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FIELD TEST PROGRAMME FOR THE PRODUCTION OF CHARCOAL FUEL FROM COTTON STALKS USING SMALL SCALE, DECENTRALIZED TECHNIQUES

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SUDAN

Technical report*

Mission 7 to 20 July 1987

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

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Vienna

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CONTENTS

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SUMMARY AND CONCLUSIONS

Biomass is the source for about 80 % of the energy consumption in Sudan, whereas about 90 % of the fuel wood (wood and charcoal) is consumed by the household sector. Lack of forest resources and a recent period of drought have lead to a fast rate of deforestation, especially in the Northern provinces. Solutions to this problem are to be found in conservation measures, development of new resources and increased planting. In this report the feasibility of alternative fuel production based on cotton stalks is studied.

Cotton stalks are an agricultural waste product which has the potential to replace 5 percent of the Sudanese wood consumption. If replacing wood charcoal this potential saving amounts to 11 percent of the domestic charcoal consumption. Carbonisation with subsequent briquetting was identified as a process by which the cotton stalks could be made available as a wood charcoal substitute to households and restaurants.

Charcoal briquetting by roll-presses is state-of-the-art technology. Such presses are characterised by large capacities (2 t/hr and above), high costs and sophisticated and expensive maintenance. With such equipment large risks of production failure are carried. The Biomass Technology Group developed a small capacity (50 kg/hr) briquetting technology which is also suitable for the medium sized briquetting plants on village scale. The principle is agglomeration and various binders can be used, although in the specific case of the Sudan cane sugar molasses appeared to be the most suitable material available.

A field test was executed in the Rahad Scheme, in order to test production methods, consider production organisation patterns and to perform a market study. Charcoal was produced in-the-field employing metal kilns made from oil drums and sheet metal. Prototype agglomeration machines were installed in a briquetting plant situated in Village 10. Five tons of briquettes were produced in total, and were used for a market study, involving selling the briquettes and evaluating users comments.

The report concludes that both the agglomeration technology, in combination with decentralised in-the-field carbonisation, and the marketability of this briquette type are promising. By considering both the large scale roll-press briquetting technology and the agglomeration technology, this study identifies the production scales, as well as the economic relationships between tenant farmers, carbonisation labourers and briquetting plant owners, necessary to make charcoal briquette production from cotton stalks possible. In this context appropriate administrative measures to be made by cotton growing scheme managements are recommended.

The findings in the report lead to some qualifications of the programme objectives. Among other goals, the programme originally aimed at the development of a local industry producing briquetting equipment. In view of the relative complexity of some of the parts of the agglomeration equipment (spray nozzles, control valves, electrical power supply), this objective is held to be not realistic for the medium term. However, local assembly and maintenance still remain possibilities which should be aimed for. Another objective was the generation of income for cotton growing tenants by the sale of cotton stalks to briquette manufacturers. The present study clearly shows that such income generation is very limited. On the other hand it is demonstrated that large employment opportunities will arise when cotton stalk carbonisation and briquetting is implemented in the cotton growing schemes.

The report concludes with recommendations for improvements to the agglomeration equipment and for a pilot project aimed at demonstrating the feasibility of cotton coal briquette production to interested investors.

ACRONYMS AND ABBREVIATIONS

BTG	Biomass Technology Group
d.a.f.	dry, ash free basis
d.b.	dry basis
Dfl	Dutch guilder
ERC	Energy Research Council
f.o.b.	free on board
hr	hour
LS	Sudanese pound
m.c.w.b.	moisture content, wet basis (%)
RERI	Renewable Energy Research Institute, (part of ERC)
US$	United States Dollar
w.b.	wet basis
yr	year

UNITS

Besides the international standard units, the following units are used:

Dfl	0.497 US$ (Ultimo July 1987)
Feddan	0.42 ha; 4200 m^2
LS	0.247 US$ (Commercial rate ultimo July 1987)
Malwa	2.38 liter

I INTRODUCTION

Background and justification

Cotton stalks, an agricultural waste product, are a potential energy source for the domestic sector in Sudan and other developing countries. In Sudan it may replace up to 5 percent of the total fuelwood consumption (including wood resources for charcoal production, see BTG1 86). For agricultural reasons (pest combat), cotton stalks must be destroyed or conserved (sterilized) within a short period after the cotton harvest. At present the stalks are burned in the field. Pre-feasibility studies, carried out by the Sudan Renewable Energy Research Institute in cooperation with UNIDO, GTZ and the Biomass Technology Group, have identified small scale on-site carbonisation as an acceptable alternative option (See BTG2 86, GTZ 85).

To this end locally manufactured carbonisation kilns, were developed and commissioned during the '85 and '86 harvesting seasons. A number of those kilns have been operated under RERI supervision and considerable quantities of cotton stalk charcoal (cotton coal) were produced (See ZORGE 85, EL SHEIKH/HOOD 86).

The cotton coal produced in this way involves high transport cost and has poor burning characteristics, due to its low density. Hence it is not yet a marketable alternative to wood charcoal. Briquetting is a necessary step to improve on fuel characteristics and economics. A briquetting technology, based on milling and piston extrusion, developed by RERI and Georgia Tech., was used to show the consumers' acceptance of a cotton coal type fuel as a replacement of wood charcoal. However, that particular briquetting technology proved to be not economically feasible (See EL SHEIKH/HOOD 86).

On basis of about 2 m^3 cotton coal that were despatched to the Netherlands by RERI, the Biomass Technology Group (BTG) developed the principles of a cotton coal densification process which was expected to be more promissing. The process consists of cotton coal milling and subsequent agglomeration. Molasses is used as a binder. The briquettes have a bulk density of about 500 kg/m^3 (which is more than wood charcoal). Laboratory combustion tests showed very favourable burning characteristics, although some smoke and a sweet odour was obeserved. These features might influence the fuel's acceptability by potential consumers.

On basis of a spread-sheet based pre-feasibility study, BTG has identified a number of promising cotton coal briquette production options (See BTG 87). The data used in that study were now verified or corrected in the field programme.

The further development of this briquetting technology however, calls for identification of feasible production volumes and capacities as well as users' requirements.

Therefore the present study aims at both the assessment of briquette development, production, marketing and utilization aspects.

Objectives

The use of wood as domestic fuel is a contributory factor to uncontrolled deforestation in the Sudan and in several of its neighbouring countries. Cotton residues (stalks) may serve as an alternative energy source. Cotton is grown in most of these countries and cotton stalks are an agricultural waste which becomes available in considerable amounts and for which there is no clearly defined use. The results of the programme will be applicable to several other countries in this region.

