with small hydropower)	40
Petroleum	
Gas or product pipelines a/	642
Detailed gas utilization study and delivery system design	10
Lower Priority	
Longer-Term (1987 and beyond)	
Power Sector	
Certain transmission projects	70
Geothermal power (Northern region)	50
State farm power systems (gasifiers)	10
Petroleum Sector	
Refinery modernization	135
Household Sector	
Rural cooking efficiency program	10
Other (Malka Wakana and numerous smaller investments, mostly power sector)	493
Total	3,640

a/ Depending on the outcome of further detailed studies on the market for natural gas from the Ogaden and transport options for the Addis Ababa-Asseb transport corridor.

Source: Mission estimates.

Sources of Finance

7.6 The investment program outlined herein can only be funded by a massive mobilization of local and foreign resources. Unless local funds are generated through correct pricing and appropriate tax measures, it will be extremely difficult to provide sufficient counterpart funds to attract foreign financial resources. The onus is clearly on the Government to indicate its preparedness to embark on a self-help program by generating the required local funds through the implementation of recommendations made elsewhere in this report regarding price increases for petroleum products and electricity, and through the levying of adequate resource taxes in commercial energy forestry and the like. Grant aid has averaged US$62 million a year, or only $2 per capita, for the last three years, making Ethiopia one of the lowest recipients of official development assistance in the world. By comparison, in 1981/82 aid transfers amounted to US$20 per capita for the rest of Africa. During this period, aid to the energy sector has been received from the EEC, UNDP, Sweden, Italy, and the Soviet Union. The EEC and UNDP co-financed the major geothermal exploration project and the latter has funded design studies for small hydropower as well as policy and planning studies. Sweden funds training programs in forestry, implicitly including energy forestry, and Italy has funded a number of research and resource evaluation studies including a major nationwide sample survey of household energy use, still being processed. The Soviet Union has financed the Malka Wakana Hydropower project of 150 MW (about US$150 million) and a US$20 million petroleum exploration project. The mission estimates the annual requirement for foreign exchange to be about US$220 million for the energy sector investment program alone: three times more than the total development assistance of recent years. In addition to mobilizing local financial resources, there is a need for very efficient coordination first in establishing priorities within the investment program; and, second, in project preparation and presentation. Similarly, the need for institutional strengthening to cope with the policy, analysis and coordination aspects of defining and delivering the energy sector investment program highlights the discussion on institutional arrangements later in this chapter.

Manpower Issues

7.7 Manpower training and development issues in the energy sector are made very complex by the diversity of energy sources and the inherent differences in skills required for their management. The mission concentrated on the manpower issues raised in consideration of a massive increase in the rate of afforestation, and dealt to a lesser extent with the manpower needs of the petroleum and power subsectors. The special training requirements of many unique components of major programs such as charcoal and briquette production, or of small though important programs such as ethanol, have not been examined, though must now be considered by the GOE as part of project or program preparation.

Manpower for Energy Forestry

7.8 Skilled manpower availability is seen as one of the key constraints to implementing the desired forestry program. Hence, the forestry program recommended is to some extent the outcome of a review of skill-training capability. The estimated manpower requirements of the achievable energy forestry program for 1983-92 are 120 graduates, 650 diploma holders and 1,560 certificate holders. These can be supplied over the decade at a cost of 13.5 million Birr, including a foreign exchange requirement of US$4.1 million. The target programs, agencies and timing of the increased output at each level are depicted in Table 7.2. The current source of supply for new graduates is training at overseas universities at a rate of five per year. An increased supply of candidates can come from existing secondary education and vocational learning in Ethiopia. At best, these graduates would be available in 1987. Diploma holders come now from the Wondo Genet Training College and the training programs there should be expanded. However, another 30 graduates per year should be able to be produced from ongoing agricultural training courses such as in Jimma. Certificate holders are the product of special six month training courses at institutions such as the Farmers Training Centers. Considerable improvements can be made in the present organization of this training, partly by expanding the level of training, and by more fully involving the Wondo Genet training college. Present resources facilitate the training of only 200 candidates per year. In summary, immediate steps should be taken to:

(a) increase graduate training overseas from 5 to 20 students per year;

(b) increase training at diploma level from 60 to 90 students per year;

(c) rationalize and expand the training of certificate holders from 100 to 400 per year.

Apart from the quite essential Swedish (SIDA) funding for the Community Forestry College (B3.7 million), no capital outlay will be required to implement this training program, but additional training and technical assistance, especially with the agro-forestry component, will certainly be needed. In this respect, every effort is required to ensure full cooperation and ongoing coordination between the MOA and FAWCDA in respect of the rates to be assigned to them in the implementation of the rural energy forestry program (see Chapter II).

Manpower for Electric Power Development

7.9 EELPA have forecast a growth rate of 5.8% p.a. for the decade in their own staff which presently number about 5,300. Skilled staff are required in all categories: managerial, supervisory, technical and operational, and although an EELPA training institute has been in operation for some time, the main constraint has been the establishment of a manpower management system to ensure that training is well matched to needs.

For example, 120 basic technician trainees are graduated each year, with expansion planned to provide 2,300 over the decade compared with a maximum requirement of 800-900. Similarly, there are plans to upgrade the institute to a college for electric and electronic technicians though the market for these skills is hard to identify. The mission favors, instead, reorienting the training institute to cater more to in-house training; and provide refresher and skill upgrading courses for the present staff. Rather than train from the beginning in the basic technical skills it should be possible for EELPA to select new personnel on the basis of previous basic training and experience, and to focus just on those skills needed for its own particular operations. There is a need for an in-depth manpower assessment, leading, among other things, to a detailed staff development program and a clear determination of the responsibilities of the existing EELPA Manpower Planning Unit and the EELPA Training Institute.

Manpower for Petroleum Supply

7.10 The present staff of the EPC number about 930 and further growth is dependent upon the expansion and upgrading of refinery requirements and the corporation's particular responsibilities in the petroleum sector. Since the mission does not foresee the construction of a second refinery during the next decade, the focus of manpower training must be on the existing refinery at Asseb where there are high vacancy rates for general and technical managers, specialist engineers, secretary-typists, and financial personnel. There is a special problem of living and working in Asseb where temperatures frequently reach 40°C and amenities are few. The EPC has attempted to provide incentives through increased salaries though without noticeable success. Clearly these incentives will have to be increased and should include attractive means of upgrading professional skills with a wider and more appropriate selection of on-the-job training programs in the refineries of other countries, based possibly on an exchange scheme.

Table 7.3: TARGET ACTIVITY, TIMING AND COST OF SKILL TRAINING REQUIRED FOR ACHIEVABLE ENERGY FORESTRY PROGRAMME a/

	Graduate			Diploma			Certificate		
	1982-87	1987-92	Total	1982-87	1987-92	Total	1982-87	1987-92	Total
Peri-urban	36	21	57	67	59	126	180	510	690
Rural	3	6	9	19	38	57	227	459	686
FAWCDA (State Forests)	15	19	34	65	89	154	69	81	150
SWCD	12	10	22	116	93	209	7	14	21
Other	6	5	11	58	46	104	4	7	11
Total	72	61	133	325	325	650	487	1,071	1,558
				(million Birr)					
Estimated Costs	4.61	3.90	8.51	1.95	1.93	3.88	0.33	0.73	1.06

a/ "Achievable" program includes 960,000 ha equivalent in agroforestry and rural woodlots and 195,000 ha of peri-urban and state farm plantations.

Source: Mission estimates.

The existing training department has no professional staff despite many attempts at recruitment. Again, incentives should be increased to the level required to fill two of these posts and a training workshop should be established. The training unit should not only conduct in-plant refresher and new skill training but should also organize supervising and middle-management training, and be in charge of the scholarship program. Foreign assistance could be sought to equip the workshop and to supply teaching materials.

Institutional Arrangements For Energy Planning and Management

7.11 The Central Planning Supreme Council has been preparing a set of development objectives for all the economic sectors, including energy, for each of the short-term plan periods. The Council also has been setting up development strategies which include corresponding investment programs for priority projects. These planning activities are carried out in constant consultation and collaboration with the implementing agencies. In this way the Central Planning Supreme Council plays a central role in coordinating and setting priorities in the energy sector. Energy investment priorities already have been identified within the framework of the ten-year indicative plan. However, the current institutional arrangements are not optimal for effective energy planning. This fact is known to the GOE which has commissioned the Ethiopian National Energy Committee (ENEC) through the Ministry of Mines and Energy to propose, by mid-1983, an alternative arrangement. The present arrangement places the Ministry of Energy and Mines as the lead agency in policy formation and development planning for the sector with ENEC initially operating as a planning secretariat reporting to the minister. ENEC is provided with a general secretary and staff. The energy parastatals, including EELPA (with ERESA), EPC, and the agencies established for geothermal and petroleum exploration variously report to the Permanent Secretary of the Ministry or to the Minister himself. ENEC is technically comprised of the permanent heads of all of these agencies plus other energy-related ministries meeting under the chairmanship of the Minister or the Permanent Secretary for Mines and Energy. However, since its formation in 1978, this committee has met only a few times, which is indicative of the lack of meaningful cooperation between the implementing agencies and the ENEC. In practice, the energy production and distribution agencies plan their investment programs independently of ENEC and usually address and deliver policy guidelines for their subsectors directly to the Central Planning and Supreme Council (CPSC), in parallel to ENEC, taking little heed of any guidance ENEC offers. The CPSC is neither well-equiped to judge the relative merits of each subsector proposal nor to undertake independent analyses to verify either conclusions drawn or the macroeconomic impact of major projects or programs. The result is that analyses to determine the relative priorities for investment in the energy sector are minimal; that supply and demand forecasting and resource evaluation is superficial, uncoordinated and contradictory; and that monitoring and integration of sector-wide trends in consumption and costs of production and delivery of each fuel type are inadequate.

7.12 There are a number of choices available to the GOE, all of which should be addressed first in relation to specified goals and objectives. Final decisions to do with energy pricing, other major policies, and investment will be made ultimately at cabinet level. However, the energy sector proposals before the cabinet must be well supported with analysis, and must reflect the available options and their relative costs. The matters to be resolved are to do with which agency performs this task and what kinds of tools and authority it needs to be effective. Presently it is more the status and discipline of ENEC that is deficient than the statutory framework in which it is placed. There is a need for a small, powerful and talented secretariat, perhaps with direct responsibility to the cabinet, but whether this resides within the Ministry or is within an office of the cabinet, or linked to CPSC, is an open question. Furthermore, it is more important for this secretariat to be in a position of influence in the cabinet than for it to have any direct authority over the various energy agencies and parastatals, whose responsibility to carry out operations and execute prospects should be as independent as possible within broad policy and investment guidelines. There is a need for the authority to command and to receive information of all kinds from the parastatals, and a need for the resources to gather and process such information in the required time. However, the management of parastatals must be independant, answering through their respective boards to the parent ministries in relation to agreed goals, objectives and principles of operation in respect of which the energy secretariat would be regularly consulted. The status of the secretariat should develop through its position of influence, and out of respect for its independence, objectivity and analytical skill. If consultation in the form of a board or committee is seen as desirable, it should be to keep the secretariat abreast of the needs and opinions of consumer groups within the community influenced by, and influencial in determining, the sector plans and policies it formulates and proposes to the cabinet. Here, the mission favors a small group composed of independent adivsors rather than permanent secretaries or heads of parastatal authorities in respect of whom concern might only naturally arise regarding objectivity of judgment.

