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February 1986

ENGLISH

DEMONSTRATION PROGRAMME ON USE OF INDIGENOUS BIOMASS RESOURCES
FOR MEETING ENERGY NEEDS

RP/RAF/85/627

ETHIOPIA

Technical Report *

Mission 9 to 29 December 1985

Prepared for the Government of Ethiopia
by the United Nations Industrial Development Organization
acting as executing agency for United Nations Development Programme

Based on the work of Mr. Hubert E.M. Stassen
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ACKNOWLEDGEMENT

The author wishes to thank UNIDO for inviting him to undertake this mission. Dr. Robert Williams, Vienna and Dr. Kadress Vencatachellum, Addis Abeba, are thenked for their kind assistance during the mission.

Dr. Ghebru Wolde Giorgis, Executive Secretary of the Ethiopian National Energy Committee (ENEC), Mr. Omar Mohamed Geta, Mr. Yahya Mohammed and Mr. Tekola Shimelis actively assisted the consultant during his mission in Ethiopia, both by providing facilities as well as usefull oral and written information. Without their generous co-operation this mission would not have been possible.

Last but not least the author wishes to thank Prof. Prem Grover from IIT New Delhi, for detailed discussions and informed opinions as to the theoretical and practical aspects of biomass conversion technologies.

SUMMARY AND RECOMMENDATIONS

The objective of this report is twofold, i.e.:

1) To outline the characteristics of a biomass gasification demonstration program in Ethiopia,
2) To identify suitable applications and sites for gasifier demonstration projects in Ethiopia

1. Biomass gasification demonstration program characteristics

From a point of view of fuel availability and suitability, the expert has come to the conclusion that maize residues (especially maize cobs) are the most promising gasifier feedstock available in Ethiopia. The availability of wood residues at sawmill sites is unclear and calls for further study.

From an user's point of view, three promising applications were identified, i.e:
- small scale irrigation (gasifier fueled by carbonized maize cobs),
- power generation on state maize farms (gasifier fueled by uncarbonized maize cobs),
- farm transport (tractors) on state maize farms (gasifier fueled by carbonized maize cobs).

The latter two options call for further data gathering and assessment.

Application of gasification systems at sawmill sites is unclear, both because of lack of information as to the number of suitable sites as well as of the competition of alternative (steam) power supply systems. The expert comes to the conclusion that only up-draft gasification systems operating on sawdust, may be implementable on a significant scale.

In order to allow evaluation, demonstration projects must include a monitoring component. For this reason a local institution (in this case ENEC) must built up capability and know how both in gasification as well as in monitoring procedures.

In view of the above, the following activities are proposed:

- Implementation of a small-scale gasifier demonstration program for lift irrigation (see 2. below).
- A three months overseas training course in gasification technology and monitoring procedures for a qualified engineer to be designated by ENEC.
- Execution of a project monitoring program (at first only for the lift irrigation project, but to be extended to

other gasification projects in the future) by ENEC and other involved ministries and institutions.

- Execution of three feasibility studies relating to:
  a. the viability of gasifier power generation at state maize farms.
  b. the viability of energy supply to sawmills by means of up-draft gasification plants fueled by sawdust.
  c. the viability of mobile gasifier application (tractors) on state maize farms.

A budget detailing the financial consequences of the above recommendations is given in Chapter 4. A detailed workplan and bar-chart of activities is presented in Annex 2.

2. Site identification

The expert recommends the installation of a small scale (15 hp) charcoal fueled gasification system for lift irrigation at Golibee irrigation project. It is necessary that ENEC comes to an agreement with ARDU (Asela) with respect to the technical back-up facilities for this plant. A detailed list of equipment specifications is to be found in Annex 1. In Annex 5 and 6, the requirements with respect to spare part supply and training have been detailed.

For a number of reasons it was not possible to identify a suitable sawmill site for gasifier application. As described in the report, the complex situation of the Ethiopian logging and sawmill sector calls for further data gathering and evaluation.

1.0 INTRODUCTION

1.1 Energy situation

The Ethiopian energy sector has been facing increasing difficulties in the last decade. Certainly the most important problem is the increasing scarcity and cost of domestic fuel with the associated deforestation and desertification. Therefore a major effort in forest preservation and afforestation is urgently needed. However, because this will only provide a solution in the medium to long term, on a short time basis there is a need to develop alternative indigeneous fuel substitutes based on agricultural residues and forestry wastes, as well as to improve on the conversion efficiencies of domestic heating appliances.

The other pressing problem is in the enormous cost of imported petroleum fuels. In the year 1982/83 the cost of liquid fuel imports amounted to approximately half the export earnings. Because Ethiopia has no known reserves of coal or crude oil, conservation or substitution of petroleum products is a priority. Taking into account the decentralized nature and relatively small capacity of power generating equipment there appears to be a possibility for the introduction of thermochemical biomass gasification technologies on basis of agricultural residues and logging and sawmill wastes. Applications can be found in agricultural and forestry industries, in irrigation projects, in power generation in remote areas and on state farms, as well as in (farm) transport.

Both the Government of Ethiopia as well as a number of international and bilateral organizations are well aware of the urgency of the situation and the need for immediate action.

1.2 Programme Background

As a result of a fact-finding and program identification mission (lit. 1) it was proposed that the UNIDO Biofuels Demonstration Program (UC/ETH/82/164) should aim at the identification, demonstration and implementation of a number of biomass based energy technologies in Ethiopia. Following specific projects were identified:

- Demonstration of small scale carbonisation techniques, suitable for the conversion of different types (coffee husk, cotton stalk, maize cob, wheat barley and teff straw) of agricultural residues.

- Demonstration of small scale briquetting technologies, for the production of cooking fuels from different types of carbonized materials.

- Demonstration of cooking stoves fueled by different types of agricultural residues and sawmill wastes.

- Demonstration of a stationary small-size gasification system for lift irrigation fueled by carbonized materials.

- Demonstration of a stationary medium-size gasification system for powering a sawmill fueled by wood waste.

1.3 Scope of report

This report is exclusively concerned with the gasification component of the above Biofuels Demonstration Program. Its objective is twofold:

1) To outline the characteristics of a biomass gasification demonstration project in Ethiopia.

2) To assess the suitability of the locations (lit. 1) that were proposed for biomass gasification demonstration projects.

Those issues will be adressed in the following chapters.

2.0 CHARACTERISTICS OF A BIOMASS GASIFICATION DEMONSTRATION PROGRAMME IN ETHIOPIA.

2.1 Biomass gasification

An overview of the current state-of-the-art in biomass gasification can be found in lit. 2. From the input biomass fuel, gasifiers produce a combustable gas by means of a number of subsequent pyrolysis, oxidation, cracking and reduction reactions. This gas can be used for fueling internal combustion engines when sufficiently free from tars and dust. In case spark ignited engines are used the system can be run on producer gas only, without the need for an auxiliary fuel. However the maximum power output of spark ignition engines when run on producer gas is only approximately half the maximum power output when run on petrol. Diesel engines can only partly run on gas (dual-fuel operation). Normally 15 % of the engine's maximum diesel fuel consumption is continuously needed for ignition purposes. This means that dual-fuel operation is only attractive from an economic point of view when the engine load factor is high. In general diesel engines in dual-fuel operation can deliver approximately 85 % of the maximum power output in full-diesel operation.

Down-draft gasifiers can produce a tar-free gas when operated on specified biomass fuels. Specifications deal especially with parameters like moisture content, ash content, size and bulk density. In general the fuel has to be fairly dry (moisture content below 20 %), show a relatively low ash content (below 5 %), must be of rather uniform size and have a bulk density of approximately 250 kg/m3 or above. Difficulties exist with applications that show large fluctuations in engine load. Especially in case non-carbonized fuels are used those applications can lead to a relatively large tar content in the gas, which may result in engine maintenance problems. Therefore down-draft gasifiers that are to be used under fluctuating stationary and mobile load conditions, are best fueled by carbonized biomass. In case uncarbonized biomass is used as a fuel, base load type constant power applications are recommended.