The following general objectives are mentioned in the project documents (See BTG 87):

- To encourage the use of agricultural residues as a source of energy and to supply rural people with a domestic fuel at an acceptable cost;
- To develop an alternative to wood as a source of charcoal fuel thus relieving pressure on the rapidly degrading forest resources;
- To develop 4 small-scale, rural industries involved in i) the fabrication of charcoal kilns, ii) the fabrication of briquetting equipment, iii) the production of charcoal from cotton stalks and in iv) the production of charcoal briquettes from the resulting charcoal;
- To develop cotton stalks as an income-generating resource in agriculture.

Outline of the study

The questions which the present study attempts to answers are:

A. Economical

- Can cotton stalk charcoal briquettes be produced in an economically acceptable way?
- What socio-economic effects can be expected if such a technology were to be implemented on a large scale?

B. Organisational

- What people are to be involved in the production of charcoal briquettes from cotton stalks, and under which economic conditions will those people (traditional charcoal entrepreneurs and/or charcoal manufactureres, farmers, agricultural labourers) take part?
- Must governmental or irrigation scheme management decisions be taken in order to make large scale implementation possible?

C. Technical

- Is the proposed briquetting technology (agglomeration with a molasses binder) suitable to meet consumer requirements?
- What technological developments are necessary to make the production of charcoal briquettes from cotton stalks feasible?

In order to look for answers on these questions, 20 kilns were operated during two months under real field conditions near Village 10 in the Rahad Scheme. The kilns were operated by professional charcoal manufacturers on basis of a weekly wage. About 30 t of cotton coal was produced. The cotton stalks charcoal was briquetted with cane sugar molasses as a binder, in a briquetting plant also situated near Village 10. Thus 5 t of briquettes was produced. The briquettes were partly distributed among potential consumers, in order to test the briquette's acceptability, and partly sold directly to households.

The study has been carried out through close cooperation between the Renewable Energy Research Institute, the Biomass Technology Group, the Netherlands Economic Institute and UNIDO. The management of the Rahad Scheme was very cooperative and assisted with a lot of practical problems which had to be dealt with.

II PRESENT ORGANISATIONAL STRUCTURES AND RECENT DEVELOPMENTS IN COTTON GROWING AND CHARCOAL TRADE

Agricultural organisation of cotton growing in Sudan

Cotton cultivation in Sudan began in the 1920's, during the colonial period, in one of the world's largest settlement schemes - the Gezira Scheme. The favourable climatic and soil conditions were the main reasons for the establishment of the scheme. Becoming the backbone of the Sudanese economy, the cotton cultivation area increased to almost 1 Million feddan (420,000 ha). Cotton is grown both rainfed and irrigated. Table 2.1 shows the various schemes with their cultivation areas and type of water supply.

Table 2.1 Cotton production in Sudan (Average during 1979 - 1984).

Region	Scheme	Area under cotton (feddan)	
		Irrigated	Rainfed
Central	Blue Nile	92,000	
	Gezira and Managil	493,000	
	Suki	27,000	
	White Nile	79,000	
	Aarab Sudanese		n.a.
Eastern	New Halfa	68,000	
	Rahad	109,000	
	Tokar	17,000	
	Gedaref		9,000
Northern	Zedap	5,000	
Kordofan	Nuba Mountain		64,000
Southern	Maridi		24,000
TOTAL		890,000	97,000

The main cotton varieties are long and medium staple (both in irrigated schemes) and short staple (in rainfed schemes). Sowing takes place in the period from 1 July to 15 August. Depending on the variety, cotton picking starts by the end of November and continues until the end of February. Several pickings are carried out. After picking, the residues (cotton stalks) remain on the fields until they are uprooted and burnt. Starting as from May 15, these same fields are prepared for groundnut or sorghum cultivation (Although other rotation systems exist in some schemes).

The cotton plant is extremely susceptible to diseases and pests. Some parasites hibernate on the stalks during the dry season. After complete damage of 1928's and 1933's harvests by cotton pests (e.g. pink ballworm), phyto-sanitarian regulations were put into action. In the irrigated schemes law requires the incineration of the stalks before the 1st of June, and prohibits any use or storage of the stalks after that date. Through their plant protection departments, the schemes intend to prevent the spread of cotton pests and parasites from infected fields by strict application of the law. However, in recent years with intensive use of insecticides (More than 6 sprays in the 1986 season in Rahad), the application of the phyto-sanitarian rules shows some flexibility. After June 1 one may see many a bundle of cotton stalks stored in the homeyards of tennants and settled migrant labourers. Wood scarcity and high charcoal prices also might be reasons for this flexibility.

Cotton stalks availibility

Several estimates about the amount of produced cotton stalks can be found in literature (FWAR 86, GTZ 85, SCHMITT/SIEM 85, HOOD 84). Figures vary between 0.9 and 1.5 t/feddan (2.1 - 3.6 t/ha). From the amount produced, an amount must be substracted which is consumed traditionally by households for cooking and building and by grazing. Concerning this matter a number of arguments and estimates are given in literature (FWAR 85, GTZ 85, SCHMITT/SIEM 85, HOOD 84, EL SHEIKH/HOOD 86). All investigators agree that traditional stalk use amounts to about 25% of the total. In a recent investigation that was carried out in the Rahad Scheme (EL SHEIKH/HOOD 86), and based on a sample of 10 differently located feddans, the amount of available stalks was found to be 0.8 - 1.2 t/feddan, with an average of 1.0 t/feddan. Stalks production appears to depend on tennant care, soil condition, irrigation and the amounts of fertiliser and pesticides used.

After the last cotton picking, the cotton fields are grazed by herds owned both by tennants as well as nomads who migrate towards the irrigated schemes for this period. In general the grazing period is over on March 1. As will be shown in Chapter IV the short period of availibility of the stalks constitutes an organisational problem.

The main problem to a more or less centralised use of cotton stalks lies in the harvesting method and transfer of stalks to the processing site. (See Chapters IV and V for uprooting and collection costs in relation to the cost of the whole briquetting process). Manual uprooting is the most widely spread method for stalk harvesting. It is carried out with the aid of a special tool (the "Kamasha"). Hand pulling is a slow process and hence labour intensive (on average 4.5 man day/fedddan). Up to now several mechanical stalk removal techniques have been tested, both for root cutting and for uprooting. The reasons that manual uprooting is still the most generally applied technique are:

- Failures of mechanical uprooting systems;
- Excessive cost (besides technical problems) of mechanical rootcutting;
- A disadvantageous soil structure after mechanical root cutting;
- Ample labour availibility for manual uprooting.