The Role of the Secretariat

7.13 It is possible to illustrate by example the role of an energy secretariat. Take the case of preparation of demand forecasts and planning in the power sector. A key function of an energy secretariat would be to provide EELPA with guidelines on the current economical and socially justifiable uses of electricity in each end-use sector, as well as review power demand forecasts and least-cost development proposals prepared by EELPA or its consultants. For example, in the present market the secretariat would be advising on the economic and strategic place of electric boilers and electric cookers. The secretariat also should be readily able to make an objective well-documented assessment of the relative priority within the energy sector of the EPC's refinery and pipeline proposals. At no time, however, should there be any confusion about the respective roles of existing agencies (such as EPC, EELPA, FAWCDA, MOE) and an energy secretariat: executing agencies should implement according to agreed priorities and plans and the secretariat should monitor, integrate, analyze and advise.

Production and Marketing of Biomass Fuels

7.14 While the responsibilities for electricity production and petroleum supply are clear and established, the responsibility for the production, distribution and marketing of biomass fuels is less so and the institutional arrangements are embryonic. The supply and marketing of firewood and charcoal recently have been made the responsibility of the Fuelwood and Charcoal Marketing Corporation (FCMC) of FAWCDA. At present, FCMC supplies 5-10% of the charcoal and 20-30% of the firewood to Addis Ababa. While its current activity is mostly confined to 50km around Addis Ababa, its jurisdiction is national. The FCMC's pronounced objective is to supply the whole of the urban market within ten years. During the late 1970s the supply of woodfuels deteriorated rapidly, accompanied by a sharp escalation in the open market price of firewood and charcoal. The government was concerned that a few entrepeneurs might illegitimately be exploiting this situation to increase their profits and that charcoal production in savannah lands was responsible for major deforestation. Hence, in 1980, private supply of charcoal by private entrepreneurs was made illegal except if carried by donkey. Now, there are at least 2,500 donkeys carrying charcoal (besides about 10,000 carrying firewood) to the city on market days plus about 1,000 trucks and cars carrying from 1 to 15 sacks in addition to their main cargo, as well as large numbers of individuals. Some 90% of the total Addis Ababa supply of charcoal is transported in this way. Similarily, firewood can only legally be trucked to the city by FAWCDA, though it is clear from survey results that many non-FAWCDA supplies exist. The FCMC is intent on marketing charcoal and firewood directly to consumers through its own depots, of which it has 34 in Addis Ababa and nine in surrounding towns and cities. In the longer-term there is an obligation under government proclamation to retail these products through Kebele stores just as are sugar, tea, matches and the like now.

7.15 While the FCMC has little difficulty marketing its firewood, its charcoal, which is sold only in 40 kg average bags, is difficult to sell, despite being one-third to one-half the price of charcoal traded on the open market. FAWCDA and the mission agreed that this is due to a combination of factors including parcel size, depot opening times, charcoal quality, perception of the difficulty of transactions, and so on. However, the real question is whether or not FAWCDA should be involved in marketing these products at any level. The appropriate response to the perceived situation in which a few private entrepreneurs hold a large proportion of the woodfuels market, and generate possibly huge profits, would have been to increase competition rather than to attempt complete government takeover and regulation. It is likely that the restrictions on private supply have worked to increase the cost of the woodfuels, which still reach the market in abundance from private sources, due to inefficient use of transportation and to premiums charged to offset the risks in illegally supplying the market. Furthermore, with the proposed huge increase in charcoal supplies, the production and supply of crop residue briquettes, and a much increased supply of wood fuel from peri-urban plantations, the roles and responsibilities of each agency concerned need to be carefully reevaluated. The mission sees a number of options open to the government though all have in common:

(a) the need for government agencies to keep the retail marketing of woodfuels open to, and preferably in the hands of, private entrepreneurs to ensure adequate and efficient distribution; and

(b) the need to maximize the involvement of the private sector in all stages of production, transportation, and wholesaling of biomass fuels, so as to ensure the maximum rate of resource mobilization.

It is acknowledged that FAWCDA and the Ministry of State Farms have a legitimate need to closely manage, and possibly to undertake the conversion of forest logging and crop residues respectively. However, from the edge of the forest, or from the farm gate to the market, unhindered private sector involvement is desirable. Similarly, with respect to harvesting and marketing the product of peri-urban plantations, small-holder entrepeneurs should be included. It is noteworthy that at least 20,000 people are employed regularly in the transport phase alone of woodfuel supply to Addis Ababa. It will prove exceedingly difficult and expensive to duplicate this network of supply and delivery to every tiny marketplace. The GOE could consider instead, a wholesale facility for the new biomass fuels generated by either itself or major contractors, whereby traders or retailers at all levels could bid for fuels of stated quality for retailing throughout the city. Here, the emphasis should be on strengthening marketing through regulation of quality and package size so that the market is better able to set fair prices.

Coordination in the Petroleum Sector

7.16 The EPC has responsibility only for petroleum refining and the regulation of additional supply through the major oil companies. Exploration for petroleum is ostensibly the responsibility of the Ethiopian Institute of Geological Survey (EIGS) which, in turn, is part of the Ministry of Mines and Energy. Within the EIGS there are three exploration projects operating quite independently: the oil and gas project which oversees the joint Ethiopian-Soviet oil exploration program (SPEE), the Bank-funded petroleum exploration and production project; and the UNDP/ECE geothermal exploration project. The SPEE coordinator reports directly to the Minister of Mines and Energy first. This rather fragmented arrangement for exploration does not appear conducive to rational resource evaluation and development, and consideration should be given to its rationalization under one program management. Second, it is obvious that if natural gas is developed or oil is discovered, the entire planning for petroleum refining and supply will be greatly altered. It is preferable to have the rather dynamic developments in the petroleum sector reviewed and coordinated by one organization. The mission considers that one option is to expand the charter of the EPC, giving it full responsibility for investigations towards the production of natural gas, for local use. This rearrangement would require a substantial expansion in the professional staffing of the EPC, including additional executives and economists, lawyers and production managers, none of which are being trained as part of the existing IDA petroleum exploration promotion project. The implications of maintaining the present institutional arrangements in the petroleum sector are that refinery and petroleum product transport, planning and investment would not adequately take account of the prospects for production and local use of known and prospective petroleum resources, leading possibly to inefficient use of scarce manpower resources and to expensive duplication of, or underutilization of petroleum subsector infrastructures.

ETHIOPIA: ENERGY BALANCES, 1982 (10^3 x TOE)

	Primary Energy						Secondary Energy											
	Traditional			Non-Traditional					Petroleum Products									
	Fuel-wood	Dung	Straw	Bagasse	Hydro	Crude Oil	Char-coal	Electri-city	LPG	Gasoline	Avgas	Jetfuel	Kerosene	Diesel Oil	Fuel Oil	Others	Total	Line Total
1-Gross Supply	3403.3	2539.2	1803.6	58.6	187.3	738.4				14.1	5.8	24.7	11.2	92.8	8.9		157.5	8877.9
1.1 Production	3403.3	2539.2	1803.6	58.6	187.3													
1.2 Imports						773.3				9.9	9.0	52.2	11.2	93.5			175.8	
1.3 Primary Exports																		
1.4 Stock Changes						44.9				4.2	(3.2)	(27.5)		0.7	8.9		(18.3)	
Conversion:																		
2-Petroleum Refinining						(702.8)			5.4	108.3		57.5	0.3	212.9	303.2	15.2		0.0
3-Charcoal Production	(101.8)						101.8											0.0
4-Elect. Power Generation				(11.7)	(187.3)			267.9						(48.8)	(20.1)			0.0
5-Conversion Losses	(343.8)			(17.6)		(25.6)		(195.5)										582.5
6-Power T and D Losses								(8.5)										8.5
7-Non-Energy Use																15.2		15.2
Net Supply	2957.7	2539.2	1803.6	29.3			101.8	63.5	5.4	122.4	5.8	82.2	11.5	256.9	292.0	0.0	776.2	8271.3
8-Secondary Exports															213.5		213.5	213.5
9-Bunker Sales												30.1		2.9	9.1		42.1	42.1
10-Domestic Consumption	2957.7	2539.2	1803.6	29.3			101.8	63.5	5.4	122.4	5.8	52.1	11.5	254.0	69.4		520.6	8015.7
10.1 Industry a/				29.3			0.8	35.0	0.2				0.2	34.3	67.2		101.9	167.0
10.2 Transport										122.4	5.8	52.1		168.8			349.1	349.1
10.3 Agriculture								1.1						31.0			31.0	32.1
10.4 Households	2957.7	2539.2	1803.6				101.0	16.3	5.0				11.2	1.6			17.8	7435.6
10.5 Commercial b/								11.1	0.2				0.1	18.3	2.2		20.8	31.9

a/ - Including construction.
b/ - Including Government.

Source: Mission estimates

Summary of Methodology for Demand Forecasting in the Ethiopian Energy Assessment

1. A microsectoral, fuel by fuel, approach was used for demand forecasting whereby the greatest level of detail possible was gathered on the present and likely future patterns of energy use in each major economic activity and manipulated and compiled progressively to provide a composite picture of energy use at a given future date. Only in subsectors where insufficient data is available is there a reversion in forecasting either to using conventional GDP-based elasticities or to the use of more global trend data. In practice, the analysis is more rigorous for the major petroleum and electricity consuming sectors such as industry where investments underway, committed, or proposed have been closely reviewed, leading to an independent estimate of the likely commissioning schedule for new industrial capacity under each economic growth scenario.

2. General macro-economic parameters assumed for the projection of energy demand are as follows [adopted from World Bank (CEM, 1983)]:

(a) GDP growth: 4% p.a.
(b) Agriculture sector, 3.7% p.a.; industry, 5.4% p.a.; services sector 3.7% p.a.
(c) Exports are projected at 7.5% per annum in real terms.
(d) Imports are projected at 4.7% p.a.

3. The development of the Business as Usual Scenario (BAU) is based on the following treatment of individual fuels:

Diesel

(a) Diesel use in power generation is to remain constant due to a balance between growth in the SCS and private sector systems, interconnection with the EELPA ICS, and the complete conversion to fuel oil firing in the ERESA ICS.
(b) Diesel in industry will grow at the rate of industrial expansion forecast, about 5.4% p.a.
(c) Diesel in transportation is to grow in proportion to fleet size: 7% p.a.

Gasoline/Jetfuel/Avgas

Gasoline is assumed to grow at 5% and c.f. 4% between 1977-82. Jetfuel and Avgas are assumed to grow at 6% p.a. based on information provided by Ethiopian Air Lines.

Kerosene and LPG

Growth is prevented due to restriction on imports of both products and by the present operation of the refinery.

Fuel Oil

Growth is estimated for each major factory now committed or planned and, in the mission's view, likely to be operational in the period. Cement and textile plants comprise 93% of new demand by 1992. Annual growth rate estimated is 9.2%

Electricity

Demand growth and consumption are projected in Annex 3.2.

Traditional biomass fuels

These are projected so as to maintain the supply of 2kg of air-dry wood equivalent per capita per day, but with no growth in forest resources, hence additional fuel supplies will come from agriculture in the form of crop residues and dung.

4. The development of the "Accelerated" scenario is based for petroleum end use on subtracting all the interfuel substitution and conservation measures recommended in industry for fuel oil and in transport for diesel (see Chapter IV) from the BAU scenario total. Additional LPG and kerosene supplies (55,000 toe total) are then added as recommended to household fuel consumption. For biomass fuels for cooking, all new production from forests and new biomass fuel sources (see chapter II Table 2.3) recommended by the mission are included and act to reduce the consumption of the less desirable agricultural fuels of dung and crop residues.