In recent years interest has developed in the use of briqueted fuels in down-draft gasifiers. Varying results are reported and, apart from fuel characteristics, seem to depend to a large extend on the type of briqueting technology applied. In general piston and roller type briqueting presses produce fuel of insufficient quality for use in down-draft gasifiers. Screw-type presses, depending on fuel characteristics, may produce briquets that can be usefully employed.

Up-draft gasifiers produce a tar containing gas which must be cleaned before engine application is possible. This results in the production of a tar containing condensate which may present disposal problems. However this type of gasifier is less sensible to fuel specifications then the down-draft gasifier and also more suited to fluctuating engine loads. Especially for powering sawmills, up-draft gasifiers have been in operation in Europe on a large scale. At least at one site equipment is still in operation and has been so since 1903.

Fluidized bed gasifiers are especially suited for gasification of fine grained materials. Drawbacks are the rather high tar content of the gas, the incomplete burn-out of carbon and the poor response to load fluctuations. Because of the control equipment necessary to cater for the latter difficulty, fluidized bed gasifiers have an economic minimum capacity of approximately 500 kW(el). In view of the decentralized nature and relatively small scale of the energy production and consumption in Ethiopia, implementation of fluidized bed gasifiers is not foreseen in the near future.

2.2 Fuel availability

In Table 1 (lit. 3) an estimate of the amount of agricultural residues as produced in Ethiopia durir the 1984/85 harvesting season is presented. The figur take alternative uses (grazing, cattle feed, soil repleishment and direct energy use) into account.

Type of residue	amount produced (t/yr)
Coffee wastes	220,000
Cotton stalks	116,000
Wheat straw	
National	701,400
State farms	79,800
Corn residues	
National	2,270,500
State farms	46,000

Table 1. Ethipia residue availability, 84/85 season (lit.3)

Due to collecting difficulties, only the residues which are produced at State Farms or central processing facilities are of interest for energy generating purposes. Therefore it may be surmised that the following quantities of agricultural residues are effectively available on an annual basis:

- coffee husk : 220,000 t/yr
- cotton stalks : 116,000 t/yr
- wheat straw : 79,800 t/yr
- corn cobs : 165,600 t/yr

In a number of sawmills wood waste in the form of slabs, offcuts and sawdust is produced. Except for sawdust, the major part of those residues is used for domestic purposes. However there are a small number of isolated sawmill sites, where no alternative use for the wood residues exists.

Wood residues in the form of branches, trunks and other lumber wastes are also produced in the field as a result of logging operations. Those residues are normally burnt in the forest as a means of disposal.

Table 3 (lit. 1) presents an overview of wood waste residues which are not used at present, and as such would be available for gasification purposes. However it must be remar-ked that the twigs, branches and other lumber residues present a collection problem which may be difficult to solve in an economic way. Sawdust (either in an uncarbonized or in a carbonized form) must be briquetted or pelletized before it can be used in down-draft gasifiers. Only up-draft gasifiers can utilize sawdust in unprocessed form.

Wood waste	tons/year
Twigs, leaves etc.	265,000
Lumber wastes	26,250
Sawdust	17,750
Total	309,000

Table 2. Forest waste availability 1982 (from lit.1)

2.3 Fuel suitability

From a gasification point of view the most interesting type of residue is corn cobs, which can be used, both in a carbonized and in an uncarbonized form, in down- and up-draft gasifiers.

In case yearly produced amount of corn cobs where to be used for gasification in an uncarbonized form, this would result in the production of approximately 120,000 MWh/yr and substitute approximately 36 million liters of diesel fuel per year. If alternatively, the cobs where first to be carbonized (conversion efficiency 20 % on weight basis), subsequent gasification would lead to the production of approximately 40,000 MWh/yr or the substitution of approximately 12 million liters per year of diesel fuel.

Coffee husks may be gasified in a gasifier of classical (fixed bed down- or up-draft) design after briquetting. Cotton stalks are unsuitable because of insufficient bulk density, but can be used after briquet-ing by means of a screw press. Wheat straw, even in a briqueted form is insuitable because of high ash content which leads to a severe degree of slagging in classical gasification equipment (lit. 4).

The wood residues that are available on isolated sawmill sites consist out of slabs, off-cuts, chips and sawdust. In view of the fluctuating power needs of the mill and the characteristics availability of this fuel, only the installation of an up-draft gasification system can be envisaged. As an alternative it is also possible to equip the mills with single cylinder reciprocating steam engines of the type that have been in use in a number of mills in the Darrar region since at least 25 years. In cases where there is sufficiently waste available on site, the decision as to which system to install is not governed by conversion efficiency considerations but depends entirely on relative economics.

2.4 Applications

In the rural areas of Ethiopia, a large number of stationary small and medium-size diesel engines are in operation, both for direct mechanical energy purposes as for electric power generation. Applications are varied and include power provision to sawmills, coffee processing facilities, small-scale lift irrigation systems as well as electricity generation on state farms.

Because of the constant engine load, from a gasification point of view, the most attractive and simple application is certainly lift irrigation. In case a suitable location especially with respect to adequate fuel provision can be identified (see below), a gasifier demonstration project in this sector should be implemented.

From the point of fuel availability, electric power generation on maize growing state farms seems attractive. However, before a demonstration project can be proposed, detailed information as to the power generation structure and daily and seasonal power need fluctuations must be gathered and evaluated.

Sawmills in Ethiopia are relatively small, employing installed power capacities ranging from 80 - 150 kW. Fig. 1 (lit. 5) presents a comparison of of unit energy costs from gasification systems as compared to reciprocating steam systems in relation to the installed capacity. Clearly energy costs from gasifiers are approximately 20 % below energy costs generated by means of steam. A comparison of initial investment costs (fig. 2) also shows that in the power range under consideration, the initial investment in a gasifier system is approximately 35 % below the cost of an equivalent steam system. For this reason there seems to be scope for demonstrating an (up-draft) gasification system in an Ethio-