Cotton growing in the Rahad Scheme

The field test was performed in the Rahad Scheme and therefore this scheme is discussed here more in detail. The Rahad Scheme is one of the recently developed large scale irrigation projects in Sudan. The scheme was funded by the World Bank and investments started in 1973. The first harvest was in 1978. The Scheme is located in both the Central and Eastern Regions along the road from Khartoum to Port Sudan, about 300 and 100 km from Khartoum and Wad Medani respectively. It covers a total area of 300,000 feddan (126,000 ha) and employs about 15,000 tennant families plus associated labourers. The Scheme Headquarters is situated in El Fau, a village located in the middle of the scheme, 1 km from the Khartoum - Port Sudan road.

The management of the Scheme is divided into three major departments:

- Agriculture;
- Operation and maintenance;
- Civil engineering.

The Agricultural Manager is assisted by assistants responsible for specific activities, e.g. agricultural engineering, plant protection, forestry, horticulture and animal production. The Rahad Scheme is divided into 3 groups, each consisting of 3 blocks of about 5 villages. In total there are 44 villages situated within the Scheme and 2 villages just outside the Scheme. At group level the Scheme is represented by a Group Director with his assistants, at block level by a Block Inspector and several other officials. Tennants are represented in the Board of Directors of the Scheme by their Tennant Union.

The number of tennants per village is 250 to 400. The cultivated area per village is 4,000 to 6,000 feddan. This land was alloted to those families which lived traditionally in the region. The relationship, rights and duties, between the Scheme and the Tennants are specified in the "Rahad Corporation Act". Among other things it states that:

- The Scheme has the right to reject applications from persons which she judges to be unsuitable, even if these persons hold titles of rights to land in that area;
- The tennancy agreement provides that the tennant may grow approved crops only and must follow the Scheme's rotation rules.

- The Scheme will provide inputs and services, and market cotton, groundnuts and any other cash crops which might be adopted in future;
- The Scheme will provide a full range of mechanised field operations, including land leveling, crop planting and harvesting;
- Tennants pay a fixed "land and water charge", which is substracted from the profits of crop sales;
- The tennancy agreement is valid for an indefinite period, but can be terminated in case of default by the tennant.

It may be concluded that the Scheme Management has the authority to oblige the tennants to follow the necessary regulations concerning future use of cotton stalks.

In the Rahad Scheme every tennant owns 22 feddan, 11 of which he uses to grow cotton. The other 11 feddan are under groundnuts and sorghum. Cotton cultivation is organised in such a way that the 11 cotton feddans (1 hawasha) of 8 tennants form 1 plot, thus forming cotton fields of 280 x 1440 m^2.

Presently the tennants are legally obliged to clear their lands from cotton stalks before the 1st of June. This work is contracted to labourers and usually costs the tennant 200 - 400 LS per hawasha (18 - 36 LS/feddan). Fixing of this sum takes considerable negotiations and costs rise with the coming dead line of June 1. For cotton stalk cleaning the tennants receive a loan by the Scheme which is substracted from the tennant's cotton revenues as payed by the Scheme. For 1987 this loan amounted to 17 LS/feddan for uprooting and 6 LS/feddan for stalks collection and incineration.

Charcoal production and trade

In 1984 and 1985 two studies were published by the Energy Research Council concerning charcoal production and marketing in the Sudan (GAAFAR 84, GAAFAR 85). The following information has been collected partly from these studies and partly by interviewing charcoal entrepreneurs.

A. Production areas and resources

According to the forest policy of 1932 all commercial wood cutting activities should be concentrated inside forest reserves, in order to assure regeneration. This policy has not been applied, with the exception of Acacia Nilotica reserves along the Blue Nile, and in general, charcoal production takes place outside the forest reserves. Commercial production, in the last years, is mainly concentrated in the Blue Nile Province. This province is relatively proximate to concentrated demand areas (Khartoum, Central and Northern Regions), where the wood resources are depleted. Wood and charcoal are now transported to Khartoum from the Southern part of the Blue Nile Province over 400 - 600 km. The Blue Nile Forestry Administration concentrates all production of charcoal and industrial wood inside areas which are allocated for mechanised farming development. To this end an understanding was reached with the Mechanized Farming Corporation to allot carbonisation schemes of 1000 - 1500 feddan. Most probably all these existing charcoal resources in the existing and projected agricultural schemes will be used by the mid 1990's. Charcoal and other industrial wood will then have to come from forest reserves and probably from other regions (Kordcfan and Darfour).

B. Producers and production organisation

In the Blue Nile Province all charcoal is produced by the private sector, dominated by approximately 25 permanent entrepreneurs who have been in this business for 20 years or more. However, as it became more profitable, also a considerable number of other, less experienced entrepreneurs entered this business. Self owned lorry derivers, also recently entred the charcoal market. Benefiting from some marginal profit, they easily deliver charcoal to wholesalers and large scale retailers, by passing the depots and central markets. Most charcoal entrepreneurs are also occupied by other types of trade. Often they own one or more lorries and practice some form of agriculture.

Due to the heavy rains during July - October, charcoal production is a seasonal activity. Entrepreneurs employ agents to act as supervisors of the charcoal burners. The agent's bear the responsibility for the recruitment of workers, the quality control and the running of the provision shop on the production site. They are payed a commission per bag produced. Each entrepreneur employs 1 to 3 agents whereas each agent supervises about 50 charmen. These charmen are recruited in various regions. Most workers are well experienced and employed by the same entrepreneur each year. Workers are paid per sack delivered charcoal. The amount varies with location and entrepreneur and increased tremendously during the last years: from an average of LS 1.60 in 1984 to LS 8.00 in 1987. Advance payment to the workers is a common practice in charcoal production. The entrepreneur provides the charmen with tools and drinking water.

The kilns are owned by the charmen; all the wood necessary for firing the kiln and the produced charcoal is cut respectively owned individually. In wood transport and kiln guarding during the first few days after firing them, the carbonisers help each other.