ETHIOPIA: ENERGY BALANCES UNDER BUSINESS AS USUAL SCENARIO, 1992 (10^3 x TOE)

	Primary Energy						Secondary Energy											
	Traditional			Non-Traditional					Petroleum Product									
	Fuel-wood	Dung	Residue	Bagasse	Hydro	Crude Oil	Char-coal	Electri-city	LPG	Gasoline	Avgas	Jetfuel	Kerosene	Diesel Oil	Fuel Oil	Others	Total	Line Total
1-Gross Supply	3403.3	3981.7	2824.7	117.3	577.0	739.6				91.1	10.4	89.7		434.8			626.0	12269.6
1.1 Production	3403.3	3981.7	2824.7	117.3	577.0													
1.2 Imports						739.6				91.1	10.4	89.7		434.8			626.0	
1.3 Primary Exports																		
1.4 Stock Changes																		
Conversion:																		
2-Petroleum Refinining						(714.0)			5.4	108.3		57.5	11.5	212.9	303.2	15.2		0.0
3-Charcoal Production	(101.8)						101.8											0.0
4-Elect. Power Generation				(11.7)	(577.0)			649.1						(48.8)	(20.1)			0.0
5-Conversion Losses	(343.8)			(17.6)		(25.6)		471.6										867.1
6-Power T and D Losses								(22.6)										22.6
7-Non-Energy Use																15.2		15.2
Net Supply	2957.7	3981.7	2824.7	88.0			101.8	154.9	5.4	199.4	10.4	147.2	11.5	598.9	283.1	0.0	1310.9	11364.7
8-Secondary Exports															102.3		102.3	102.3
9-Bunker Sales												53.9		4.3	13.5		71.7	71.7
10-Domestic Consumption	2957.7	3981.7	2824.7	88.0			101.8	154.9	5.4	199.4	10.4	93.3	11.5	594.6	167.3		1081.9	11190.7
10.1 Industry a/				88.0			0.8	97.6	0.2				0.2	58.0	165.1		223.5	351.2
10.2 Transport										199.4	10.4	93.3		332.1			635.2	635.2
10.3 Agriculture								2.2						176.5			176.5	178.7
10.4 Households	2957.7	3981.7	2824.7				101.0	41.8	5.0				11.2	2.1			18.3	9925.2
10.5 Commercial b/								13.3	0.2				0.1	26.3	2.2		28.8	42.1

a/ - Including construction.
b/ - Including Government.

Source: Mission estimates.

Ethiopia: Energy Balances Under Accelerated Scenario, 1992 (10^3 X TOE)

	Primary Energy						Secondary Energy															
	Traditional			Non-Traditional					Petroleum Product									New Fuels				
	Fuel-wood	Dung	Residue	Bagasse	Hydro	Crude Oil	Char-coal	Electri-city	LPG	Gasoline	Avgas	Jetfuel	Kerosene	Diesel Oil	Fuel Oil	Others	Total	Fuelwood	Bio-mass	Ethanol	Solar	Line Total
1-Gross Supply	3403.3	2867.9	2014.8	132.3	577.0	794.6				67.7	10.4	89.7		388.0			555.8	1179.5	547.3	23.3	4.1	12,099.9
1.1 Production	3403.3	2867.9	2014.8	132.3	577.0													1179.5	547.3	23.3	4.1	
1.2 Imports						794.6				67.7	10.4	89.7		388.0			555.8					
1.3 Primary Exports																						
1.4 Stock Changes																						
Conversion:																						
2-Petroleum Refinining						(769.0)			12.5	108.3		57.5	59.4	212.9	303.2	15.2						0.0
3-Charcoal Production	(101.8)						101.8															0.0
4-Elect. Power Generation				(11.7)	(577.0)			649.1						(37.4)	(23.0)							0.0
5-Conversion Losses	(343.8)			(17.6)		(25.6)		(471.6)														858.6
6-Power T and D Losses								(22.6)														22.6
7-Non-Energy Use																15.2						15.2
Net Supply	2957.7	2867.9	2014.8	103.0			101.8	154.9	12.5	176.0	10.4	147.2	59.4	563.5	280.2	0.0	1249.2	1179.5	547.3	23.3	4.1	11,203.5
8-Secondary Exports															125.0		125.0					125.5
9-Bunker Sales												53.9		4.3	13.5		71.7					71.7
10-Domestic Consumption	2957.7	2867.9	2014.8	103.0			101.8	154.9	12.5	176.0	10.4	93.3	59.4	559.2	141.7		1052.5	1179.5	547.3	23.3	4.1	11,006.8
10.1 Industry a/				103.0			0.8	97.6	0.2				0.2	58.0	139.5		197.9				1.4	400.7
10.2 Transport										176.0	10.4	93.3		296.7			576.4			23.3		599.7
10.3 Agriculture								2.2						176.5			176.5					178.7
10.4 Households	2957.7	2867.9	2014.8				101.0	41.8	12.1				59.1	2.1			73.3	1179.5	547.3		2.7	9,786.0
10.5 Commercial b/								13.3	0.2				0.1	26.3	2.2		28.8					42.1

a/ - Including construction.
b/ - Including Government.

Source: Mission estimates.

Annex 2.1

FOREST RESOURCES
(natural forest)

		ha
A.	**Natural Forest Type**	
	1. Closed high forest	
	a. Coniferous	52,300
	b. Montane mixed broadleaved/coniferous	158,500
	c. Montane broadleaved	1,863,200
	Total closed high forest	2,345,100
	2. Disturbed forest	
	a. Coniferous	7,300
	b. Montane mixed broadleaved/coniferous	48,300
	c. Montane mixed broadleaved	285,300
	d. Lowland Broadleaved	61,300
	Total disturbed forest	402,200
	3. Woodland	357,000
	4. Bamboo thicket (Arundinaria)	112,700
	5. Thicket and low woodland	121,500
	6. Lowland bamboo (Oxytenanthera)	113,400
	Subtotal	3,451,900
B.	**Savannahland** (Acacia sp.)	20,000,000
C.	**Planted Forests**	
	1. Urban plantations (of which Addis Ababa has 20,000 ha)	80,000
	2. State forest plantations	120,000
	3. Community Forest Plantations	200,000
	Subtotal	400,000

LOGGING WASTE PLUS NON-COMMERCIAL SPECIES AVAILABLE FOR ENERGY 1981/82
(all solid m^3)

Region	Forest	Log supply	Logs	Logging area	Biomass	Available for energy	Distance to Addis Ababa,		Transport cost
		(m^3)	(m^3/ha)	(ha)	(m^3/ha)	(m^3)	(Gravel/Asphalt)		(Birr/m^3)
Arsi	Munessa	14,000	40	350	250	73,500	30	220	30.20
	Arba Gugu	7,000	50	140	300	35,000	70	190	26.10
Bale	Adaba-Dadola	17,400	30	580	250	127,600	130	310	66.60
Hararghe	Din Din	6,000	40	150	200	24,000	70	200	40.40
	Chercher	2,600	30	85	200	14,500	120	230	53.80
Kaffa	Tiro-Folla	24,700	50	495 c/	300	86,600	70	300	40.40
	Limo-Boter	4,100	30	135	150	16,200	80	120	31.30
	Bebeka a/	17,400	-	-	-	-	-	-	-
Shoa	Jibat	2,500	40	65	250	13,700	60	140	30.30
	Addis Ababa	28,000 b/	-	-	-	-	-	-	-
Sidamo	Kebre-Mengist	16,300	30	540	250	118,800	160	340	76.30
	Magoda	3,800	60	65	300	15,600	10	490	69.10
Wollega	Gorgo-Woto	500	40	15	250	3,200	50	330	54.60
Total/Average		144,300 d/	40	2,620	250	528,700	98.7	282.7	53.30

a/ Clearing for coffee plantation.
b/ Eucalyptus around Addis Ababa for chipboard and hardboard.
c/ 50% selective cutting.
d/ Excluding Addis Ababa and Bebeka 98,900 m^3.

For the future, the following scenario can be envisaged:

1. According to the FAWCDA 10-year plan, logging areas will be increased from the present 2,600 ha to 4,800 ha by 1987/88 and to 7,700 ha by 1992/93.

2. Utilization will improve from $40m^3$/ha today to $60m^3$ by 1987/88 and to $80m^3$/ha in 1992/93 by using more of the at present non-commercial species and also variable log lengths.

3. Selective cutting will increase from 20% today to 30% by 1987 (77 and to 40% in 1992/93. Available "waste" will be the same, $100m^3$/ha.

4. Average total stand volume will be the same as today, $250m^3$/ha.

With these assumptions, the following calculation can be made:

1987/88: "Waste" from selective cuttings:	
0.30 x 4,800 x 100 =	144,000 m^3
"Waste" from clearfellings:	
0.70 x 4,800 x 190 =	638,400 m^3
Total	782,400 m^3

1992/93: "Waste" from selective cuttings:	
0.40 x 7,700 x 100 =	308,000 m^3
"Waste" from clearfellings:	
0.60 x 7,700 x 170 =	785,400 m^3
Total	1,093,400 m^3

Annex 2.3

AN ILLUSTRATION OF THE PLACE OF CARBONIZATION IN A PROGRAM OF UPGRADED FOREST MANAGEMENT

Month	Year 1												Year 2												REMARKS
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Operation																									
Selection of logging area Site inspection	—																								
Decision on silviculture treatment. Selective clearfelling	—																								
Marking of trees. Calculations of volume, area, seedlings needed species etc.		—																							
Planning of logging tracts, loading points, etc. Roads?		—	—																						
Planning of labor, tools, trucks, transportation, hiring, same			—	—																					
Building of tracks, landings, improvement of roads				—	—	—																			
Logging of timber									—	—	—	—	—	—	—	—	—	—							
Cutting of fuelwood											—	—	—	—	—	—	—	—							
Charcoaling												—	—	—	—	—	—	—	—						
Transportation										—	—	—	—	—	—	—	—	—	—						
Measuring of logs										—	—	—	—	—	—	—	—	—	—						
Nursery work									—	—	—	—	—	—	—	—	—	—	—	—					
Site clearing, pitting												—	—	—	—	—	—	—	—	—					
Transport of seedlings Planting																—	—	—	—	—	—				
Weeding																									
Replanting, weeding																									July/August, year 3

Annex 2.4
Page 1 of 2

SAWMILL PRODUCTION, AVAILABLE WASTE, 1982/83
(volumes in solid m^3)

Location	Number of mills	Capacity log input	Log allocation	Production		
				Lumber	Slabs	Dust
Arsi						
Arba Gugu	2	8,100	7,500	4,500	1,900	1,100
Bale						
Adaba	1	3,600	2,000	1,000	500	400
Hararghe						
Asba Tefari	2	6,700	3,000	1,400	900	600
Din Din	4	20,200	10,000	4,700	3,000	2,000
Kaffa						
Jimma	6	32,700	24,600	12,200	6,800	4,200
Botor Becho	1	4,500	3,100	1,700	900	700
Bebeka	1	8,400	8,400	4,800	4,200	2,400
Shoa						
Addis Ababa	6	26,500	16,100	7,700	4,600	8,000
Ambo	1	4,500	2,500	1,000	900	500
Arsi Negelle + Shashamane	5	26,100	12,800	5,900	3,800	2,600
Sidamo						
Awassa	1	5,000	3,000	1,200	1,100	600
Kebre Mengist + Wodera	7	51,900	29,200	1,400	7,200	5,800
Hagare Mariam	1	11,200	5,000	2,500	1,250	1,000
Wollega						
Gimbi	1	4,500	2,000	1,000	500	400
Total/Average	39	213,900	129,200	63,600	37,550	25,300

The following scenario is envisaged for the future:

1. Demand of lumber will increase as forecasted by Ethiopian Wood Working Corporation (EWWC) i.e. to 235,000 m^3 in 1987/88 and to 336,000 m^3 in 1992/93.

2. The sawmill industry will expand accordingly (also as per EWWC plan).

3. Log supply will increase according to the FAWCDA 10-year plan, i.e. to 288,000 m^3 in 1987/88 and to 616,000 m^3 in 1992/93.