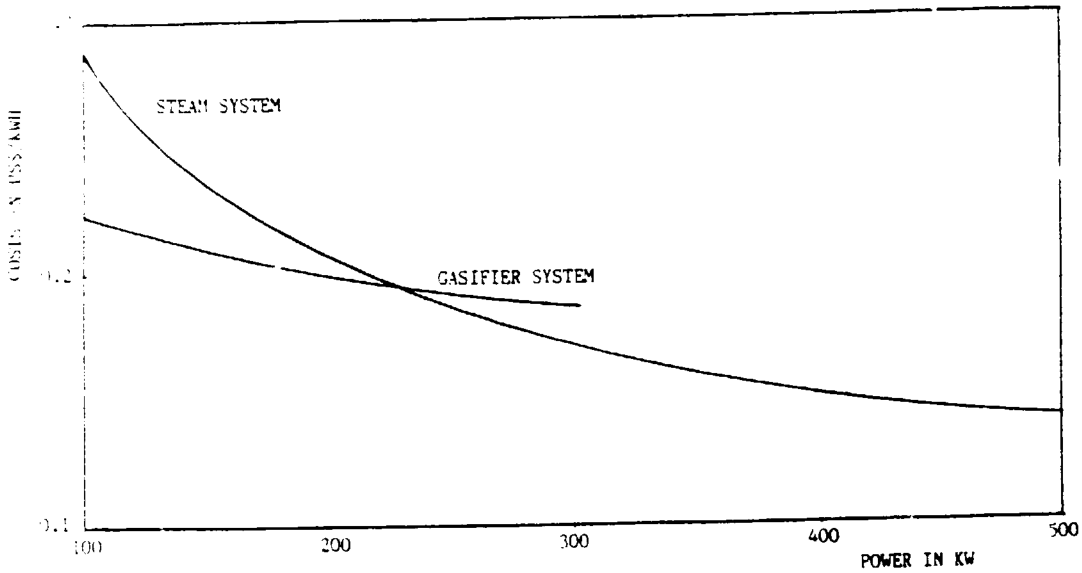


Fig. 1: Energy costs as function of power output for gasifier/steam systems

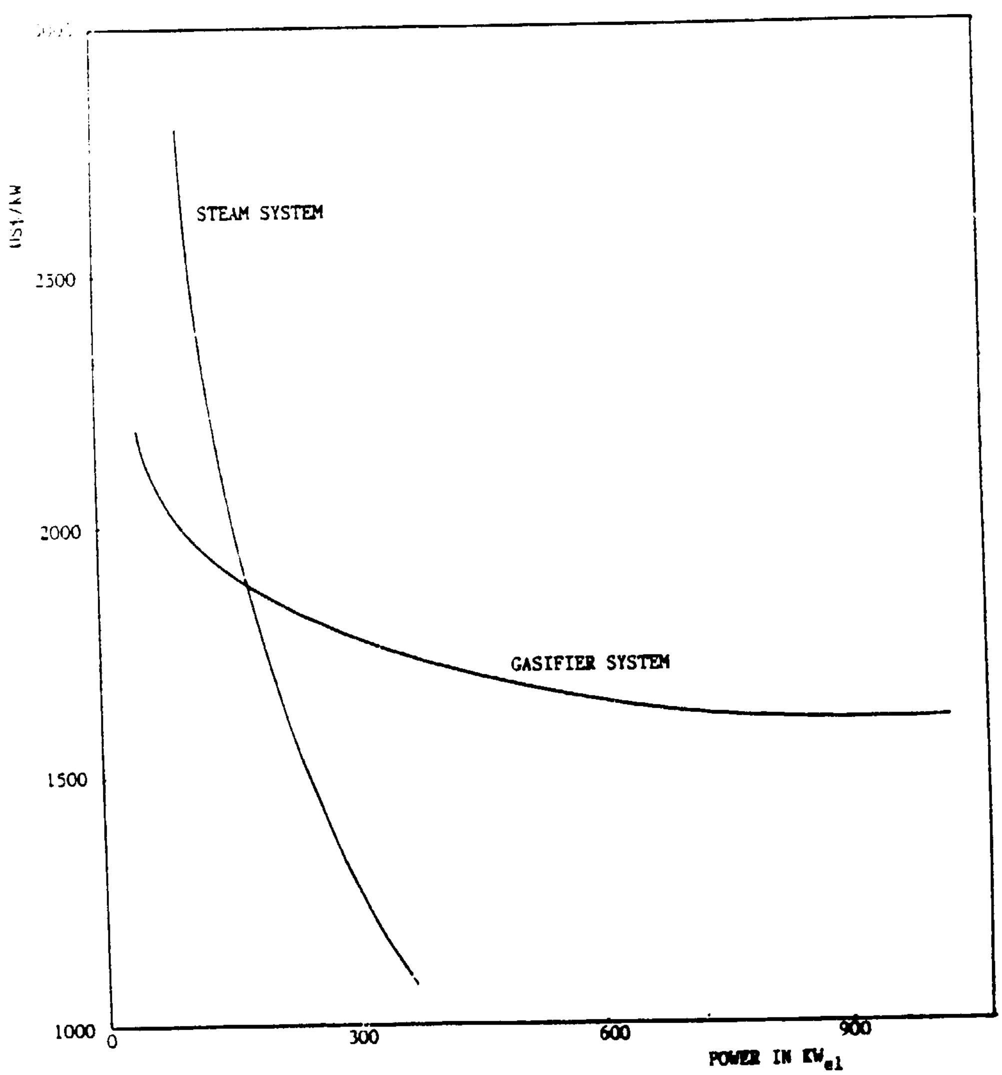


Fig. 2: Investment costs of gasifier/steam systems

pian sawmill. However, at the moment the number of sawmills producing wood wastes without alternative uses, is not clear and may be very small. Because a demonstration programme must aim at further technology dissemination, installation of a demonstration gasification system at a sawmill can only be proposed, in case a sufficient number possible sawmill sites can be identified.

Finally a large number of tractors are in use on state farms, consuming considerable amounts of fuel. In view of the fact that possible fuels are available on-site, it is proposed that the possibility of demonstrating a mobile (corn cob charcoal) gasification system mounted on a tractor be further studied.

2.5 Gasification know-how and capability

In order to arrive at a usefull project evaluation, a demonstration project should not only be installed at a suitable site, but also must be consistently monitored during a prolonged (approximately 6 months or more) period. Adequate monitoring asks for a number of specialized instruments, which should be provided by the project. Besides the national organisation responsible for monitoring must develop capability and know-how, both in the gasification field as well as in operating and maintaining the special measuring equipment needed for monitoring purposes. Therefore it is necessary that a manpower training scheme be established, and it is proposed that a designated engineer is sent for a 3 months overseas training at a suitable institute. In view of its involvement both in biomass gasification projects in developing countries as well as in gasifier monitoring programs, the Biomass Technology Group of Twente University of Technology, Enschede, The Netherlands, may be a suitable institute for conducting this training programme.

2.6 Conclusions

In view of the above, the following plan of action is proposed:

- Purchase, transport and installation of a small charcoal gasification system for irrigation purposes (for project specification see chapter 3 and Annex 1).

- Purchase of a set of adequate gasifier monitoring instruments (see Annex 1).

- Execution of a biomass gasification and monitoring manpower training program at a suitable foreign institute (one engineer for three months).

- Commissioning of a feasibility study concerning:

  1) the viability of power generation on state farms by means of corn cob fed down-draft gasification systems.

  2) the viability of energy supply to small sawmills by means of wood waste fed up-draft gasification systems.

  3) the viability of operating tractors on state farms by means of gasifiers fueled by corn cob charcoal.

A workplan and bar chart of proposed activities is incorporated in Annex 2.

3.0 SUITABILITY OF SITES PROPOSED FOR BIOMASS GASIFICATION PROJECTS

3.1 General

During an initial fact finding mission (lit. 1) two sites were tentatively identified as possibly suitable for implementation of a gasification demonstration project. The first possible location was one of the small scale irrigation projects which are installed in Lake Ziway area by Arsi Rural Development Unit of Asela. On this location a small charcoal fueled gasifier powering a waterpump was foreseen. The other possible site identified was the small sawmill situated on the grounds of the Forestry and Wild Life Resources Institute at Wondo Guenet. In this case installation of a wood waste gasifier, fueling the mill's existing diesel engine was proposed.

Objective of the mission was to confirm, in co-operation with the Ethiopian National Energy Committee (ENEC), the suitability of the above sites. In case locations were found suitable, the expert was required to draw up detailed specifications for the equipment that must be purchased for the demonstration projects.

3.2 Small scale irrigation projects in Lake Ziway area

3.2.1 Arsi Rural Development Unit (ARDU), Asela

ARDU is situated in Asela, approximately 160 km to the south of Addis Abeba. The Unit is responsible for integrated rural development including activities like training of small farmers and peasant associations in the use of agricultural implements as well as for the provision of infra-structure like the building of feeder roads and the establishment of small irrigation projects for vegetables and fruit production. The Unit runs a Rural Technology and Promotion Centre which is equiped with a small metal and wood working shop for the manufacture of farm implements and domestic appliances. The Unit's Irrigation Brigade has a small metal working shop (mainly welding and steel cutting) at its disposal. In order to maintain the Unit's lorries and cars, a garage with limited overhaul and repair facilities is available.

Recently the area to be covered by the Unit's activities has been considerably expanded. As a result of this enlargment of scope ARDU is suffering from an acute lack of trained manpower, which has led to a lower level of service to farmers and peasant associations. Formerly ARDU personnel used to visit regularly the different project sites in order to supply assistance in case of malfunctioning of equipment. At present, peasant associations are largely expected to cater for their own needs, including repair and maintenance. Effectively this means that peasant associations have to organize spare part supply lines from Addis Abeba as well as means of getting equipment in need of repair to and from the capital. Whether peasant associations under current circumstances have sufficient financial and organisational capacity to keep their equipment in running order is doubtful.

The overall situation is such, that both from a point of view of trained technical manpower as well as from a point of view of workshop facilities and spare parts provision, ARDU's back-up capacity is very limited. The latter factor can be balanced by endowing a gasifier irrigation system at one of ARDU's irrigation projects with ample quantities of spare parts. But besides this, the demonstration project needs also a definite commitment from ARDU, that at least during the six initial months of the project, technical back-up personnel for maintenance and repair as well as transport to and from Addis Abeba for equipment in need of repair, will be made available. It is necessary that this commitment is backed by the Ministry of Agriculture.