C. Production costs

Entrepreneurs have to take big financial risks for starting charcoal production. Incidents of labourers fleeing away with loans, getting sick, dying or just not producing enough for paying back the advanced money, occur frequently. Apart from the direct labour costs involved in producing charcoal, entrepreneurs have to pay permision fees, royalties per sack of produced charcoal and often also local taxes, as in the case when charcoal is produced in areas of macro schemes. Table 2.2 gives a review of charcoal production costs in the

Blue Nile Province for the season 1984. Major cost items are labour, empty sacks as well as transport.

Table 2.2 Charcoal production costs in the Blue Nile Province, 1984 (GAAFAR 85).

Item	Cost range per sack (LS)	% Of total
Labour per packed sack	1.55 - 1.80	45 - 35
Water	0.20 - 0.40	5 - 7
Agent	0.20 - 0.25	5 - 4
Empty sacks	0.60 - 0.75	17 - 14
Transport to depot	0.55 - 1.30	15 - 15
Royalty and local tax	0.27 - 0.30	7 - 5
Sundries including deficit from repacking	0.10 - 0.30	2 - 5
TOTAL*	3.47 - 5.10	

*) The total cost does not include storage costs (investment in the depot and supervision costs).

D. Charcoal marketing

The charcoal price is usually lowest during the months of April - May. It steadily increases with the start of the rainy season June-July and reaches its maximum during the months of October - December. Entrepreneurs and traders with big investment capabilities, usually have several large storage facilities to store the charcoal until prices escalate up during the rainy season and shortly thereafter before the new production starts.

Cotton coal briquettes should be wedged into the present charcoal market. Still cotton coal briquettes cannot cover all charcoal market sectors. Especially the fines and brands (incomplete carbonised wood) are by-products of charcoal with their own end use. Typically these are collected by the retailers at the charcoal consumer market and sold separately to the lime industry and households.

The household consumer and the services sector obtain their charcoal from retailers; in two ways: per sack (at average containing 35 kg charcoal of which 20 % is fines and brands) and per "malwa" (a smaller volume of 2.375 l, legalised by the Bureau of Measurements for the sale of cereals). Officially a sack should contain 45 kg of charcoal. In practice this never occurs. GAAFAR 84 gives figures ranging from 34 to 42 kg. Selling the charcoal by malwa, a retailer has 3 profits: Firstly, the price per kg of charcoal as sold per malwa is higher than as sold per sack, secondly, the fines are sold, and thirdly, the brands are sold. By interviewing retailers in Wad Medani and estimating that 20 % of a sack of charcoal consists of fines and brands it can concluded that this way of marketing is quite profitable. Revenues if sold separately, as compared with sale per sack, are as follows:

27 malwas/sack of charcoal =	27 LS
0.2 sacks of fines or brands/per sack of charcoal =	2 LS
Total revenue per sack of charcoal =	29 LS
Revenue if sold per complete sack =	22 LS

In above calculation it is assumed that fines, brands and charcoal have the same bulk density. Asked about purchase prices, most retailers reported 19 - 20 LS/sack.

For cotton coal briquettes only the households and the services sector form a potential market. This also means that a retailer who sells briquettes can satisfy the demand for fines or brands less easily. The malwa does not contain fines nor brands. For a potential consumer of cotton coal briquettes this product, (which almost doest not form fines or brands) replaces either the 28 kg of useful charcoal contained in a sack or the volume of charcoal in the malwa.

The above marketing techniques have consequences for the way in which cotton coal briquettes are sacked and also for the price setting (See Appendix I and II).

E. Price trends

From statistics kept by ERC it follows that the charcoal prices triplicated since 1982. This may continue until the consumers are not able to afford charcoal anymore. The reasons are quite obvious:

- There is an increasing demand;
- Resource become scarcer;
- Transport distances increase;
- Labour cost increases;

In Chapter IV it is shown how cotton coal briquetting becomes a more and more feasible option due to this development.

III THE TECHNOLOGY

Cotton stalks characterisation

Cotton stalks are a woodlike agricultural residue with the following main characteristics:

m.c.w.b. = 10 - 20 %;
ash content (d.b.) = 5 %;
length = 60 - 110 cm;
diameter = 1 - 15 mm;
bulk density (stacked) = 55 kg/m^3.

The above figures are only indicative and may vary with cotton species and drying time after uprooting of the stalks. The ash content, which is somewhat higher than in wood, must inevitably lead to a charcoal type with more ashes (10 - 15 %) than wood charcoal (± 5 %).

Carbonisation and briquetting: Process description

Based on the experience in the present field test a carbonisation and briquetting technology is proposed. The process is described in this chapter. The production of charcoal briquettes from cotton stalks as left in the field after the cotton harvest, calls for the following steps:

- Root-cutting or up-rooting, the former is done mechanically while the latter can be carried out either mechanically or manually;
- Stalks collection;
- Carbonisation;
- Cotton coal transport to the briquetting plant;
- Milling and subsequent briquetting of the resulting charcoal;
- Sacking and storage.

In this study basically 3 production capacities ranging from 0.2 to 2 t briquettes/hr. are considered. Chapter IV gives also several feasible alternatives for medium and large scale production with capacities of respectively about 1 and 2 t/hr. In this place a brief outline of the technology and production organisation of alternatives I and V is given (For more details on the alternatives see Appendix II).

Production capacity influences the number of carbonisation kilns, the transport and storage logistics of the cotton coal and the choice of briquetting technology.

A. Carbonisation

A decentralized carbonisation technology in transportable open-ring kilns is proposed. In the Rahad Scheme, where the study was carried out, cotton is generally grown on 280 x 1440 m^2 fields, boarded by two 50 cm ditches on the longer sides. Traditionally, these ditches are dry in the period when the carbonization has to take place. However, for operation of the kilns (preparation of mud sealings and for extinguishing of the fire) a regular water supply is necessary. Consultation with the Rahad Scheme management learned that solutions can be found to supply water in the future to those ditches for this purpose. Due to drought, the fields itself are much cracked (thus, preventing the use of the simple open-ring kiln on the fields because of the danger of air leakage through channels and pipes in the earth). However, there is sufficient space and smooth soil for setting up the carbonisation kilns along the water supply ditches. The stalks are transported manually from the field to the kilns by the same labourers who do the uprooting of the cotton stalks.