4. Utilization of logs will increase to 60 m^3/ha in 1987/88 and to 80 m^3/ha in 1992/93.

5. Recovery rates will improve to average 50% in 1987/88 and to 60% in 1992/93. Waste will decrease accordingly.

With these assumptions, available waste will be:

	1987/88	1992/93
Slabs	72,000 m^3	123,200 m^3
Sawdust	56,600 m^3	92,400 m^3
Total	129,600 m^3	215,600 m^3

OPTIMUM SCHEDULE OF NEW BIOMASS ENERGY PRODUCTION AND SUPPLY TO SOUTHERN REGION
(i.e., all provinces besides Eritrea, Tigrai, Wollo and Gondar)

	THOUSAND TONNES OF WOOD EQUIVALENT*									Actual Weight of the Specified Fuel in Use at 1992 ('000)
	1984	1985	1986	1987	1988	1989	1990	1991	1992	
A. New Biomass Sources										
1. Charcoal										
(i) Logging residues	—	25	50	50	400	400	450	500	535	143
(ii) State Farms — Bebeka	53	107	214	427	—	—	—	—	—	17
Other	10	15	20	25	30	35	40	60	64	
(iii) Sawmills	—	10	20	30	40	50	50	55	60	16
SUBTOTAL	63	157	304	532	470	485	540	615	659	
2. Coffee Residue	—	10	20	40	80	120	160	180	191	150
3. Cotton Residues	—	10	20	40	80	150	200	250	334	239
4. Cereal Straw Residues	—	10	20	40	60	80	100	120	151	108
5. Cereal Stover Residues	—		10	20	40	80	160	200	255	211
6. Bagasse	—	—	—	—	—	—	—	—	60	43
7. Sawdust Briquettes	—	—	3	6	9	12	14	20	29	20
SUBTOTAL	—	30	73	146	269	442	684	770	1020	
TOTAL NEW SOURCES	63	187	377	678	739	927	1224	1385	1679	
B. Addis Ababa Plantation Options										
1. Addis Peri-urban Fuelwood: Plantation area					1,400ha	2,100ha	2,100ha	5,000ha	5,000ha	
Production '000 twe									90	
2. Addis Enrichment Planting: Plantation area										
Production '000 twe				1,000ha	1,000ha	2,000ha	2,000ha	2,000ha	2,000ha	
3. Upgraded Management '000 twe						113	141	181	163	
of AFDB Project		1,500ha	1,880ha	2,400ha	3,400ha	2,900ha	2,900ha			
Overall TOTAL Supply	63	187	377	678	739	1040	1365	1566	1917	

Notes:
15,600ha additional to AFDB project in the period
- 10,000ha or half of plantation replanting
- additional yield gained during 1983-92 by adding fertilizer, adopting a 5 year rotation & achieving 25m^3 mai

* See Annex 2.6.

Annex 2.6

SUPPLY AND DEMAND FOR ADDIS ABABA AS THE PRIME TARGET MARKET OF THE SOUTHERN REGION
('000 Tonnes of Wood Equivalent -- See Conversion Chart Annex 2.7)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	
Mid-Year Population (6.5% p.a.) ('000)	1,543	1,643	1,750	1,863	1,984	2,113	2,251	2,397	2,553	2,719	
Number of Households	309	329	350	373	397	423	450	479	511	544	
Projected Demand ('000 twe)	1,126	1,191	1,277	1,360	1,448	1,542	1,643	1,769	1,863	1,984	
Projected Supply											
A. Non-Woody Fuels											
1. Kerosene	54	60	70	80	91	91	91	91	91	91	-i.e. addn. 5.2 Ml by 1987
2. LPG	48	55	90	120	132	132	132	132	132	132	-i.e. addn 7,000te by 1987
3. Electricity	38	45	59	84	107	130	136	137	138	138	-(see Annex 3.2)
SUBTOTAL A.	140	160	219	284	330	353	359	360	361	361	
B. New Woody Fuel Sources											
4. Charcoal		63	157	304	532	470	485	540	615	659	
5. Residue Briquette			30	73	146	269	442	684	770	1,020	
SUBTOTAL B.		63	187	377	678	739	927	1224	1385	1679	
C. Other											
6. City Agriwastes (factory/mill wastes; dung household trees, grass, etc.	50	53	55	58	61	64	67	70	74	78	
D. Plantations											
7. Existing Urban Plantations	180	169	158	147	135	130	125	120	100	165	-i.e. 90+75 from B.2. Annex 2.5
8. New Upgraded Enriched Plantations							113	141	181	163	
TOTAL SUPPLY (A+B+C+D)	370	508	619	866	1204	1286	1591	1915	2101	2446	
E. Deficit Met By FAWCDA and Others:											
(i) As woody fuels	499	500	525	483	244	256	52				
(ii) As charcoal	257	183	161	11							
F. Surplus								146	238	462	
Deficit equivalent in hectares of Savannah Forest (30m3/ha and 700kg/m^3 basic density) per year	27,000	24,440	24,500	17,640	8,710	9,140	1,860				

Annex 2.7

Wood Equivalence

One tonne of wood air dried 25% moisture content on a wet basis and 20 MJ/kg oven dry is 14.3 MJ lower heating value and is equivalent to:

* 267 kgs of charcoal
* 141 litres of kerosene
* 83 kgs of LPG
* 200 kg of sawdust briquettes
* 712 kg of cereal straw briquettes
* 784 kg of coffee residue briquettes
* 716 kg of cotton and bagasse briquettes
* 400 kWh (substituting injera cooking at av. efficiency of 60%)
* about one tonne of dung burned on an open fire
* 826 kg of cereal stover (corn, sorghum) briquettes

- when burned in stoves in common use in Ethiopia and taking into consideration the lower heating value of the fuels concerned.

Annex 2.8

PERI-URBAN PLANTATIONS (URBAN > 5000 INHABITANTS VOLUMES IN SOLID m^3 ON BARK)

Region	1982														
	Population	Fuelwood demand	Estimated demand satis-faction	Additional Supply Needed, 1982	Plantation Production	Needed	Plantation Cost **	Total Cost	Incremental demand 1987	Incremental demand 1992	Incremental demand 1997	Total Cost *** 1982-1992	Incremental demand 2002	Total area to be planted by 1997 for 2002 demand	Total cost *** 1982-1997
	('000)	('000 m^3*)	(%)	('000 m^3)	(m^3/ha/year)	('000 ha)	(Birr/ha)	(Birr '000)	('000 ha)	('000 ha)	('000 ha)	(Birr '000)	('000 ha)	('000 ha)	(Birr '000)
Arsi	83	90	50	45	20	2.3	868	1,996	1.7	2.3	3.1	8,159	4.3	13.7	11,891
Bale	45	48	40	29	18	1.6	868	1,389	1.1	1.3	1.9	5,121	2.6	8.4	7,378
Eritrea	782	852	5	809	10	80.9	924	74,752	31.5	43.3	59.2	198,568	81.1	296.0	273,504
Gemo Gofa	48	52	50	26	15	1.7	736	1,251	1.3	1.7	2.4	5,225	3.3	10.4	7,654
Gojam	165	180	30	126	18	7.0	913	6,391	3.7	5.1	6.9	20,725	9.5	32.2	29,399
Gondor	163	178	15	151	12	12.6	736	9,274	5.4	7.6	10.3	26,423	14.1	50.0	36,801
Hararghe	266	290	20	232	15	15.5	924	14,322	7.1	9.8	13.5	42,411	18.4	64.3	59,413
Illubabor	29	32	90	3	20	0.2	868	174	0.6	0.8	1.1	2,344	1.5	4.2	3,646
Kaffa	117	128	90	13	20	0.7	868	608	2.4	3.3	4.4	9,374	6.1	16.9	14,669
Shoa (excl. Addis)	490	534	25	401	18	22.3	736	16,413	10.9	15.0	18.6	49,178	28.2	95.0	69,933
Sidamo	204	222	60	89	20	4.5	868	3,906	4.2	5.6	7.8	19,183	10.2	32.3	28,037
Tigrai	165	180	5	171	10	17.1	924	15,800	6.6	8.9	12.4	41,580	17.0	62.0	57,288
Wollega	88	96	50	48	15	3.2	736	2,355	2.4	3.2	4.4	9,714	6.4	19.6	14,424
Wollo	191	208	10	187	12	15.6	924	14,414	6.4	8.8	12.1	39,639	16.5	59.4	54,885
Total	2,836	3,090	(27)	2,251	(12.2)	185.2	(880)	163,045	85.3	116.7	158.1	477,644	2,942	764.4	668,922

* At 2 kg per person and day, air-dry, 670 kg per m^3 = 1.09 m^3 per person and year.
** Excluding infrastructure and administration. About 100% may be added.
*** 1982 prices, excluding infrastructure and administration.

Peri-Urban Plantations 1/
Silvicultural Model I, Lowlands, below 1800m a.s.l.
Eucalyptus camaldulensis

Year	Silvicultural treatment
1	Site clearing (cutting of existing bush) Charcoaling (if enough material) Pitting 40 x 40 x 30 cm. sparing 2.0 x 2.5m Planting of potted seedlings Application of fertilizer, 50 gram per seedling (Application of insecticide 2/) Weeding Protection (from cattle)
2	Weeding Replanting of blanks (Application of insecticide 2/) Protection (from cattle)
3	(Weeding 2/) (Application of fertilizer 2/) Protection (from cattle)
4-5	Minor checking only
6	Clearfelling 60 m^3 Removal of excessive coppice shoots Protection (from cattle)
7-10	Minor checking only
11	Clearfelling 25 m^3 Removal of excessive coppice shoots Protection (from cattle)
12-15	Minor checking only
16	Clearfelling 75 m^3 Removal of excessive coppice shoots Protection (from cattle)
17-20	Minor checking only
21	Clearfelling 60 m^3

1/ Note that the cost data provided in this annex are for direct costs only. Total costs include roading, administration and other infrastructure and are approximately double the direct costs. Total costs for peri-urban forestry have been assumed to average B1,760/ha in costing the forestry sub-sector programs.

2/ When needed, not standard.

Cost Model I
(Shadow values: Labor 0.5 = 1.00 Birr per day, foreign exchange 1.33)

Year	Activity	Man-days required	Cost Labor	Cost Material	Cost Total
				(Birr)	
1	Siteclearing, pitting	64	64	-	64
	Tools	-	-	10	10
	Seedlings, 2000	8	8	224 a/	232
	Planting	20	20	-	20
	Fertilizer	-	-	160 b/	160
	Application of fertilizer	16	16	-	16
	Weeding	24	24	-	24
	Protection	4	4	-	4
	Total	136	136	394	530
2	Weeding	24	24	-	24
	Replanting	15	15	70*	85
	Protection	4	4	-	4
	Total	43	43	70	113
3	Protection	4	4	-	4
6	Clearfelling ($60m^3$)	30	30	-	30
	Cutting shoots	15	15	-	15
	Protection	4	4	-	4
	Total	49	49	-	49
11	Clearfelling ($75m^3$)	38	38	-	38
	Cutting shoots	15	15	-	15
	Protection	4	4	-	4
	Total	57	57	-	57
16	Clearfelling ($75m^3$)	38	38	-	38
	Cutting shoots	15	15	-	15
	Protection	4	4	-	4
	Total	57	57	-	57
21	Clearfelling ($60m^3$)	30	30	-	30

a/ 50% foreign exchange
b/ 100% foreign exchange

Cost Model I

Year	Cost	Discounted Cost a/	Felling Volume
	(Birr)		(m^3)
1	530	530	-
2	113	103	-
3	4	3	-
6	49	27	60
11	57	20	75
16	57	13	75
21	30	4	60
		700	

a/ At 10%.