3.2.2 Golibee small scale irrigation scheme

3.2.2.1 Geography and access

Golibee small scale irrigation scheme is situated at a distance of approximately 2.5 hours driving from Asela, at the western shore of Lake Ziway. To the expert's knowledge, this area has not recently been troubled by disturbances.

Access to the site is by means of a rather difficult dirt road strictly limited to 4-wheel drive vehicles and lorries. Because this road is probably not negotiable in the rainy season, installation of gasification equipment must be done during the dry season which starts in september.

3.2.2.2 Situation and personnel

The irrigation project produces fruits and vegetables during the dry season. At the time of the expert's visit the irrigation area was only partly cultivated. Reason was the breakdown of the 15 hp Yanmar diesel engine/irrigation pump combination, which with the project was initially equiped. The engine cannot be repaired because of unavailability of spare parts. Irrigation activities have recently been resumed on basis of a 14 hp Lombardini diesel engine/pump combination, which is on loan from a neighbouring peasant association. The village chairman is of the opinion that this situation is rather insecure and is looking for irrigation equipment that is unconditionally at the disposal of the Golibee peasant association.

The diesel engine/pump combination is run by a village operator, who received training under ARDU's irrigation implementation scheme. Naturally, the level of technical skill attained, is limited to operation and simple maintenance (lubrication oil change). The expert is of the opinion, that assuming a proper gasifier design and a suitably defined fuel, from a technical point of view the operator should be able to run a gasification system. Because however, the operation of such a system is more time consuming and sometimes a bit cumbersome as compared to a diesel engine, both the Golibee peasant association, ARDU as well as ENEC should try to devise measures to compensate the village operator for this additional workload.

3.2.2.3 Suitability of application

As explained in Chapter 2, because of constant engine load, from a technical point of view waterpumping constitutes an excellent application for a down-draft gasification system.

According to the village chairman the system is operated for approximately 8 hours per day (5 hours in the morning and 3 hours in the afternoon). This means that , both in the morning as well as in the afternoon, the periods of uninterupted functioning of equipment are sufficiently long to make gasification potentially attractive.

From an economic point of view a comparison must be made between the current cost of diesel fuel and charcoal in Golibee. According to the village chairman at present on-site cost of diesel fuel (when available) is 0.80 Birr/l. Alternatively wood charcoal manufactured in Golibee area can be sold at approximately 0.35 Birr/kg. In a conservative estimate two kg of charcoal, when gasified and used in a spark ignition engine, will provide power equivalent to the one liter of diesel fuel as consumed by a diesel engine. Therefor the actual saving in money terms to the peasant association would amount to at least 10-15 %. In case corn cob charcoal (for which there exists no commercial market in Golibee at present) was to be used, the actual gains in direct money terms to the peasant association would amount to an estimated 80-90 % of the current diesel fuel costs (taking into account the costs of manufacture of corn cob charcoal). In addition, for the peasant association, there would be the argument of increased self-reliance and independance of incontrollable outside fuel supply. From the national point of view considerable savings in foreign currency are possible when gasification systems of this type are to be implemented on a significant scale.

3.2.2.4 Fuel availability

Wood charcoal is produced in Golibee area by means of the earth pit method. As mentioned above, this charcoal is sold for domestic use in urban areas at a price of approximately 0.35 Birr/kg. Daily diesel fuel consumption for irrigation was estimated by the village chairman at approximately 10 liters per day. The accuracy of this information may be somewhat questionable but still, both from the order of magnitude of this fuel consumption figure as well as from an estimation of the water amounts actually pumped by the currently installed pumping system, the expert comes to the conclusion that daily charcoal consumption for irrigation purposes, will be in the order of 20-30 (max) kg of wood charcoal. It is the opinion of the expert (confirmed by the village chairman) that this level of daily wood charcoal consumption is only a relatively small part of production, and for this reason - quantity wise - no problems as to fuel provision to a charcoal gasification system are foreseen.

The quality of the charcoal produced by means of the earth-pit method is somewhat questionable for gasification purposes, both from a point of view of sand contamination (slagging) as from size uniformity. It is for this reason that besides the gasification system, the provision of one or two small oil-drum charring systems and two char sizing sieves is necessary (see Annex 1).

The higher slopes around Lake Ziway are to a large extent under maize. For this reason there are plenty of inutilized maize residues available in the area. Because of the possibility to carbonize maize cobs in the above mentioned drum charring system, an irrigation charcoal gasification system in this area, will open the possibility to demonstrate the possibility of using carbonized maize cobs for powering irrigation water pumping systems.

3.2.2.5 System capacity

Based on the diesel fuel consumption figures that were provided for the Lombardini system that is currently in use, the expert is of the opinion that the engine capacity of the Golibee irrigation system is probably fairly underutilized; in practice the actual power demand of the Golibee irrigation scheme under normal circumstances probably does not exceed 4-7 kW. However, both in order to avoid a possible disappointment in comparison to the system currently in use, as well as to take into account the elevated altitude of the site (above 2,000 m), a system of 15 hp capacity will be specified. Because the system will be operated on wood or corn cob charcoal, underutilization will have no influence on the tar content of the gas.

3.2.3 Dodicha small scale irrigation system

The Dodicha irrigation scheme is located on the northwestern shores of Lake Ziway, approximately 5 km from the asphalt road that links Addis Abeba to Awassa and ultimately Nairobi. Driving distance from ARDU's Asela headquarters is approximately four hours (dry season circumstances; 4-wheel drive vehicle). As the project is installed under ARDU's responsability, it shows the same general characterics as Golibee, i.e. a 15 hp Yanmar diesel engine waterpump combination is installed for irrigating the fields. Apart from this a 2 kW photovoltaic waterpumping system has been in operation for approximately one year.

Although Dodicha is more accessible than Golibee, the expert is of the opinion that this site is less suitable for installation of an irrigation gasification demonstration plant for the following reasons:

- On the Awassa road side of Lake Ziway, increased deforestation is apparent. For this reason the access of the Dodicha scheme to wood charcoal (which is of importance in the beginning of the demonstration project; see below) seems limited.

- The enlarged distance to ARDU's headquarters in Asela (4 hours under dry season conditions) will make the anticipated technical back-up as well as monitoring of the project more difficult.

3.2.4 Conclusions

3.2.4.1 General

The expert is of the opinion that the installation of a waterpumping gasification system for demonstration purposes at Golibee irrigation scheme is useful and feasible, in case a number of boundary conditions (see below) can be fulfilled. Because of the remoteness of the site and the low level of technical skills that are locally available, the expert proposes that the system initially be run on wood charcoal manufactured by means of a drum charring system on site. Once the operator(s) have sufficient experience with this easiest of all gasification fuels, the switch to the use of corn cob charcoal should be made.

3.2.4.2 Boundary conditions

The demonstration project is likely to run into problems in case one or more of the following boundary conditions are not fulfilled:

1. The project must have a budget to cover costs of:
   - maintenance and repair of equipment,
   - transport of equipment in need of repair to Asela or Addis Abeba,
   - transport of service and advisory personnel to and from Golibee site.

   This may imply that purchase of a 4-wheel drive vehicle must be incorporated into the demonstration project's budget.

2. The project must incorporate a very heavy training component, incorporating personnel from ENEC, ARDU as well as the village operator(s).

   The theoretical aspects of gasification will be covered in depth during the 3-months' training course proposed for a qualified engineer from ENEC (see Chapter 2).

   The practical training as to operation and maintenance of the waterpumping gasification system to ENEC and ARDU personnel and to village operator(s), will have to be supplied in Ethiopia by the manufacturer of the system as part of his contract (see Annex 2, Specification of charcoal gasification system for Golibee irrigation project).

3. Because of ENEC's limited possibility to control the proceedings at Golibee from Addis Abeba, it is absolutely essential that ARDU makes technical back-up personnel available, at least during the six initial months of the demonstration project. In view of ARDU's current situation a commitment in writing, confirmed by the Ministry of Agriculture will be necessary.

4. The project budget must allow for the possibility to call on expatriate gasification expertise, especially during the first months of the demonstration project.