Though in the field tests a small kiln with a capacity of 40 kg coal per cycle was used, it is proposed to use a bigger kiln of 90 kg/cycle capacity in future implementation. This kiln was developed and tested in 1985 by RERI and a UNIDO expert. Its design and use is described in extenso in other reports (See ZORGE 85). Here only those data that are important for the assessment of the economic feasibility are given:

Capacity = 90 kg cotton charcoal/cycle;
Cycle period = 24 hrs;
Yield = 25 - 30 weight %;
Number of operators = 0.3 operators/kiln;
Investment cost = 1000 LS/kiln;
Life time = 5 yr.

Per day 2 labourers operate 6 kilns. In early morning the 6 kilns are discharged. 3 Kilns are then filled with fresh stalks and started. After 1 hour all air supply holes are closed and the next 3 kilns are started similarly. Finally the cotton coal produced the previous day is sacked in jute bags of 50 kg. All cotton stalks from a plot of 8 hawashas are subsequently carbonised by moving the kilns (rolled manually) along the water supply ditch. After enough cotton coal has been produced (at least 1 lorry load) from a particular plot of hawashas, it is weighed and transported to the briquetting plant where it is stored.

B. Briquetting

The briquetting step is meant to improve on both combustion and transport characteristics of the cotton coal. It involves milling, binding and densifying.

For milling a hammer mill with a 3 mm sieve diameter is used. Depending on production capacity the hammer mill has a capacity of 1 to 2 t/hr. The price of hammer mills varies from 40,000 - 20,000 Dfl for mills of respectively 1 to 2 t/hr. The estimated lifetime of a hammer mill is 10 yrs.

Cane suger molasses dissolved in water is used as a binder. Depending on molasses quality approximately 20 % (by weight) of molasses is needed. Two densifying technologies are considered i.e.:

- Agglomeration;
- Roll pressing.

The agglomerator developed by BTG has a design capacity of 50 kg/hr. After final development of such equipment each agglomerator will cost about 2,000 Dfl. The lifetime of these machines can be estimated at 10 yr. In the proposed medium scale briquetting plant 8 to 16 agglomerators, depending on production organisation, are installed.

In the large scale plant which is considered as an alternative, a 2 t/hr roll press is installed. Its cost and lifetime are 140,000 Dfl and 10 yr respectively.

After agglomeration or pressing the 20 - 30 mm dia. balls are dryed either in open air on grids or in a forced-draught dryer. With a relative air humidity of 5 to 15 % and a maximum day temperature of 45 °C, open air drying takes 24 hours.

C. Plant lay-out and organisation

The cotton coal is bought from the charmen (who do the carbonisation) and taken to the briquetting plant by contracted transporters with lorries (See Appendix I for the plant lay-out in the present field test). The cotton coal purchase is supervised by briquetting plant employees. Unloading the lorries is performed by the transporter, while the piling of the sacks of cotton coal is done by briquetting plant employees. For the medium and large scale alternatives 11 and 76 t/day is stored respectively during the 13 weeks carbonisation season. Since part of this stock is also briquetted during this period, the finally built-up stock of cotton coal is 453 and 3,540 t for the 2 alternatives. 2 Labourers keep transport un-milled cotton coal from the storage to the grinding mill by means of hand carts. The grinding mill is operated by 2 men, 1 of them having overall responsibility for mill operation. The ground cotton coal is brought to the agglomerators or the mixer (in case of the roll press system) in woven plastic bags. One labourer supplies two agglomerators. The same men prepare the molasses/water mixture in sufficiently large buffer batches. The total amount of water used, for cotton coal grinding and for molasses dilution, is approximately 1000 l per ton of dryed briquettes. The produced briquettes are transported to the dryer. In case of roll pressing the entire process from mixing to drying is automatic and needs supervision by two men. Sacking involves 2 men for the medium scale plant and 4 for the large scale plant. The bags are filled with 30 kg and sealed. From July until November an airtight plastic bag is necessary to protect the briquettes against the relatively high air humidity in the rainy season. From November until July ordinary jute charcoal bags or woven plastic bags can be used. The sacked briquettes are stored by piling in the open air (2 Labourers in the medium scale production alternative, 4 in the large scale alternative).

IV FEASIBLE SCALES OF PRODUCTION

Identification of production alternatives

In Table 4.1 a range of technical alternatives, of which the economic feasibility will be considered in detail, are presented. These alternatives are constructed on basis of the following parameters:

Table 4.1 Technical characterisation of production alternatives.

Alternative	A1	A2	B11	B12	B211	B212	B221	B222	C11	C12	C21	C22
Carbonisation season length (week/yr)	13	8	13	8	13	8	13	8	13	8	13	8
Briquetting scale	s	s	m	m	m	m	m	m	l	l	l	l
Briquetting season length (month/yr)	8	8	8	8	8	8	12	12	12	12	12	12
Shift nr.	1	1	1	1	2	2	2	2	1	1	2	2

A. Mobile or stationary briquetting plants

A mobile briquetting plant is technically possible. The main problem with such a plant is that it can only be applied in the limited period of uprooting and carbonisation activities. Briquetting is thus reduced to a seasonal activity. For economic reasons this is most probably not a feasible alternative. Therefore this study only takes stationary briquetting plants into consideration.

B. Carbonisation period

Somewhere between the cotton harvest and the first of June, which is the date that legally all cotton stalks must be destroyed, a period for carbonisation must be found. Cotton picking starts about 1 December and ends in the last week of February. After the last cotton picking the cotton fields are grazed. Since the cotton picking does not start and end at the same time for all farmers, some farmers start uprooting already at the 1st of March, others postpone uprooting and burning of the stalks until June. Many farmers attempt to have their land cleared by the 15th of May, when land peparations for groundnut and sorghum sowing starts. This sowing, however, is generally not completed before the end of July. The carbonisation period for cotton stalks is limited by the end of the grazing period and the start of land preparation for the sowing of groundnuts and or sorghum. Without any coordination of uprooting activities only about 4 weeks will be available for carbonisation of the stalks. Provisional calculations on that basis learned that investment cost in kilns in this case absorb a considerable part of total cost of briquetting (65 %). This cost may be halved if for example an 8 or 13 weeks carbonisation period were agreed upon. Coordination of uprooting activities and good planning of the successive activities on the hawashas should make this possible, however, will require a cooperative attitude of the tennant. Anticipating on this issue two alternatives with respect to carbonisation period have been considered i.e.: 8 weeks and 13 weeks.