Peri-Urban Plantations
Silvicultural Model II, Highland Plateaux 1800 - 2800 a.s.l
Eucalyptus globulus

Year	Silvicultural treatment
1	Site clearing (cutting of existing bush) Charcoaling (if enough material) Pitting 40 x 40 x 30 cm, spacing 2 x 2 m Planting of potted seedlings Application of fertilizer, 50 gram per seedling Weeding Protection (from cattle)
2	Weeding Replanting of blanks Protection (from cattle)
3	(Weeding *) (Application of fertilizer, 50 gram per seedling *) Protection (from cattle)
4-5	Minor checking only
6	Clearfelling 75m^3 Removal of excessive coppice shoots Protection (from cattle)
7-10	Minor checking only
11	Clearfelling 90m^3 Removal of excessive coppice shoots Protection (from cattle)
12-15	Minor checking only
16	Clearfelling 90m^3 Removal of excessive coppice shoots Protection (from cattle)
17-20	Minor checking only
21	Clearfelling 75m^3

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* When needed

Cost Model II
(Shadow values: Labor 0.5 = 1.00 Birr per day, foreign exchange 1.33)

Year	Activity	Man-days Required	Cost Labor	Cost Material	Total
			(Birr)		
1	Site clearing, pitting	80	80	-	80
	Tools	-	-	10	10
	Seedlings (2500)	10	10	268 a/	278
	Planting	24	24	-	24
	Fertilizer	-	-	200 b/	200
	Application of fertilizer	20	20	-	20
	Weeding	30	30	-	30
	Protection	4	4	-	4
	Total	168	168	478	646
2	Weeding	30	30	-	30
	Replanting of blanks	20	20	58*	78
	Protection	4	4	-	4
	Total	54	54	58	112
3	Protection	4	4	-	4
6	Clearfelling 75m^3	38	38	-	38
	Cutting Shoots	18	18	-	18
	Protection	4	4	-	4
	Total	60	60	-	60
11	Clearfelling 90m^3	45	45	-	45
	Cutting Shoots	18	18	-	18
	Protection	4	4	-	4
	Total	67	67	-	67
16	Clearfelling 90m^3	45	45	-	45
	Cutting Shoots	18	18	-	18
	Protection	4	4	-	4
	Total	67	67	-	67
21	Clearfelling 75m^3	38	38	-	38

a/ 50% foreign exchange
b/ 100% foreign exchange

Cost Model II

Year	Cost	Discounted Cost a/	Felling Volume
	(Birr)		(m^3)
1	646	646	-
2	112	102	-
3	4	3	-
6	60	34	75
11	67	23	90
16	67	15	90
21	38	5	75
		828	

a/ At 10%.

Peri-Urban Plantations
Silvicultural Model III, Erosion Prone Highlands, 1800-2800 in a.s.l
Eucalyptus globulus

Year	Silvicultural treatment
1	Pegging of bunds (50% of area) a/ Site clearing (cutting of existing "brush") Simple terracing (soil bunds on 50% of the area) Pitting 40 x 40 x 30 cm, spacing 2 x 3 m Planting of potted seedlings Application of fertilizer, 50 gram per seedling Weeding Protection (from cattle)
2	Weeding Replanting of blanks Repair of bunds Protection (from cattle)
3	(Weeding b/) (Application of fertilizer, 50 gram per seedling b/) Protection (from cattle)
4-5	Minor checking only
6	Clearfelling 40m^3 Removal of excessive coppice shoots Protection (from cattle)
7-10	Minor checking only
11	Clearfelling 50m^3 Removal of excessive coppice shoots Protection (from cattle)
12-15	Minor checking only
16	Clearfelling 50m^3 Removal of excessive coppice shoots Protection (from cattle)
17-20	Minor checking only
21	Clearfelling 40m^3

a/ Leaving 1m between rows (bunds)
b/ When needed

Cost Model III
(Shadow values: Labor 0.5 = 1.00 Birr per day, foreign exchange 1.33)

Year	Activity	Man-days required	Cost Labor	Cost Material	Total
			(Birr)		
1	Pegging of bunds	4	4	-	4
	Site clearing	15	15	-	15
	Terracing	175	175	-	175
	Pitting	30	30	-	30
	Tools	-	-	20	20
	Seedlings (1670)	3	3	188 a/	191
	Planting	16	16	-	16
	Fertilizer	-	-	133 b/	133
	Application of fertilizer	16	16	-	16
	Weeding	20	20	-	20
	Protection	4	4	-	4
	Total	283	283	341	624
2	Weeding	40	40	-	40
	Replanting of blanks (incl. repair of bunds)	35	35	73 a/	108
	Protection	4	4	-	4
	Total	79	79	73	152
3	Protection	4	4	-	4
6	Clearfelling 40m^3	20	20	-	20
	Cutting shoots	15	15	-	15
	Protection	4	4	-	4
	Total	39	39	-	39
11	Clearfelling 50m^3	25	25	-	25
	Cutting shoots	15	15	-	15
	Protection	4	4	-	4
	Total	44	44	-	44
16	Clearfelling 50m^3	25	25	-	25
	Cutting shoots	15	15	-	15
	Protection	4	4	-	4
	Total	44	44	-	44
21	Clearfelling 40m^3	20	20	-	20

a/ 50% foreign exchange
b/ 100% foreign exchange

Cost Model III

Year	Cost	Discounted Cost a/	Felling Volume (m^3)
	(Birr)		
1	624	624	
2	152	138	
3	4	3	
6	39	22	40
11	44	15	50
16	44	10	50
21	20	3	40
		815	

a/ At 10%.

RURAL ENERGY FORESTRY REQUIREMENT
(Volumes in solid m^3 on bark)

Region	Population	Demand Fuelwood & Poles a/	Estimated demand satis-faction	Additional supply needed	Estimated Production	Equiv. Area of Planning	Direct Cost b/	Man-days per ha	Man-days Total, mill.	Incremental demand 1987	Incremental demand 1992	Incremental demand 1997	Area to be planted by 1992 for 1997 demand	Total area cost b/ 1982-92	Total Man-days 1982-92	Incremental demand 2002	Area to be planted by 1997 for 2002 demand	Total cost b/ 1982-97	Total mandays 1982-97
	('000)	('000 m^3)	(%)	('000 m^3)	(m^3/ha/year)		(Birr '000)			('000 m^3)	('000 m^3)	('000 m^3)	('000 ha)	(Birr '000)	(million)	('000 m^3)	('000 ha)	(Birr '000)	(million)
Arsi	1,124	1,338	50	669	18	37.2	3,348	164	6.1	157	176	195	66.5	5,986	10.8	219	78.7	7,084	12.9
Bale	877	1,044	40	627	15	41.8	3,762	164	6.9	123	138	152	69.3	6,237	11.4	170	80.6	7,254	13.3
Eritrea	1,804	2,147	10	1,931	8	241.4	21,726	261	63.0	252	283	314	347.6	31,282	90.7	350	391.4	35,224	102.1
Gemo Gofa	1,003	1,194	50	597	12	49.8	4,482	132	6.6	140	157	175	89.2	8,030	11.7	194	105.4	9,488	13.8
Gojam	1,976	2,351	40	1,411	15	94.1	8,468	164	15.4	277	308	345	43.5	14,051	25.6	382	181.6	16,343	29.8
Gondar	1,993	2,372	20	1,897	12	158.1	14,229	132	20.9	280	312	346	236.3	21,264	31.2	388	268.6	24,171	35.5
Hararghe	3,018	3,591	40	2,155	12	179.6	16,164	261	46.9	422	472	525	297.9	26,814	77.8	587	346.8	31,216	90.6
Illubabor	820	976	95	49	20	2.5	226	164	0.4	115	127	143	21.9	1,972	3.7	159	29.9	2,687	5.0
Kaffa	1,574	1,873	95	94	20	4.7	422	164	0.8	220	246	274	41.7	3,753	6.8	306	57.0	5,130	9.3
Shoa	4,876	5,802	30	4,061	18	225.6	20,304	132	29.8	683	762	848	352.9	31,763	46.6	947	405.5	36,498	53.5
Sidamo	2,744	3,265	70	979	20	49.0	4,410	164	8.0	384	429	477	113.6	10,224	18.5	533	140.3	12,623	22.9
Tigrai	2,105	2,505	10	2,254	8	281.8	25,362	261	73.5	295	330	367	405.9	36,532	105.9	408	456.9	41,122	119.2
Wollega	2,028	2,413	60	965	15	64.3	5,788	132	8.5	284	316	352	127.8	11,505	72.9	394	154.1	13,869	76.2
Wollo	2,552	3,037	10	2,734	10	273.4	24,606	261	71.4	357	400	444	393.5	35,416	102.7	496	443.1	39,880	115.6
Total	28,479	33,908	(40)	20,423	12	1,703.3	153,298	(210)	358.2	3,989	4,456	4,957	2,607.6	244,829	616.2	5,533	3,139.9	282,589	669.7

a/ 1.09 m^3 per person per year for fuelwood, plus 0.1 m^3 per person per year for building poles, agricultural implements, etc.
b/ At 90 Birr per ha for inputs in Peasant Association nurseries, 1982 price level.

Annex 2.11

SIMPLE COST ESTIMATE FOR RURAL AFFORESTATION BUDGET

	Per ha Established (Nearest Birr)
1. Overheads of National and Regional Administration	
Total Cost of:	
* Transportation	8
* Housing: offices and homes	4
* Office Expenditure (Annual)	10
* Staff	40
2. Direct Costs at Peasant Association Level	
A. Nursery Materials	
Seedling Production (includes seed, building, services)	90
B. Civil Works	
Minor roading, bridging, drainage, etc.	50
C. Tools and Sundries	8
3. Labor	
Peasant labor input throughplant plantation life is:	
* Planting 190 man-days	
* Harvesting 14 man-days	
* Weeding 6 man-days	
210 man-days	
(budgeted at average cost of one Birr per manday)	210
	420

Annex 2.12

ESTIMATES OF NUMBER OF CATTLE AND OF DUNG PRODUCTION
BY REGION OF ETHIOPIA, 1981/82

Regions	Cattle Population	Human Population	Ratio Cattle/Human	Annual Dung Production a/ (1000 tonnes) Fresh Weight	Dry Weight
	('000)	('000)		(13% dm)*	(85% dm)**
Arsi	1,644	1,207	1.4	10,134	1,550
Bale	509	922	0.6	3,138	480
Gemo Gofa	602	1,051	0.6	3,711	508
Gojam	2,316	2,141	1.1	14,277	2,184
Gonder	1,524	2,156	0.7	9,394	1,437
Hararghe	1,249	3,284	0.4	7,699	1,178
Illubador	450	849	0.5	2,724	424
Kaffa	1,323	1,691	0.8	8,155	1,247
Shoa	6,419	6,792	0.9	39,569	6,052
Sidamo	1,863	2,744	0.7	11,484	1,756
Wollega	1,815	2,116	0.9	11,188	1,711
Wollo	2,181	2,743	0.8	13,444	2,056
Tigrai*	1,735	2,270	0.8	10,695	1,636
Eritrea*	989	2,586	0.4	6,096	932
TOTAL	24,619	32,741		151,758	23,211

* Base numbers estimated in the 1980/81 census of livestock. Assumption is that due to drought and conditions of starvation, the livestock population in these regions will not have grown noticeably within the last year.

** dm=dry matter. All data is in metric tonnes=te.

a/ Conversion factor, cattle to dung, is 202.5 kg average live weight and 83.4 kg fresh weight of dung production per day per ton of live weight (fresh weight is at 87% m.c.w.b.).

Source: CPSC, CSO. Agriculture Sample; Survey, 1981/82. Preliminary results of livestock and poultry for Ethiopia, Addis Abeba, October 1982, and ICLA survey data.