5. Demonstration projects are only useful when they are adequately monitored. The proposed overseas training of the ENEC engineer will lead to the capability to execute a detailed monitoring program on the Golibee system. ENEC must commit itself to execute (in co-operation with ARDU) a program of this kind. Instrumentation for monitoring gasification systems, must be incorporated in the budget for the project.

3.2.4.3 Specifications

In Annex 1 is to be found a detailed set of specifications dealing with:

- waterpumping gasification system design requirements,
- requirements for transport and packaging,
- requirements for installation and commissioning,
- requirements for training of personnel,
- requirements for project monitoring.

3.3 Wood waste gasification systems for powering sawmills

As has been described in Chapter 2, the majority of wood residues that are produced at sawmill sites are put to use in the domestic sector for cooking purposes. In effect there are only two exceptions to this rule:

(1) Normally the sawdust that is produced during wood and timber production is not used and therefore available on-site in large quantities.

(2) A number of mills are located in very isolated places where no effective demand exists for wood residues. Because transport is not attractive for economic reasons, those mills, besides sawdust, have effectively access to slabs and off-cuts. Unfortunately, for two reasons, the number of mills in this position is not easily established:

- Because of the high prices that can be made for wood fuels in more or less urbanized areas, a fluid situation exists as to the financial feasibility of extracting wood residues from isolated sites. Therefore at present, no hard data are available with respect to the number and location of sawmills producing access of residues in slab or off-cut form.
- A number of isolated sawmills are already biomass powered since a long time, by means of reciprocating single cylinder steam engines in the 125-175 kW range (see below). Unfortunately it is difficult to gather data as to the number of mills operated in this mode as well as to the current operational status of those systems (which are mostly more than 40 years old).

In order to assess the feasibility of installing a gasifier system ar a sawmill site, the expert visited a number of locations which are described below.

3.3.1 Wondo Guenet (FRI) sawmill

In a former fact-finding mission (lit. 1), this location was considered possibly suitable for gasifier installation. The mill is situated on the grounds of the Forestry and Wildlife Resources Institute (FRI) at Wondo Guenet. The mill's main sawing blade is directly coupled to a Caterpillar D 311/H dieselengine which is run at 1800 rpm. This very small mill is used for demonstration and student training purposes as well as for test sawings. In the past the mill has been very little used, because of unavailability of sawlogs. Mr. Roger Salomonsson (lecturer utilization and engineering) estimates that in the next semester about 100 logs will be sawn. In a longer time frame a yearly operational period of 3 months (including some commercial sawing) is anticipated.

Because of the current and future low utilization factor of this mill as well as the uncertain log and fuel supply, the expert is of the opinion that installation of a gasification system, both from a point of view of technology demonstration as well as for economic reasons, makes no sense. The conclusion is that a more suitable sawmill site must be identified. A number of SIDA sponsored sawmills are in the procedure of being transported up from Assab and are anticipated to start operation in the middle of 1986. At present information as to their actual installation location is not available to the expert. Therefore it is advised to find out details of those mills, and assess their future locations with respect to the feasibility of gasifier installation.

3.3.2 Kibri Mengist sawmills

Working on information that in Kibri Mengist area a number of isolated sawmills were in operation, the consultant proceeded to this location, which is at a distance of approximately 4 hours driving from Wondo Guenet.

However, one sawmill at Kibri Mengist turned out to be dismantled and transported to another location, while the second mill will be dismantled soon. Reason is the increasing lack of sawable logs in the area. Possibly the third mill in the area will remain in operation. During the visit it became clear that at present, wood residues like slabs and off-cuts are completely sold into the local market. Some of the workers of the mill take the sawdust, which at present has no commercial value, home.

In view of the insecure future of logging and sawmilling in Kibri Mengist area, as well as of alternative use and decreasing availability of wood residues, the expert is of the opinion that in Kibri Mengist area no scope exists for installation of a wood waste gasifier.

3.3.3 Dindin and Darrar sawmills

Based on information provided by the Sawmilling and Joinery Enterprise, which is under the Ministry of Agriculture, the expert visited two rather remote sawmills in Harrar region. The sites (Dindin and Darrar) are located at a distance of approximately 6 hours driving from Addis Abeba. The last 30 km (from Metta Hara to Dindin) are extremely bad and certainly not negotiable in the wet season. Because of this reason extraction of residues from those mill sites is not practical. As there is also no village situated in the neighbourhood of the mills, ample sawmill residues (slabs, chips and sawdust) are available on site.

At Dindin those residues are presently not utilized. For the moment the mill is powered by a Caterpillar turbo charged diesel engine, type 3406, delivering a maximum continuous power output of 240 hp at 1500 rpm. It is however, interesting to note that up to about 6 months ago, the mill was driven by a single cylinder reciprocating steam engine, build by Esterer AG, Altoetling, Bavaria, Germany and producing 135 kVA at 750 rpm (steam pressure 9 bar). The expert estimates that this engine is at least 40 years old, and according to the mill manager it has operated satisfactorily up to recently. Because of the ample availabilty of slabs and off-cuts for fueling the boiler, the mill management wants to revert to the use of the steam system, and is confident that the mill's technicians will be able to repair and start up the steam engine in a matter of weeks. Awaiting this recommission-ing considerable quantities of wood residues are being stored as boiler fuel.

At Darrar the sawmill is at present powered by a single cylinder reciprocating steam engine with a capacity of approximately 175 hp. The boiler is fueled by wood residues, mainly reduced slabs. The plant has been in operation for a long time to the full satisfaction of the mill management.

Because both the mills in Dindin and Darrar are or will be soon again, completely fueled by wood wastes, the expert is of the opinion that both sites are not suitable for implementation of a demonstration wood waste gasification program.

3.3.4 Conclusions

From the above site descriptions it will be clear that the expert has not been able to identify a suitable sawmill site for installation of a wood waste gasification unit. The reasons for this are threefold:

- Because of a shortage of sawable logs in a number of traditional logging areas, the sawmill sector in Ethiopia is in a state of reorganisation. Quite a number of mills have been or soon will be dismantled, the equipment awaiting transport to locations were it can be more effectively used. Unless there is adequate information as to the life-time expectancy on a given location of the different mills, it is not possible to propose the installation of a wood waste gasifier.

- At present, the residues from most of the mills that are still operating, are utilized in the domestic sector for cooking purposes. This means that the only residue effectively available on those locations is sawdust. Therefor, in the opinion of the expert, the only gasification equipment that could be implemented on those sites are up-draft gasifiers of traditional design

- Because of little domestic demand, a number of sawmills in very isolated locations, produce (in addition to sawdust), wood residues for which no alternative use exists. The expert has not been able to get information as to the number of locations that fall in this category. Also, in view of the equipment reallocation policy and the new sawmills that are in the procedure of being installed, the actual number of sites may be undefined for the moment.

Because of the above reasons, the expert has some doubts as to the usefulness of planning a gasification demonstration project in the Ethiopian sawmill sector. In order to be cost effective, expensive demonstration projects must be set up because there is a reasonable scope for wide-spread implementation and a possibility for considerable savings in liquid fossil fuels. It is not clear, that at present this is indeed the case in Ethiopia.

Therefore (see Chapter 2 and Annex 2) a more detailed study as to the viability of demonstrating a wood waste gasification system at a sawmill site is proposed. For reasons of cost-effectiviness this study should be combined with the proposed studies on stationary maize cob gasification systems for power generation on maize farms and the use of carbonized maize cobs for mobile (tractor) gasifier applications.