C. Briquetting scale

Within the framework of the Rahad Scheme small, medium and large briquette production scales have been considered:

- A small plant with 4 granulators as used in the present field test. Such a plant will absorb 1/5 of the annual cotton stalks production of an average village in the Rahad Scheme. Main reason for formulating this alternative is to obtain an understanding of the economics of such a plant, since it was used in the field test. It is, however, not a logical production capacity in the situation of the Rahad Scheme.
- A medium scale plant absorbing approximately all cotton stalks produced by 1 average Rahad Scheme village. This plant can be considered as being built up from 4 to 5 small scale briquetting plants. Economies of scale of any importance cannot be expected from such an increase of scale. This scale is mainly considered because of potential organisational as well as employment advantages.
- A large scale plant, using a completely different production process (roll pressing). In this case the smallest capacity briquetting press available in the market is considered (2 t/hr). Such an alternative investment is much more expensive than a relatively small granulation plant. Its labour cost however is much smaller. Given its capacity, one plant can produce all year round using the cotton coal produced in an area covering to 3 - 5 villages. Since in the Rahad Scheme every 5 villages form a "Block", with one central village, such a plant may be centrally located in or near the main village. This scale is considered for reasons of both economies of scale as well as of potential oganisational characteristics.

D. Briquetting season length

If outdoor drying tables are used for briquette drying, year round production is not possible. Production has to be interrupted in the rainy season (July - October). However, if an investments is made in a forced draught dryer, such an interruption will be prevented. Forced drying is considered for medium and large scale production.

E. Operation in more than one shift

Producing in more than one shift improves capital utilisation. Especially in the large scale briquetting plant, which goes with high investment cost in the briquetting press, operation in more than one shift may prove to be an attractive proposition. Also for medium scale operation applying a shift system may reduce production costs per unit of product. The shift system considered consists of two 6 hour shifts during 6 days per week, which seems an appropriate alternative under Sudanese conditions.

Economical evaluation of production alternatives

The above mentioned alternatives are evaluated with respect to the above parameters while starting from a number of assumptions. Whether these assumptions are exactly true, or whether they have to be adjusted in a later stage of this report, does not influence the conclusions that can be drawn on the relative importance of the various parameters.

With regard to the micro-economic evaluation the following general rule is applied: the consumer market price for the briquettes minus transport cost from the plant gate to the market and minus other costs and profit of marketing always has to fully compensate the production cost. For briquettes and charcoal some of the figures needed for such calculations are known; others are either unknown or only available for recent years in rough estimates and cannot be produced before more experience with briquette marketing has been gained. Table 4.2 shows the voids in information. The actual availibility of data has resulted in the applied method of assessment.

Figure 4.1 shows the market structures on village and urban level. The production capacity in all alternatives is ample to serve the charcoal needs of a village. However, in all alternatives it is assumed that the village market will only absorb cotton coal briquettes for half of its charcoal needs, being approximately 325 t of briquettes per year

It is further assumed that the remaining production is sold to wholesalers, serving urban markets. Probably the marketing and transport costs for the village retailers will be very low; consequently their profit may find an equilibrium somewhere between the charcoal price and the plant gate price, and, moreover, their profits will be positive when the briquette price exceeds the plant gate price. Gaafer, in his survey (GAAFAR 85) found that retailer profits are in general lower than wholesalers profits.

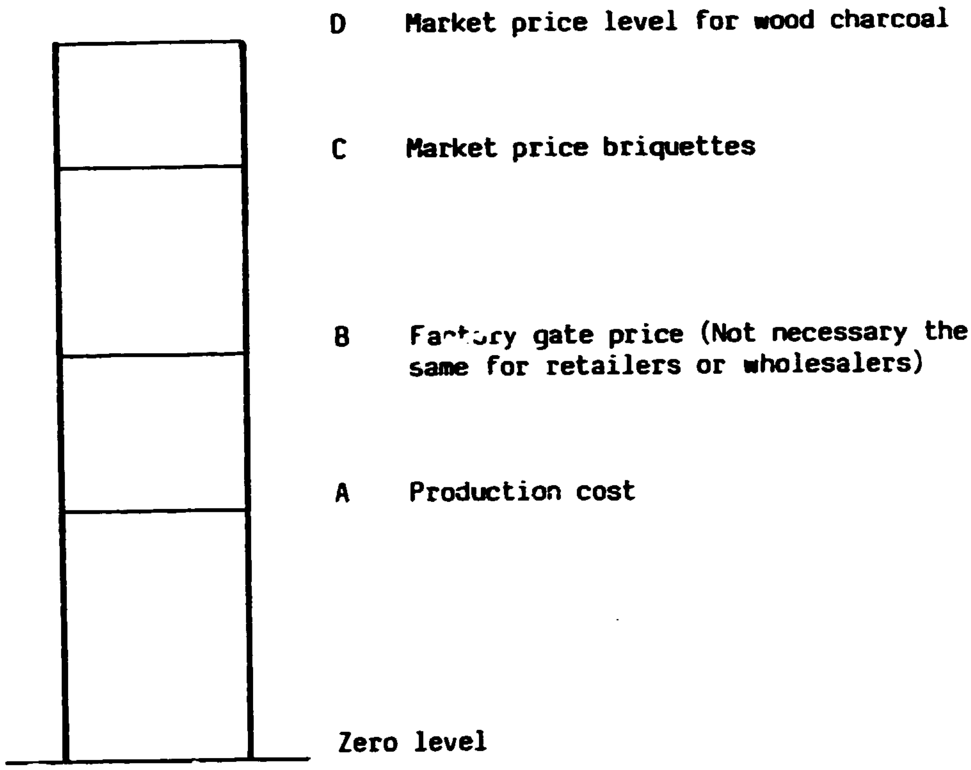
As for the wholesalers, who buy larger amounts, discounted prices may be applied, leaving the briquetting factory with a lower profit margin than in case of selling to village retailers. The wholesaler, contrary to the village retailer, has to pay the transport cost to the urban market. Urban market prices for charcoal are accordingly higher than the local market price in the Scheme villages.

Table 4.2 Availibility of micro-economic data.

Cost component	Known	Unknown/roughly estimated	
		Obtainable in next project phase	Not obtainable ex-ante
Production cost	x		
Transport cost	x		
Charcoal marketing cost		x (*	
Charcoal marketing profits		x (*	
Briquette marketing cost			x (**
Briquette marketing profits			x
Charcoal market price	x		
Briquette market price			x (**

*) Has for 1984 been estimated in GAAFAR 85. The marketing structure presently however is changing considerably (Acc. to the same source).
**)May be roughly estimated on basis of further investigations in a next phase of the project.