Annex 2.13

FUELWOOD DEFICITS AND DUNG AND CROP RESIDUE CONSUMPTION
ESTIMATES BY REGION, 1981/82

Region	Fuelwood Demand Satisfaction	Fuelwood Deficit	Dung Equivalent	Cow Dung Available	Dung Burnt in Households	Straw and Stover Burnt
	(%)	('000 m^3)	('000 te)	('000 te at 15% mcwb)	('000 te, 15%mc)	('000 te (15% m.c.)
Arsi	50	613	423	1,550	85	310
Bale	40	574	396	480	198	182
Eritrea	10	1,769	1,220	932	932*	264
Gamo Gofa	50	547	377	568	75	277
Gojam	40	1,292	891	2,184	446	408
Gondar	20	1,738	1,199	1,437	1,079	328
Hararghe	40	1,974	1,361	1,178	681	624
Illubador	95	45	31	424	3	26
Kaffa	95	86	59	1,247	6	49
Shoa	30	3,720	2,566	6,052	1,283	1,177
Sidamo	70	897	619	1,756	124	454
Tigrai	10	2,065	1,424	1,636	1,282	130
Wollega	60	884	610	1,711	122	446
Wollo	10	2,504	1,727	2,056	1,554	461
Total					7,864	5,138

Note: Equivalence is established using the calorific value of dry cow dung (15% m.c. wet basis), 13.8 MJ/kg, and $1m^3$ of wood (solid) at 25% m.c.w.b. (as sold), 500 kg/m^3 basic density, and 14.3 MJ/kg, thus 9,524 MJ/m^3, giving 1 tonne dung = $1.45m^3$ wood. Cereal straw is 15 MJ/kg, thus 1 tonne straw = 1.09 tonne dung or $1.57m^3$ of wood. In all, the combustion efficiency of straw/stover and dung is assumed to be the same as for wood (i.e. 8% with clay pots on open 3 stone fires).

Annex 2.14

FORECAST DEFICIENCY OF WOODFUEL SUPPLY TO URBAN AREAS
---- '000 hectares ----

Planted By	Deficit Under Achievable Planting a/ Total	North	South	Surplus to Addis b/ From all Sources c/	Net Deficit to South
1982 for 1987	271	165	106	--	106
1987 for 1992	342	212	130	73	57
1992 for 1997	350	218	132	93	39
1997 for 2002	234	142	92	119	(27)

a/ From Table 2.11.

b/ From Annex 2.13, equated to hectares of plantation equivalent using 1.67 m^3 per tonne of wood equivalent and 17.4 m^3/ha mai average for southern urbn areas.

c/ Assuming a growth in the surplus of all new fuels to Addis Abeba requirements of 5% per year.

Annex 3.1

STATUS AND ELECTRICITY DEMANDS OF BOILER ELECTRIFICATION PROGRAM

Project	Existing Boilers (te=tonnes)	Current Oil Consumption	Electrical Boiler Installation Status	Boiler Capacity	Estimated Maximum Demand	Estimated Energy/Yr	Date Load Demand	Standby Boiler Condition
Pulp & Paper	1-14 te/hr	4500 te/y	Operational (+12 months)	12MW	12MW	42 GWh	1982	Existing boiler to be refurbished
Dire Dawa Textiles	5-42 te/y	7035 te/y	Installation complete-requires electricity supply	15MW	12MW	66 GWH	1987+	Existing plant retained
United Oil & Soap	4-4 te/hr	Wood	Civil works complete no mechanical or electrical	12MW	12MW	40 GWh	1985	Some refurbishment of boilers--some may be scrapped
Awash Tannery			Project Abandoned (equipment purchased)					
Akaki Textiles	1-6.3 1-4.6 1-6 1-3.7	5000te/y	Works complete commissioning required	12MW	12MW	42.3 GWh	1983	Existing plant retained as standby
Rubber and Canvas	Steam from Tyre Co. nil	nil	Operational (1 month)	650kW	0.7MW	1.88 GWh	1983	n/a
Tyre Factory	2-6 te/hr	3000 te/y	Installation proceeding	6MW	3MW	26.4 GWh	1983	Boiler being kept as standby
St. Georges Brewery	1-42 te/hr 1-53 te/hr 1-42 te/hr	1460 te/y	Installation complete except feeder	9MW	9MW	13.8 GWh	1983	1 boiler requires new furnace tube
Akaki Oil Mills	1-1 te/hr	150 te/y	Only civil half completed	3MW	3MW	1.8 GWh	1985	Boiler retained as standby
Mokjo Textiles	2-3.5 te/hr	900 te/y	Installation complete awaiting commissioning	3MW	3MW	8.4 GWh	1983	Boilers OK as standby
Hilton Hotel	2-3 te/hr	(252 te/y) part comm'n	Operational	650kW	650kW	2.0 GWh	1982	Boiler OK as standby
Ras Hotel	none	60 te/y	No installation work started	200kW	200kW	0.6 GWh	1983	Boilers scrapped
Wabe Hotel	1/2 - 1 te/hr	100 te/y	Installation complete	380kW	380kW	1.1 GWh	1983	Boiler OK as standby
Yakatit School	?	?	?	140kW	140kW	0.21 GWh	?	No information
			TOTAL		68MW	246 GWh		

? = Not Known

Annex 3.2

EELPA ICS MISSION'S POWER DEMAND FORECAST

	FY	—— Residential —— Cookers		Lighting & Power		Commercial St. Lighting & Agriculture		Small Industry		— Large Industries — Existing		Boilers		New Large Industry		Subtotal		Addition to ICS		Total		Change (%/yr)		System Load Factor (%)
		GWh	MW	GWh	MW	GWh	MW	GWH	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	
Base Year Sales	1982	12.24		123.12		57.44		43.71		227.99		20.26		---		484.76	---	---	---	484.76	---			
Losses on Sales (%)		14.6		14.6		14.6		14.6		8.7		8.7		8.7		11.6	---	14.6	---	11.6	---			
Base Year Sales	1982	14.03		141.10		65.83		50.09		247.93		22.02		---		541.00	102.5	---	---	541.00	102.5			60.3
Forecast Demand																								
	1983	15.26	8.1	150.98	34.5	70.44	14.6	53.60	10.2	257.85	42.1	76	17.4	---	---	618.13	125.5	---	---	618.13	125.5	14.3	22.4	56.2
	1984	18.18	9.6	161.55	36.9	75.37	15.6	57.35	10.9	268.16	43.8	149	44.6	5.76	2.4	735.37	163.8	---	---	735.37	163.8			51.2
	1985	23.57	12.3	172.85	39.5	80.64	16.7	61.37	11.7	278.89	45.5	195	60.9	40.06	11.3	852.38	197.9	9.94	2.3	862.32	200.2			49.2
																						11.2	11.2	
	1986	33.59	17.5	184.96	42.3	86.29	17.9	65.66	12.5	290.05	47.4	98	(46.9)	96.72	23.5	855.27	208.0	21.85	5.0	877.12	213.0			47.0
	1987	42.88	22.0	197.90	45.2	92.33	19.1	70.26	13.4	301.65	49.3	0	0	193.07	38.7	898.09	187.7	36.05	8.2	934.14	195.9			54.4
	1988	52.16	26.7	211.76	48.4	98.79	20.5	75.12	14.3	313.71	51.2	0	0	248.2	40.1	999.74	201.2	52.15	11.9	1051.89	213.1	--	--	56.3
	1989	54.51	27.8	226.58	51.8	105.71	21.9	80.44	15.3	326.36	53.3	0	0	280	45	1073.50	215.1	71.72	16.4	1145.22	231.5			56.5
	1990	55.10	27.9	242.44	55.4	113.11	23.4	86.07	16.4	339.31	55.4	0	0	310	50	1146.03	228.5	94.67	21.6	1240.70	250.1			56.6
																						8.3	8.2	
	1991	55.28	27.7	259.41	59.3	121.03	25.1	92.10	17.5	352.88	57.6	0	0	340	55	1220.70	240.2	121.49	27.7	1342.79	269.9			56.8
	1992	57.17	28.5	277.57	63.4	129.50	26.8	98.54	18.8	367.00	59.9	0	0	370	60	1299.78	257.4	152.73	34.9	1452.51	292.3			56.7
	1993	59.25	29.4	297.00	67.9	138.56	28.7	105.44	20.1	381.68	62.3	0	0	400	65	1381.93	278.4	183.84	42.0	1565.77	315.4			56.7
	1994	62.23	30.9	317.79	72.6	148.26	30.7	112.82	21.5	396.95	64.8	0	0	430	70	1468.05	290.5	218.57	49.9	1686.62	340.4			56.6
	1995	65.35	32.5	340.04	77.7	158.64	32.9	120.72	23.0	412.83	67.4	0	0	460	75	1557.58	308.5	233.86	53.4	1791.44	361.9			56.5

Annex 3.3

EXISTING AND COMMITTED ERESA ICS GENERATION

Station Name	Number and Type of Generation Units	Total Installed Capacity (MW)	Year of Commissioning	Retirement Date
A. Existing				
Belesa	1 X 10 MW steam	20.0	1966	1996
	1 X 5 MW steam		1964	1994
	1 X 5 MW diesel		1969	1989
Kagnew	4 X 1.5 MW diesel	6.0	1966	1981
Gajaret	10 X 0.58 MW diesel	5.8	1979	1994
Girar	1 X 1.1 MW diesel	9.4	1958	1978
	1 X 1.1 MW diesel		1959	1979
	1 X 1.1 MW diesel		1961	1981
	1 X 1.1 MW diesel		1962	1982
	1 X 5.0 MW diesel		1973	1993
Total Existing (1982 year end)		41.2		
B. Committed				
	2 X 5.0 MW diesel	10.0	1983	2003
Total ERESA ICS (1983)		51.2		

Source: ACRES International - EELPA.

Annex 3.4

PROJECTED INVESTMENTS IN THE ETHIOPIAN POWER SECTOR a/
(Birr million-1983 Prices)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Generation													
EELPA ICS													
Malka Wakana b/	56	94	94	75	--	--	--	--	--	--	--	--	319
Amarti Diversion	12	18	19	12	--	--	--	--	--	--	--	--	61
Finchaa 4th Unit	5	14	14	14	--	--	--	--	--	--	--	--	47
Gibe Daka	--	--	--	--	--	48	95	119	142	71	--	--	475
Next Hydro Project	--	--	--	--	--	--	--	--	--	--	60	60	120
EELPA SCS													
Lake Tana Regulation	9	6	--	--	--	--	--	--	--	--	--	--	15
Tis Abay 3rd Unit b/	1	--	--	--	--	--	--	--	--	--	--	--	1
Sor minihydro	--	8	10	8	--	--	--	--	--	--	--	--	26
Hoha minihydro	--	1	1	--	--	--	--	--	--	--	--	--	2
Dedissa minihydro	--	5	6	4	--	--	--	--	--	--	--	--	15
Other minihydro	--	--	7	7	7	7	7	--	--	--	--	--	35
Diesel Plants	10	2	2	2	2	2	2	2	2	2	2	2	32
ERESA ICS + SCS													
Diesel Plants	26	--	1	--	1	--	1	--	1	--	1	--	31
SUBTOTAL	119	148	154	122	10	57	105	121	145	73	63	62	1179
Transmission & Distribution													
230kV/132kV													
Dessie Extension b/	24	15	--	--	--	--	--	--	--	--	--	--	39
Muger Extension b/	3	--	--	--	--	--	--	--	--	--	--	--	3
Shashamene-Malka Wakana b/	7	7	--	--	--	--	--	--	--	--	--	--	14
Shashamene-A. Minch b/	13	12	--	--	--	--	--	--	--	--	--	--	25
Geferressa-Addis N. b/	1	--	--	--	--	--	--	--	--	--	--	--	1
Lake Tana Region b/	1	--	--	--	--	--	--	--	--	--	--	--	1
Alaba-Gibe Daka	9	8	--	--	--	--	--	--	--	--	--	--	17
Finchaa-Bahar Dar	--	--	--	--	--	23	31	23	--	--	--	--	77
Malkassa-Dire Dawa	--	25	34	25	--	--	--	--	--	--	--	--	84
Gibe Daka-Jima	--	--	7	7	--	--	--	--	--	--	--	--	14
Yirgalem-Shakisso	--	--	6	8	6	--	--	--	--	--	--	--	20
Addis N.-Cotobie	--	--	--	3	6	--	--	--	--	--	--	--	9
Awash-Angelle	--	--	--	7	10	7	--	--	--	--	--	--	24
66kV/45kV													
Harrar Region b/	2	--	--	--	--	--	--	--	--	--	--	--	2
Nekemte Region	--	--	--	--	9	9	--	--	--	--	--	--	18
Jimma Region	--	--	--	--	6	6	--	--	--	--	--	--	12
Muger-Fitchie	--	--	--	--	4	4	--	--	--	--	--	--	8
M. Wakana-Robie	--	--	--	--	--	4	4	--	--	--	--	--	8
Ambo-Ghion	--	--	--	--	--	3	3	--	--	--	--	--	6
Dessie Region	--	--	--	--	--	9	12	4	--	--	--	--	25
Debre Markos-Dejen	--	--	--	--	--	--	--	3	3	--	--	--	6
Dilla-F. Genet	--	--	--	--	--	--	--	3	3	--	--	--	6
Finchaa-Shabo	--	--	--	--	--	--	--	3	3	--	--	--	6
Other 66kV exten.	--	--	--	--	--	--	--	--	--	5	5	5	15
Substation Expansion	--	--	17	32	24	11	7	7	5	5	5	5	118
Distribution Expansion (inc. Village elec.)	12	12	12	12	12	12	12	12	12	12	12	12	144
Subtotal	72	79	76	94	77	88	69	55	26	22	22	22	702
Infrastructure													
Workshop	3	10	10	10	--	--	--	--	--	--	--	--	33
Training Inst.	3	5	5	3	--	--	--	--	--	--	--	--	16
Office Bldgs	--	4	6	6	4	--	--	--	--	--	--	--	20
Vehicles	5	5	5	5	5	2	2	2	2	2	2	2	39
Subtotal	11	24	26	24	9	2	2	2	2	2	2	2	108
Total Investment	202	251	256	240	96	147	176	178	173	97	87	86	1989