4.0 BUDGET

The expert estimates the costs of a programme as proposed in Chapters 2 and 3 as follows:

1. Golibee charcoal gasification demonstration project for irrigation

Cost item	amount (US $) jan. '86
- Gasifier irrigation installation ex-factory (see Annex 1)	24,600.00
- Packaging and transport (Assab)	3,250.00
- Spare parts (incl, charcoal sieves)	3,690.00
- Installation (21 days)	
- salary installation engineer (US $ 230/day)	4,830.00
- travel (Addis Abeba)	1,480.00
- allowances (7 days US $ 100; 14 days US $ 30)	1,130.00
- Training (17 days)	
- salary trainer (US $ 430/day)	7,310.00
- travel (Addis Abeba, Vienna)	1,730.00
- allowances (12 days US $ 100; 3 days US $ 80)	1,440.00
- Contingency (incl. possible ex-patriate assistance)	10,000.00
Sub-total	59,460.00

2. Training and monitoring

- Overseas training ENEC engineer	
- travel	1,480.00
- allowances	3,200.00
- tuition fee	3,000.00
- Monitoring	
- equipment (incl. transport)	4,650.00
- project maintenance & transport budget (incl. car)	10.000.00
Sub-total	22,330.00

3. Feasibility studies

- maize cob gasification on state farms for power generation (14 days)	9,100.00
- wood waste gasification at sawmill sites (8 days)	5,200.00
- corn cob charcoal gasification for mobile purposes (5 days)	3,250.00
- travel costs consultant	1,480.00
Sub-total	19,030.00

4. Grand total

Sub-total 1.	US $	59,460.00
Sub-total 2.	US $	22,330.00
Sub-total 3.	US $	19,030.00
Grand total	US $	99,820.00

5.0 LIST OF REFERENCES

(1) Prem D. Grover, Thermochemical conversion of biomass materials for energy production, UC/ETH/82/164, ETHIOPIA, Technical Report prepared for the Government of Ethiopia by the United Nations Industrial Development Organization, June 1984

(2) H.E.M. Stassen, W.P.M. van Swaaij, Application of biomass gasification technologies in developing countries, page 705-714, Energy from biomass (2nd E.C. Conference), Ed. A. Strub, P. Chartier, G. Schleser, Applied Science Publishers, London & New York, 1983

(3) Agricultural residue briquetting pilot projects for substitute domestic and industrial fuels in Ethiopia, Energy Department, The World Bank, Washington D.C., 1985

(4) A. Kaupp, J.R. Goss, State-of-the-art for small scale (to 50 kW) gas-producer engine systems, U.S. Agency for International Development, Science and Technology Division, Washington D.C. 20523, 1981

(5) Technischer und wirtschaftlicher Vergleich von kleinen Anlagen zur Vergasung/Verbrennung van Holz und Holzaehnlichen Biomassen, Gesellschaft fuer Entwicklungstechnologie mbH, Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) mbH, Eschborn, West Germany, 1984

ANNEX 1

SPECIFICATION OF CHARCOAL GASIFICATION SYSTEM FOR GOLIBEE IRRIGATION PROJECT

1.1 Scope of project

The scope of this demonstration project shall include the following:

1.1.1 The supply of a 15 kW(mech) charcoal fueled gasification system for water pumping application.
1.1.2 The testing of item 1.1.1 at manufacturer's site
1.1.3 The seaworthy packaging and transport to harbour of the item under 1.1.1.
1.1.3 The installation at Golibee of item 1.1.1.
1.1.4 The commissioning at Golibee of item 1.1.1.
1.1.5 The execution of a personnel training program
1.1.6 The execution of an equipment monitoring program

1.2 Design requirements

1.2.1 General

Supplier to take note that the gasifier/water pumping installation will be installed at a site above 2,000 m altitude.

1.2.2 Gasgenerator

1.2.2.1 The supplier shall deliver a fixed bed gasifier plant to be fueled by wood charcoal. The type of unit proposed (down draft or cross draft), shall be capable of producing adequate quantities of clean gas with a heating value above 4,000 kJ/nm3, for producing a minimal maximum power output of 15 hp (11.25 kW), by means of a spark ignition internal combustion engine.

1.2.2.2 The plant shall work efficiently requiring only routine maintenance by unskilled labour. Supplier to state operation and maintenance requirements in manhours per plant operating hour.

1.2.2.3 The fuel feeding system and ash removal system of the plant will be manually operated.

1.2.2.4 The gasifier will be started up by means of a atart-up fan powered by an electric motor. This motor will be powered through the engine alternator/battery system. During start-up the engine will be operated on petrol.

1.2.2.5 All ancillary equipment for gas cooling and cleaning will be included in the supply.

1.2.2.6 Supplier to state and guarantee that under circumstances of 7.5 and 15 hp(mech) load and in case specified charcoal is used:

- gas dust content after gas cleaning will be below 25 mg/nm3

- gas tar content will be below 100 mg/nm3

A test run to this effect will be executed at the manufacturer's premisses and be attended by the buyer or his representative.

1.2.2.7 Supplier to state and guarantee the charcoal consumption of the plant at different loads.

1.2.3 Engine

1.2.3.1 Type of engine

Plant to be powered by a spark ignited producer gas engine at least capable of producing a continuous power output of 15 hp (mech).

1.2.3.2 Ancillary engine equipment

. The engine shall come with the following ancillary equipment:

- manual speed control

- electronic ignition system (24 V)

- a provision for ignition time adjustment during operation

- an automatic shut-down device in case of lubrication oil pressure failure or high lubrication oil temperature.

- an automatic shut-down device in case of high coolant temperature.

1.2.4 Irrigation pump

Centrifugal waterpump for irrigation purposes:

- suction head approximately 2 m
- pressure head approximately 10 m
- capacity approximately 3 l/sec
- suction inlet diameter 4"
- discharge outlet diameter 3"
- auxiliaries:
  - 10 m heavy duty rubber water hose 4" diameter
  - 10 m heavy duty rubber water hose 3" diameter
  - 6 hose clamps 4"
  - 6 hose clamps 3"

1.2.5 Overall installation

Gasgenerator, engine and waterpump will be build on a sturdy trailer, so that the whole unit can be transported by means of a tractor or lorry through rough terrain.

1.2.6 Plant instrumentation

Following minimum plant instrumentation is required:

- nipples allowing pressure difference measurement over gasifier by means of a 2-leg water manometer
- nipples allowing pressure differnce measurement over the gas filter section
- gasifier gas outlet temperature meter
- engine manifold inlet temperature meter
- engine operating hours meter
- engine inlet manifold vacuum gauge
- engine speed (rpm) meter

Moreover after the last filter section a provision for dust-/tar sampling must be included. For this purpose a 1.5" BSPT inner thread tube has to be installed in a 90 degrees elbow bent after a straight length of pipe of at least 10 times the pipe diameter.

1.2.7 Charcoal preparation

Charcoal from wood and corn cobs will be produced on site by means of a drum charring systen to be provided by tne project. Supplier to include in the delivery the necessary means (i.e charcoal sieves) for bringing up this charcoal to the necessary size specification.

1.2.8 Spares and Tools

1.2.8.1 Commissioning spares

Supplier to provide spare parts recommended by him during all stages of installation and commissioning.

1.2.8.2 Operational spares

Gasifier, engine and waterpump shall come with spare parts required for two years of operation. The list of recommended spare parts shall be based on the supplier's experience, and take into account the remote location of the project and the low level of technical skill. The list of spare parts shall therefore deal with the following:

- wear, corrosion or erosion during normal operation.
- failure that would cause shut-down of the equipment
- damage or breakage during routine maintenance or inspection of the equipment.
- special consumables (like filters, engine oils etc) which may not be readily available in Ethiopia.

The cost of the above spare parts will not exceed 15 % of the cost of the installation.

In Annex 5 an example is presented of a spare parts list judged sufficient by the expert.

1.2.8.3 Tools

Supplier to submit a complete list of tools and instruments required for maintenance of the equipment.

1.2.9 Documentation

Four full sets of specifications, drawings, workshop manuals, repair manuals etc, shall be made available to ENEC during the equipment installation and commissioning phase. This documentation shall include at least all basic design criteria, general arrangements and outline dimensions, instrumentation connections, dimensional piping corrections, electrical wiring and connection requirements, cross sections and material list, details of auxiliary equipment and performance curves.

1.3 Packaging and transport

1.3.1 Any equipment requiring site painting shall be adequately protected from corrosion during shipment and/or storage.

1.3.2 All equipment shall be packed in containers, crates or cartons that are dust tight, moisture resistant and strong enough to protect the parts during transport, ware house, port and job site handling. The packaging shall be suitable for at least six month storage in open air circumstances.