Figure 4.1 Cost levels for wood charcoal and cotton coal briquettes (LS/t)



B - A = Factory profit
C - B = Marketing costs <u>and</u> profits, probably very low for retailers (Marketing costs include costs for transport)

The first starting assumption is that selling to the retailer leaves the plant with a profit of 30 % of gross factor cost; serving the wholesaler reduces the margin to 20 %. The second starting assumption is that though the briquettes are a substitute, they have nearly the same using value as charcoal. Consequently a per ton market price equal to 90% of that of sacked charcoal without fines and brands is applied. This assumptiom may be regarded as an optimistic exaggeration, however, charcoal is actually sold on the market in quantities of about 1 kg, without fines or brands and for a much higher price than per sack (effectively about 25 % higher per kg usefull charcoal). Transport prices have been estimated for transport to Khartoum.

With these starting asumptions two percentages have been calculated:

- The maximum attainable "profit" percentage of the market selling price for the village retailer;
- The maximum attainable "profit" percentage of the market selling price for the wholesaler.

As explained before, this percentage should cover marketing cost and profit margins. Low or negative percentages point in the direction of rejecting an alternative, high percentages on the other hand indicate a potential viability of an alternative.

In summary, the assumptions on which the alternatives are based are the following:

- The investment in kilns and the briquetting plant is made by the same entrepreneur (referred to as "briquette manufacturer"). This briquette manufacturer is not yet identified (He may be the Tennant Union, the Rahad Scheme or any third party).
- Like in the present situation, the tennants pay for and take care of uprooting. No royalty is payed by the briquette manufacturer for obtaining their cooperation nor for the cotton stalks which are presently burnt.
- Carbonisation is carried out by professional charcoal makers who are payed by the briquette manufacturer on a per day rather than on a per ton basis.
- In the small scale alternative the related market is just the village where the briquettes are produced. This alternative is not considered to represent a final stage in the development of cotton coal briquettes production. In the medium and large scale alternatives the annual briquette production is partly sold in the Rahad Scheme and partly in remote urban markets. In the Rahad Scheme cotton coal briquettes replace half of the present charcoal consumption (Per village 325 t briquettes per year are consumed). The remote urban market considered is Khartoum.
- In order to avoid detailed and unreliable calculations of marketing cost, the produced briquettes are assumed to be sold to wholesalers and retailers, while applying a factory profit margin over the production cost (20 and 30 % respectively).

- Potential profit margins for wholesalers and retailers are calculated with reference to present charcoal market prices, payed by household consumers, in the Rahad Scheme (643 LS/t usefull charcoal) and in Khartoum (786 LS/t usefull charcoal). These prices are calculated on basis of the present price per sack of charcoal containing 20 % of unused fines and brands (See Chapter II).

Selection of interesting production alternatives for further elaboration

For each of the 12 production alternatives the potential profit margins for wholesalers and retailers as well as the pay-back period are calculated (See Table 4.3). Criteria for these values are not yet formulated, since at this stage only the relative importance of the various parameters is of interest. It is concluded that the carbonisation period is the most important parameter. The second important parameter is the briquetting season length. It appears that the investment in a forced draught dryer, in combination with the higher investment in storage material (bags) for the unprocessed cotton coal, does work out negatively, and does not allow a better average production per unit of investment. The introduction of a 2 shift system leads to only a small improvement. The increase of scale from alternative B to C is of great importance, which is mainly due to the lower labour cost.

From the 12 alternatives B11, B221, B222, C11 and C22 are selected in order to test their sensitivity to the assumptions made. The A alternatives are left apart since these do not reflect a potential future situation in which the main part of cotton stalks produced in the Rahad Scheme can be processed. Though at first sight the selected alternatives do not all appear to be feasible, there is some leeway for improvement. This selection still represents all different production characteristics as presented in Table 4.1.

Table 4.3 Feasibility indicators to 12 production alternatives.

Alternative	A1	A2	B11	B12	B211	B212	B221	B222	C11	C12	C21	C22
Annual production (t/yr)	201	201	803	803	956	956	1149	1149	3613	3613	5419	5419
Production cost (LS/t)	492	520	476	504	466	494	453	479	341	369	330	357
Pay-back period (yr)	5.2	5.7	4.5	4.9	3.5	4.0	3.3	3.8	4.6	5.7	4.5	5.2
Max. attainable profit margin wholesaler (% of market price)	n.a.	n.a.	13	7	15	9	18	12	51	41	55	45
Max. attainable profit margin rettailer (% of market price)	-2	-7	-6	-12	-5	-10	-2	-7	30	21	35	25

Sensitivity of selected production alternatives to major assumptions

The 5 selected alternatives are improved with respect to several important items.

First, the method for obtaining the unprocessed cotton coal. Instead of having the coal produced by hired labour under supervision, the coal is purchased from professional carbonisers on a per weight basis. No supervision is needed. Kilns are owned by the briquette manufacturer and, to secure proper care for the kilns, these are hired out to the carbonisers. Prices for the cotton coal and kiln hire are such that the carbonisers earn a reasonable daily wage.

Secondly, the investment costs of the alternatives have been established more precise (See Appendix II).

Due to the above changes in the selected alternatives, they are renamed as follows:

B11 - I;
B221 - II;
B222 - III;
C11 - IV;
C22 - V.

Precise characterisation of these alternatives is given in Table 4.4. For the resulting feasibility indicators, see Table 4.5. The conclusion may be drawn that all alternatives at first sight appear to be very strong with reference to financial feasibility

Table 4.4 Technical characterisation of production alternatives I - V.

Alternative	I	II	III	IV	V
Carbonisation season length (week/yr)	13	13	8	13	8
Briquetting scale	m	m	m	l	l
Briquetting season length (month/yr)	8	12	12	12	12
Shift nr.	1	2	2	1	2

Table 4.5 Feasibility indicators for alternatives I - V.

Alternative	I	II	III	IV	V
- Production cost (LS/t)	361	372	395	349	364
- Pay-back period (yr)	5.5	4.5	5.1	4.7	5.2
- max. profit wholesaler (% of market price)	44	40	33	48	43
- max. profit retailer (% of market price)	23	20	13	28	22

A. Charcoal market price

Since it is assumed that the briquette market price is tied to that of wood charcoal, the influence of the charcoal market price on the feasibility indicators is calculated. In the method of feasibility assessment used, the production cost, factory gate price and thus the pay-back period do not depend on the briquette market price. Only the maximum attainable profit margins of wholesalers and retailers change with varying market price. Results are presented in Table 4.6. Actually the charcoal market price showed a steep increase during the past years (appr. 15 %/yr, see Chapter II), and higher prices are still expected. It may be concluded that feasibility will increase rapidly in the coming years.