Note: a/ Investments required to meet mission's demand forecast.
b/ completion of projects started before 1984.

Source: EELPA

Annex 4.1

REFINED PETROLEUM PRODUCTS SUPPLY OPTIONS

Investment and Operating Cost for Different Cases in 1983 US Dollars

I. Investment Cost	Case 1	Case 2	Case 3	Case 4	Case 5
A. Energy Conservation					
- Revamping of heat exchange train in the distillation unit	--	1.5	1.5	1.5	--
- Revamping of three process furnaces	--	3.5	3.5	3.5	--
- Revamping/replacement of TPS boilers	--	4.5	4.5	4.5	--
Subtotal	--	9.5	9.5	9.5	--
B. Product-Pattern Improvement					
- Minor modifications in distillation unit	--	0.2	0.2	0.2	--
- Capacity increases in catalytic reforming and hydro treating facilities	--	1.5	1.5	1.5	--
- Installation of Merox treating facilities	--	2.5	2.5	2.5	--
- Modernization of Asphalt-blowing and filing facilities	--	1.5	1.5	1.5	--
Subtotal		5.7	5.7	5.7	
C. Expansion of Distillation Unit by Minor Debottlenecking	--	--	2.5	2.5	--
D. Improvement in General Operational Efficiency					
- Modernization/replacement of instrumentation	--	1.5	1.5	1.5	--
- Replacement of water coolers with air coolers/ trim coolers	--	1.5	1.5	1.5	--
- Installation of on-line blending facilities	--	0.2	0.2	0.2	--
Subtotal	--	3.2	3.2	3.2	--
E. Secondary Conversion Facilities					
- Thermal cracker (420,000 tons/year)	--	--	--	18.0	--
- Distillate hydrotreating (135,000 tons/year)	--	--	--	5.0	--
- Off-sites facilities (50% of on-site facilities)	--	--	--	12.0	--
Subtotal				35.0	

Note: Add Contingency of 20% to all subtotals

II. Operating Costs (Million 1983 Dollars)	3.8	4.0	4.5	6.0	--

Annex 4.2

Petroleum Production Transportation Analysis, Asseb-Addis Ababa

Parameters adopted on the basis of records obtained

Trucks

Medium Size Trucks

* Carrying capacity net (average): 24 tonnes
* Price (CIF) Ethiopia: US$ 122,600 fully fitted
* Shadow values of true cost of foreign exchange in US$ equivalent: US$ 163,058
* Repairs and maintenance including yptes: 0.3684 BIRR/km
* Write-off rate due to accidents: 15% per annum
* Life of vehicle other that write-off: 5 years
* Salary, trip allowances and overheads: US$12,455 (1987) per truck

Large Trucks

* Carrying capacity net (average): 36 tonnes
* Price (CIF) Ethiopia, fully fitted
  High price estimate: US$ 244,778
  Low price estimate: US$ 179,483
* Shadow value of true cost of foreign exchange
  High price estimate: US$ 324,778
  Low price estimate: US$ 238,653
* Repairs and maintenance including types: 0.2989/km
* Write off rate due to accident: 7% per annum
* Salary, allowances and overheads: US$ 12,300 (1987) per truck

Common Operating Characteristics

* Round trip Asseb-Addis Ababa: 7 days
* Availability (average actual): 2.2 trips/month, 26.4/year
* Distance covered annually: 45,408 km per vehicle
* Fuel consumption: 1.4 km/litre for both sizes of trucks
* Lubricants: 10% cost of fuel
* Fuel prices: US$ 0.30/litre Addis Ababa, US$ 0.24/litre Asseb in 1983.

Annex 6.1

IMPORT PARITY BUILD UP
(C.I.F. Assab)

		Jet A-1/ Kero	Mogas 93 Oct.	Mogas 83 Oct.	Gasoil 53 D.I.	Fuel Oil
		---------- US¢/USgallon			----------	US$/bbl
1.	F.O.B. *	110.00	100.80	97.00	103.00	31.25 US$/bbl
2.	Freight **	6.56	6.11	5.95	6.88	2.73 " "
3.	Insurance (0.12%)	0.14	0.13	0.12	0.13	0.04 " "
	CIF (US¢/USgallon)	116.70	107.04	103.07	110.01	34.02 US$/bbl
	CIF (e¢/litre)	63.82	58.53	56.36	60.16	44.29 e¢/liter
4.	Bank Charges (2.25%)	1.44	1.32	1.27	1.35	0.99
5.	Ocean Leakage (0.5%)	0.32	0.30	0.29	0.31	0.22
6.	Stamp Charges B1.00/metric tonne	0.08	0.07	0.07	0.08	0.09
7.	Service Charges B.0.30/liter	0.30	0.30	0.30	0.30	0.30
	Total e¢/litre	65.96	60.52	58.29	62.20	45.89
	**	68.28	62.81	60.57	64.53	46.87

* BMS posting effective 4/19/82.

** Price build-up worked out on basis of BMS posting of 2.23/82 and related AFRA forecast and basic rates.

*** (a) AFRA for Dec. 1982 175 plus premium for W.O. 35= 210.

(b) Basic rate US$6.56/English ton plus differential US$4.06= US$10.62/ton.
Ocean freight in US$/English ton - (a) x (b) = 2.10 x 10.62= US$22.30/ton.

PETROLEUM PRICE BUILD-UP AND MAXIMUM SELLING PRICE a/ AT SOME LOCATIONS IN ETHIOPIA

Product		Unit in Ethiopian e/Lt.	Ex-Refinery Price	Excise on Custom Tax	Municipality Tax	Distributing Company's Margin	Retailers Margin	Asaba Retailers Price	Price at Addis Ababa	Price at Dire-Dawa	Price at Asmara	Price at Combolcha	Price at Nazareth
Gasoline	(old)	e/Lt	88.50	10.5	2.0	4.0	3.0	108.0	119.0	119.0	113.0	115.0	119.0
	(new)	-	86.90	10.5	2.0	4.0	3.0	106.4	117.4	117.4	111.4	113.4	117.4
Diesel Oil	(old)	-	52.75	6.50	2.0	3.75	3.0	68.0	79.0	79.0	73.0	75.0	79.0
	(new)	-	51.76	6.50	2.0	3.75	3.0	67.01	78.01	78.01	72.01	74.01	78.01
Inland Fuel Oil	(old)	-	38.50	-	-	3.50	-	42.0	54.0	54.0	47.0	48.7	54.0
	(new)	-	41.4	-	-	3.50	-	47.9	59.9	59.9	52.9	54.6	60.0
Kerosene	(old)	-	47.75	-	-	3.75	3.0	54.50	65.50	65.50	59.5	61.50	65.5
	(new)	-	47.6	-	-	3.75	3.0	54.35	65.35	65.35	59.35	61.35	65.35
LPG	(old) b/	Br/ton	520.00	100.0	20.0	420.0	240.0	1300.0					
	(new)	-	519.66	100.0	20.0	420.0	240.0	1299.66					

a/ Consumer prices reflect the distances of the distributing centers from Assab.
b/ Prices of LPG are the same throughout the country except for differences that may be permitted by Government. For example, the LPG price in Asmara is B1460/te.

Annex 6.2
Page 2 of 2

Road & Marine Transport Rates Schedule Effective From March 27, 1981 (Abbreviated by Mission)

A. Tank Truck Tariff:

1. Following is the Tank Truck Tariff:

	Gasolines, Diesel, Aviation Fuels and Kerosene		Fuel Oil, Marine and Industrial Diesel Oil	
	Ex-Assab/ Djibouti	Ex-Massawa	Ex-Assab/ Djibouti	Ex-Massawa
Unit Rate: ¢/Litre				
1.1 Assab-Addis Abeba	11.000	-	12.000	-
1.2 Massawa-Asmara	-	2.000	-	2.150
Unit Rate: ¢/M^3/km				
1.3 Other routes (Truck & Trailer)	12.644	17.391	13.782	18.178
1.4 Other routes (Trucks only)	27.000	37.940	29.539	41.355

2. LPG Tank Trucks
   1. LPG Trucks - Assab/Addis - Birr 199.00/Ton
   2. Other routes to be paid at the rate of ¢22.87/m^3/km. Nonetheless, as long as it is compulsory to transport for Asmara ex-Assab by road - Assab/Asmara rate shall be Birr 359.00/Ton.

B. Marine Tariff

Following tariff will apply for port-to-port transfer of products by ship:

Assab - Massawa	¢3.00/Litre
Assab - Djibouti	¢2.00/Litre
Aden - Assab	¢3.00/Litre
Aden - Massawa	¢3.50/Litre
Aden - Djibouti	¢3.00/Litre

All volumes to be measured at 30°C.