1.3.3 Each container crate or carton shall be clearly marked with equipment name(s) or item number(s), and shall be suitably numbered and accompagnied by a detailed packing list.

1.4 Installation and commissioning

1.4.1 Supplier shall be responsible for commissioning of the plant and provide all specialist labour required. Estimated specialist labour manhours required for installation and commissioning will be detailed and their cost indicated.

1.4.2 During commissioning tests the equipment will be required to operate:

- 8 hours on full load (15 hp)
- 8 hours on half load (7.5 hp)
- 8 hours on quarter load (3.25 hp)
- 2 hours on 10 % overload (18 hp)

1.4.3 Supplier to state in an early stage of the contract any specific facilities he requires for installation and commissioning.

1.5 Training of personnel

1.5.1 In view of the remoteness of the location it is important that the training program is comprehensive and thorough, so that the need to call for outside help, except in the case of a major breakdown, is eliminated.

1.5.2 Supplier to submit an outline of a detailed training program for review by ENEC. This outline shall state to which level of capabilities and skills the training program will lead. Besides the estimated number of specialist manhours required for training activities as well as their cost must be detailed.

In Annex 6 an outline of a training program judged suitable by the expert is presented.

1.5.3 The training must be executed immediately after plant commissioning. The person carrying out the training must be fluent in English and preferently be an engineer.

1.6 Monitoring equipment

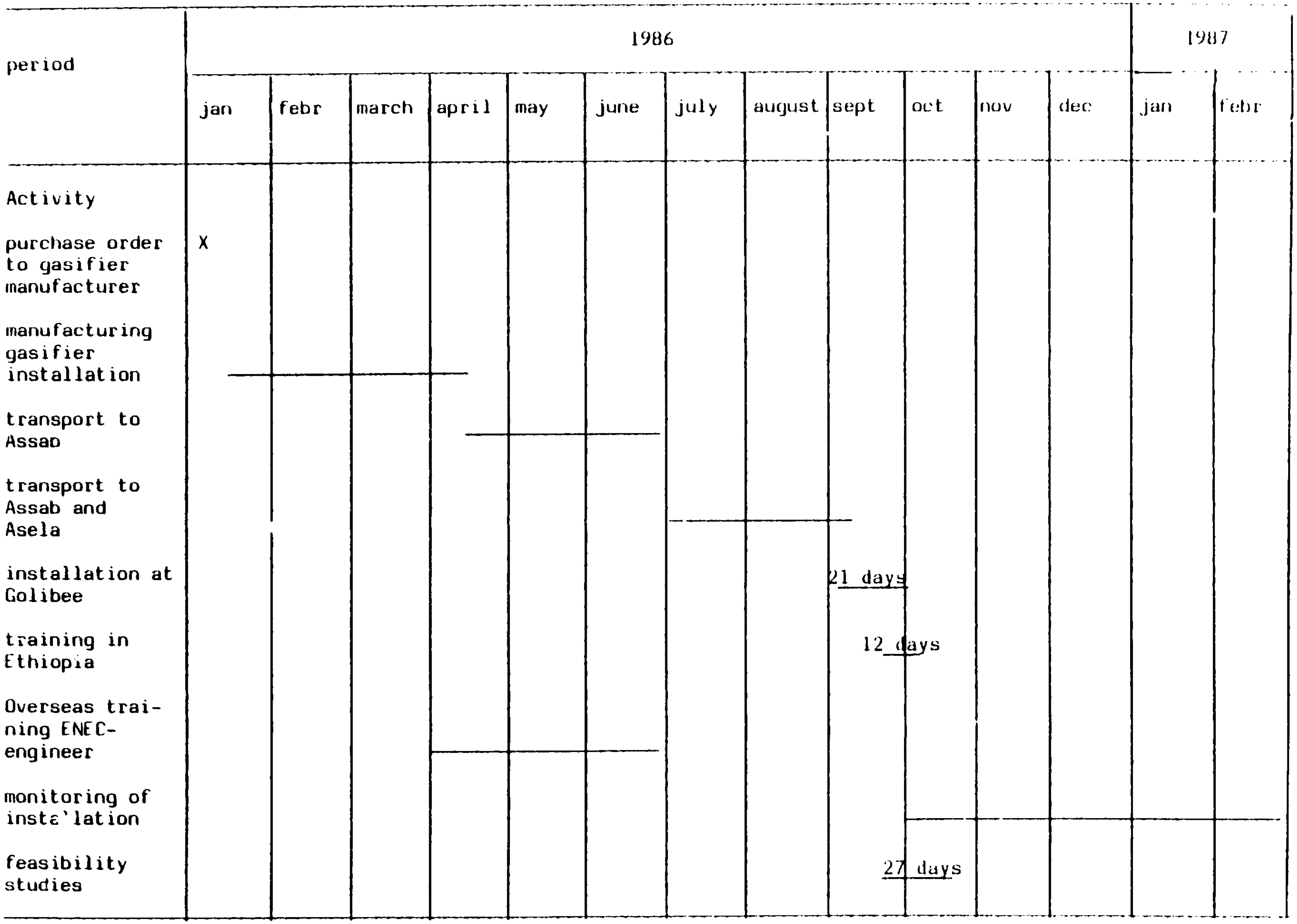
As explained in Chapter 3, the expert is of the opinion that the monitoring of performance characteristics is of utmost importance in demonstration programs. For this reason it is advised to incorporate the following instrumentation in the project. Those instruments will be operated by the ENEC engineer trained overseas, and will not only be used for monitoring the Golibee charcoal gasification system but also any other system to be installed in Ethiopia in the future.

1.6.1 Instrumentation

- Orsat apparatus (including chemicals) for measuring the composition of the producer gas.
- THT dust/tar sampling system (including auxiliary equipment and chemicals) for measuring the dust and tar content of the producer gas.
- Venturi gas flow meter, for measuring the quantity of producer gas actually produced.

ANNEX 2

WORKPLAN AND BARCHART OF ACTIVITIES



ANNEX 3

LIST OF GASIFIER MANUFACTURERS
(in alfabetical order)

- Biomass energy consultants and engineers (BECE)
  attn. Dr. F. van den Aarsen
  P.O.Box 498
  7600 AL Almelo
  The Netherlands

- Chevet
  40, Rue de Paris
  77200 Croissy Beaubourg
  France

- Evrard s.a.
  attn. Mr. G. Charlier
  51, Avenue Roi Albert
  5220 Andenne
  Belgium

- Imbert Energietechnik GmbH & Co KG
  attn. Mr. O. Zerbin
  Bonner Strasse 49
  5354 Weilerswist
  Federal Republic of Germany

- L. Johansson Engineering
  attn. Mr. L.A. Johnson
  P.O.Box 1159
  Ceres, California 95307
  USA

- NEI Fluidyne (NZ) Ltd
  attn. mr. J.P. Humphries
  2 Rabone Street
  Henderson
  New Zealand

- Touillet Ets,
  Division Gazeification MARTEZO
  237, Route de Paris
  86010 Poitiers
  France

- S.E.S. spa
  attn. Mr. C. Gloria
  Palazzina B Samim
  64, Via Marino Ghetaldi
  00143 Rome
  Italy

- Vyncke N.V.
  attn. Mr. K. Maes
  Gentsesteenweg 224
  8730 Harelbeke
  Belgium

ANNEX 4

ITINERARY

DATE	VISIT
08/12/85	Departure Oldenzaal/Amsterdam
09/12/85	Arrival Addis Abeba Discussions UNIDO, Addis Abeba - Mr. K. Vencatachellum, SIDFA - Prof. P. Grover, UNIDO Technical Expert - Mr. Said Muhammed, UNIDO Technicsl Expert Discussions ENEC, Addis Abeba - Dr. Ghebru Wolde Ghiorghis Executive Secretary Ethiopian National Energy Committee (ENEC) Ministry of Mines and Energy (MME) P.O.Box 486 Addis Abeba Tlx 21448 MNE-ET Tel 15 36 89 - Mr. Yahya Mohammed, ENEC - Mr. Tekola Shimelis, ENEC
10/12/85	Discussions ENEC (Addis Abeba) - Prof. P. Grover, UNIDO Technical Expert - Mr. Yahya Mohammed, ENEC - Mr. Tekola Shimelis, ENEC Visits Addis Abeba - Mr. Costantino Gliptis, manufacturer - Test facility ENEC
11/12/85	Discussions ENEC (Addis Abeba) - Prof. P. Grover, UNIDO Technical Expert - Mr. Yahya Mohammed, ENEC - Mr. Tekola Shimelis, ENEC - Mr. Omar Mohammed Head, Dept. of Programming and Planning Ministry of Mines and Energy (MME)

11/12/85 (c'td) Experiments at ENEC site (Addis Abeba)

- demonstration drum charring system
- demonstration sawdust/coffee husk stove

12/12/85 Departure for Asela

Discussions ARDU, Asela

- Mr. Girma Mengisto
  Head, Irrigation Development Team
  Coordinator, Rural Infrastructure Dept.

Visits ARDU, Assela

- Workshop, Irrigation Development Brigade
- Workshop, Rural Technology Development and Promotion Centre
- Garage ARDU

13/12/85 Discussions at ARDU, Asela

- Mr. Debela Dinka, Head ARDU

Departure for Golibee, Dodicha and Wondo Guenet

Visit Gobilee irrigation scheme

Visit Dodicha irrigation scheme

- Mr. Mogos Ghebreselassie
  Head, Surface Water Section, ARDU

14/12/89 Visit and discussions Forest Resources Institute (FRI), Wondo Guenet

- Mr. Hans von Schultz
  Head of Academic Section
- Mr. Roger Salomonsson
  Utilisation and Engineering Dept.
- Ato Ketema Ayalew
  Teacher Engineering
- Ato Girma Balcha
  Chemistry and Biology
- Ato Mengist Wendafresh
  Botany and Soil Science

15/12/85 Departure for Kibri Mengis

Visit and discussions sawmills Kibri Mengis

Departure for Awassa

16/12/85	Visit Awassa Junior College of Agriculture Home Science Department
	Departure for Wondo Tika
	Visit state maize farm, Wondo Tika
	Departure for Addis Abeba
17/12/85	Discussions at ENEC, Addis Abeba
	- Dr. Ghebru Wolde Giorgis (ENEC) - Mr. Yahya Mohammed (ENEC) - Mr. Tekola Shimelis (ENEC) - Prof. P. Grover (UNIDO Technical Expert)
	Visit and discussion at Min. of Agriculture Sawmilling and Joinery Enterprise, Addis Abeba
	- Mr. Taye Hosanna Head of Technical Department - Mr. Debebe Mekonnen Administrator - Mr. Samuel Benti Din Din Sawmill
	Departure for Nazaret
18/12/85	Departure for Dindin and Darrar
	Visit Sawmills at Dindin and Darrar
	Departure for Addis Abeba
19/12/85	Final discussions at ENEC, Addis Abeba
	- Mr. Omar Mohamed Getta Ministry of Mines and Energy - Mr. Yahya Mohammed (ENEC) - Prof. P. Grover (UNIDO Technical Expert)
20/12/85	Departure from Addis Abeba
	Arrival Vienna (via Rome)
21/12/85	Vienna
22/12/85	Vienna

23/12/85	Debriefing UNIDO
	- Dr. R.O. Williams Industrial Development Officer Chemical Industries Branch Division of Industrial Operations
	Departure from Vienna
	Arrival Oldenzaal (via Amsterdam)

ANNEX 5

LIST OF SPARE PARTS

The expert recommends that the following spare parts and consumables shall be incorporated in the supply:

1. Gasifier

Quantity	Designation
2 sets	top lid gasket
4 sets	ash lid gasket
2 sets	grate shaker gasket
4 sets	gas filter gasket
2	hearth rings
1	iron grate
5 sets	gas filter material complete
2	handvalves for gas/air mixer
2 sets	nuts and bolts
2 sets	cleaning tools
5 liters	paint

2. Engine

Quantity	Designation
4	inlet valves
4	outlet valves
4	valve springs
8	gasket valve cover
4	head gasket
4 sets	top overhaul joints
4 sets	top cover joints
8	collets
10	oil filters
10	air cleaning elements heavy duty
6	fan belts
6	alternator belts
40	spark plugs
1	water pump
2 years	lubrication oil

3. Electrical installation

Quantity	Designation
1	electronic ignition system complete
1	start motor
1	automatic voltage regulator
2	ignition coils
1	alternator
1	start-up fan and motor complete
2	batteries 24 V
2 years	distilled water
2 hears	battery acid
1 set	ignition cables
1 set	spark plug cables
5 sets	fuses and bulbs

4. Waterpump

Quantity	Designation
2	main gaskets
4	main shaft glands
4	V-belts

5. Tools

2 sets	screw drivers
2	hammers
2	adjustable spanners (small)
2	adjustable spanners (medium)
2	adjustable spanners (large)
2 sets	open spanners for engine and gasifier
2 sets	ring spanners for engine and gasifier
2	waterpump plyers
2	plyers (small)
2	plyers (medium)
1	pipe wrench 1"-3"
1	pipe wrench 3"-4"

ANNEX 6

OUTLINE OF PERSONNEL TRAINING PROGRAM

1. Fuel preparation

- Best way of fuel preparation to eliminate waste
- Effect of fuel particle size variations upon gasifier performance and gas quality
- Effect of fuel moisture content on gasifier performance, gas heating value and contaminant level
- Effect of fuel moisture on engine performance and overhaul time
- Practical instruction in:
  - charcoal production
  - charcoal sizing
  - charcoal storage

2. Gasifier operation

- Theory:
  - basics of thermo-chemical processes involved in the generation of producer gas from charcoal
  - factors affecting gasifier performance and gas quality
  - gas treatment: cooling, cleaning, drying
  - visual assesment of gas quality from test flame colour
  - gas/air mixing: factors affecting mixture homogeneity and combustion in the cylinder of the engine

- Operation practice:
  - The essential disciplines of all phase of normal, efficient and safe gasifier operation from pre-start plant contion insection to post shut-down service and plant condition inspection.
  - Operating technique, observations and fault diagnosis
  - Refuelling
  - Ash removal
  - Plant cleaning, routine periodic servicing, minor repairs, consumable parts replacement
  - Logbook keeping

3. Engine operation

- Theory:
  - Operating principles of Otto cycle spark ignition engine
  - Operating principle of manual engine speed governor
  - Operating principle of gas/air mixer
  - Effects on gasifier performance and gas quality of different engine loads

- Operating practice:
  - Use of manufacturer's operating and maintenance manuals for engine operation and maintenance

- Normal routine servicing of the engine (lubrication oil inspection, oil and oil filter changing, spark plug removal, appearance analysis of spark plugs, air filter changing)
- Engine starting, running, stopping
- Engine instrument monitoring
- Engine operation safety procedures
- Engine logbook keeping

4. Waterpump operation

- Theory:
  - Principles of centrifugal pumps
  - Relation between head, rotating speed and discharge volume of water

- Operating practice:
  - Speed adjustment
  - Flow adjustment
  - Priming
  - Routine maintenance

5. Gasifier engine control panel

- Theory:
  - Relation between instrument read outs and operating efficiency of individual systems
  - Instruments as aids to plant and system fault diagnosis

- Operation practice:
  - Operation
  - Protective systems
  - Instrument reading
  - Instrument adjustment
  - Maintenance
  - Operating safety procedures
  - Logbook keeping

6. Health, Safety and First Aid

In addition to instruction in safety procedures applicable to the operation of the plant in general and of particular items of plant and equipment, the training shall include general instruction in health, safety and first aid appropriate to a plant which produces and utilizes producer gas. This aspect of the training shall give particular emphasis to gas leak prevention, gas detection, carbon monoxide poisoning symptoms and remedial action, as well as fire prevention, protection against skin burns and their treatment, precautions against cuts and the treatment of cuts and bleedings.

7. Standard of operating competance and discipline

Throughout the progress of the training programme, trainees shall be called upon to demonstrate a satisfactory level of knowledge and skills in the safe and efficient exercise of the particular tasks in which they are being trained and also to demonstrate awareness of their role and responsibilities to the safe and efficient functioning of other operating personnel and the plant in general.