Annex 6.3

BUILD-UP OF ECONOMIC COST OF PETROLEUM PRODUCTS IN ETHIOPIA, 1983
(US$ and US¢)

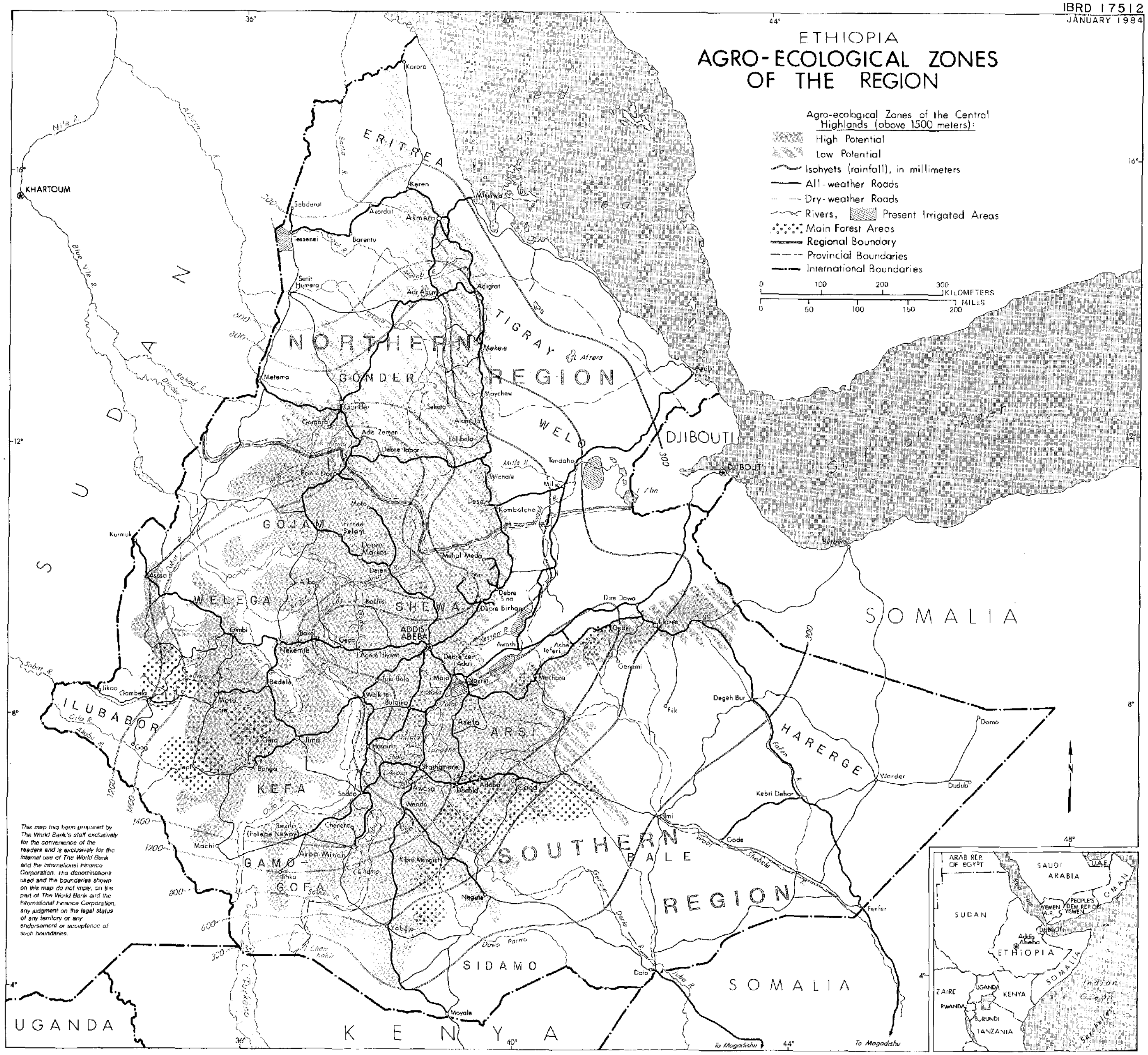
	Gasoline	Diesel	Kerosene	LPG	Fuel Oil
Offshore Costs					
US$/Tonne	297	276	297	307	153 FOB ASSEB (for export)
Freight US$/tonne	11	11	11	50	n. appl
Ocean Losses (0.5% average)	1.5	1.4	1.5	1.5	n. appl.
US$/te CIF Asseb	309.5	288.4	309.5	358.5	--
US¢/litre CIF	23.10	24.00	24.18	18.71	14.37
US¢/litre CIF at Shadow value of foreign exchange (1.33)	30.72	32.00	32.16	24.88	19.11
Inland Costs					
Port Charges (est. ¢/litre)	0.15	0.15	0.15	0.15	0.15
Freight to Addis Abeba (economic cost est.)	6.00	6.00	6.00	7.00	6.00
Distribution and Marketing	1.93	1.81	1.81	10.58	1.69
Estimated Economic Cost at Addis Abeba					
US¢/litre	38.80	39.96	40.12	42.61	26.95
e¢/litre	80.31	82.72	83.05	88.20	55.79

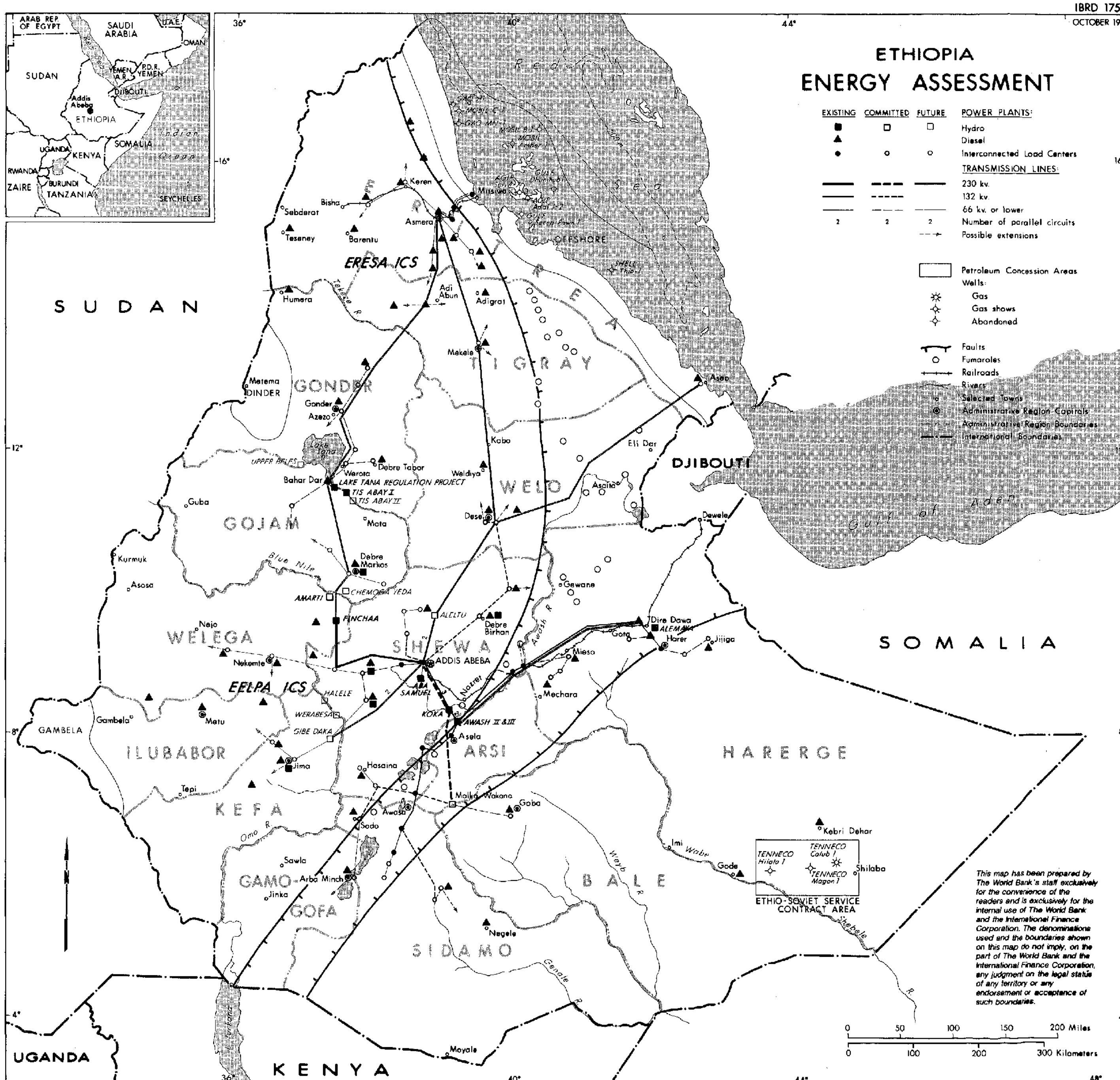
A TENTATIVE SCHEDULE OF NEW ENERGY SECTOR
INVESTMENTS IN ETHIOPIA, 1983/4-1992/3
(Birr Million)

Subsector	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	Total
1. Power											
a. Generation											
- EELPA ICS	73	126	126	101	--	48	95	119	142	71	901
- EELPA SCS	20	22	26	21	9	9	9	2	2	2	122
- ERESA SCS/ICS	26	--	1	--	1	--	1	1	--	1	31
b. Transmission/ Distribution	72	79	76	94	77	88	69	55	26	22	658
c. Infrastructure	11	24	26	24	9	2	2	2	2	2	104
Subtotal	202	251	255	240	96	147	176	179	172	98	1816
2. Petroleum											
a. Production	--	--	--	--	(5)	(5)	--	(90)	(221)	(321)	642
b. Exploration	8	9	--	--	--	--	--	--	--	--	17
c. Refining	3	4	--	(40)	(45)	(50)	--	--	--	--	142
d. Demand Management/Subs'n	7	12	8	11	--		--	--	--	--	38
Subtotal	18	25	8	51	50	55	--	90	221	321	839
3. Household Energy											
a. New biomass											
- Crop residues	--	1	1	2	3	5	9	14	16	21	72
- Charcoal	--	1	3	7	5	5	5	5	6	6	41
b. Improved Cooking	--	1	1	1	--	--	--	--	--	--	3
c. Fuelwood Production	--	--	--	--	--	--	--	--	--	--	--
- Peri-urban											
. Existing		1	1	4	4	4	5	5	5	5	36
. New	8	13	17	21	31	42	52	63	73	83	403
- Rural Forestry	7	14	22	29	36	40	43	47	51	54	343
d. Manpower T&D	2	3	3	2	2	2	2	2	2	1	21
Subtotal	17	34	48	66	81	98	116	136	153	170	919
4. Other Energy Sources											
a. Ethanol	5	15	13	--	--	--	--	--	--	--	33
b. Coal/Geothermal	3	3	?	?	--	--	--	--	--	--	6
c. Solar and Other	1	3	3	3	4	5	2	2	2	2	27
Subtotal	9	21	16	3	4	5	2	2	2	2	66
Total	246	331	327	360	232	306	294	407	548	591	3640

( ) = investment is dependent on outcome of prior study.
? = further funding dependent on prior activity.

IBRD 17512
JANUARY 1984




IBRD 17513
OCTOBER 1983
ETHIOPIA
ENERGY ASSESSMENT
EXISTING
COMMITTED
FUTURE
POWER PLANTS:
Hydro
Diesel
Interconnected Load Centers
TRANSMISSION LINES:
230 kv.
132 kv.
66 kv. or lower
Number of parallel circuits
Possible extensions
Petroleum Concession Areas
Wells:
Gas
Gas shows
Abandoned
Faults
Fumaroles
Railroads
Rivers
Selected Towns
Administrative Region Capitals
Administrative Region Boundaries
International Boundaries
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0 50 100 150 200 Miles
0 100 200 300 Kilometers
SUDAN
SOMALIA
DJIBOUTI
KENYA
UGANDA
ERESA ICS
EELPA ICS
TIGRAY
GONDER
GOJAM
WELO
WELEGA
SHEWA
ILUBABOR
KEFA
ARSI
HARERGE
BALE
SIDAMO
GAMO-GOFA
ERITREA
GAMBELA
ADDIS ABEBA
Asmera
Mitsiwa
Keren
Aseb
Dire Dawa
Harer
Jijiga
Gonder
Bahar Dar
Dese
Makele
Jima
Nekemte
Awasa
Asela
Nazret
Debre Markos
Debre Birhan
Moyale
Kebri Dehar
Gode
Shilabo
LAKE TANA REGULATION PROJECT
TIS ABAY I
TIS ABAY II
FINCHAA
AMARTI
CHEMOGA YEDA
ALELTU
ABA SAMUEL
KOKA
AWASH II & III
ALEMAYA
MELKA WAKANA
GIBE DAKA
HALELE
WERABESA
TENNECO Hilala 1
TENNECO Calub 1
TENNECO Magon 1
ETHIO-SOVIET SERVICE CONTRACT AREA
OFFSHORE
Red Sea
Gulf of Aden
SUDAN
SAUDI ARABIA
ARAB REP. OF EGYPT
U.A.E.
OMAN
YEMEN A.R.
P.D.R. YEMEN
DJIBOUTI
Addis Abeba
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SOMALIA
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