B. Briquetting machine break-down

In Sudan skilled service mechanics and spare parts may only be available on a limited scale. This lack of maintenance and repair services is one of the main reasons for occasionally poor results from investments in technology. If a briquetting machine breaks down for a longer period, this immedeately leads to a decrease of the annual production, and hence, since annual cost remains the same, to higher production cost per ton. In case the production relies on more briquetting machines than one, this effect is obviously less pronounced. To demonstrate the sensitivity of the various alternatives to such occasions (In fact this is the sensitivity of the small capacity agglomeration technology versus large capacity roll-pressing technology), the influence of down time of one briquetting machine on production cost and pay-back period has been calculated (See Table 4.7). This clearly shows a high risk in case of the roll-press system and an advantage of small capacity agglomeration.

Table 4.6 Sensitivity of maximum attainable profit margins for wholesalers and retailers to charcoal prices, ceterus paribus.

Alternative	I	II	III	IV	V
Charcoal price * 1.0					
- max. profit wholesaler (% of market price)	44	40	33	48	43
- max. profit retailer (% of market price)	23	20	13	28	22
Charcoal price * 1.1					
- max. profit wholesaler (% of market price)	58	54	46	63	57
- max. profit retailer (% of market price)	36	32	24	40	34
Charcoal price * 1.2					
- max. profit wholesaler (% of market price)	72	68	59	78	71
- max. profit retailer (% of market price)	48	44	35	53	47
Charcoal price * 1.5					
- max. profit wholesaler (% of market price)	116	110	99	122	114
- max. profit retailer (% of market price)	85	80	69	92	83

Table 4.7 Sensitivity of production cost and pay-back period to machine break-down, ceterus paribus.

Alternative	I	II	III	IV	V
0 Weeks machine break-down per year					
- Production cost (LS/t)	361	372	395	349	364
- Pay-back period (yr)	5.5	4.5	5.1	4.7	5.2
2 Weeks machine break-down per year					
- Production cost (LS/t)	362	373	397	363	380
- Pay-back period (yr)	5.6	4.6	5.2	6.0	6.8
4 Weeks machine break-down per year					
- Production cost (LS/t)	364	375	399	380	397
- Pay-back period (yr)	5.7	4.7	5.3	8.2	9.9
8 Weeks machine break-down per year					
- Production cost (LS/t)	367	379	402	417	435
- Pay-back period (yr)	6.0	5.0	5.6	33	106

C. Investment cost

Since the granulation technology for continuous manufacture of charcoal briquettes is not yet completely developed, investment cost are not exactly known. Estimates are made conservatively and may be lower than assumed. On the other hand, due to inflation, roll press equipment, which is state-of-the-art technology, may become more expensive. For this uncertainty a sensitivity analysis of production cost and pay-back period with respect to investment cost has been made and is presented in Table 4.8. It can be concluded that up to an investment increase of 20 % all 5 alternatives remain flexible enough for feasibility. Only in case of Alternative III the effect of the short carbonisation period on the amount of kilns which have to be used (and have to be paid for) is rather strong and tends to make this alternative less attractive. This stresses the necessity of coordinating uprooting activities in order to secure a long carbonisation period.

Table 4.8 Sensitivity of production costs, pay-back periods and profit margins to investment cost, ceterus paribus.

Alternative	I	II	III	IV	V
Initial investment * 0.9					
- Production cost (LS/t)	349	361	382	337	351
- Pay-back period (yr)	5.1	4.2	4.7	4.4	4.9
- max. profit wholesaler (% of market price)	48	43	37	52	47
- max. profit retailer (% of market price)	28	23	16	32	27
Initial investment * 1.0					
- Production cost (LS/t)	361	372	395	349	364
- Pay-back period (yr)	5.5	4.5	5.1	4.7	5.2
- max. profit wholesaler (% of market price)	44	40	33	48	43
- max. profit retailer (% of market price)	23	20	13	28	22
Initial investment * 1.1					
- Production cost (LS/t)	373	382	408	360	377
- Pay-back period (yr)	5.8	4.8	5.4	5.0	5.5
- max. profit wholesaler (% of market price)	40	37	29	44	38
- max. profit retailer (% of market price)	19	17	9	24	18
Initial investment * 1.2					
- Production cost (LS/t)	385	392	420	372	390
- Pay-back period (yr)	6.1	5.1	5.7	5.3	5.8
- max. profit wholesaler (% of market price)	36	34	26	40	34
- max. profit retailer (% of market price)	16	14	6	20	14

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Table 4.8 Sensitivity of production costs, pay-back periods and profit marqins to investment cost, ceterus paribus. (CONTINUED)

Alternative	I	II	III	IV	V
Initial investment * 1.5					
- Production cost (LS/t)	422	423	458	407	428
- Pay-back period (yr)	7.0	6.0	6.6	6.0	6.6
- max. profit wholesaler (% of market price)	26	25	17	29	24
- max. profit retailer (% of market price)	6	5	-3	9	4

Selection of one production alternative for a pilot project

The financial performance of all 5 alternatives, both the agglomeration and the roll pressing technology, seems to be almost equally satisfactory. However, for a pilot carbonisation and briquetting project there are more criteria than the financial ones alone. The two technologies differ clearly in other properties like sensitivity to technical damage causing delays in production, employment aspects, scale of organisation and level of investment. A list of such aspects and an evaluation for both technologies is shown in Table 4.9.

Sensitivity to production disturbances and the level of investment have a direct financial influence on the implementation chances and the real performance of these technologies. Since the agglomeration process requires the operation of more smaller units in one briquetting plant, this technology is less sensitive to damages of the equipment than the roll-press technology.

Energy consumption and employment are aspects in which it is clear that again agglomeration is preferable to roll pressing.

In the evaluation "low-tech" technology is considered an advantage over "high-tech" technology, for reasons of maintenance and repair. The roll-press system needs continuing maintenance by manufacturers from developed countries (At least every year the rolls must be polished or replaced, due to the substantial wear of the press surfaces).

Finally the organisation scale of block level production, necessary for the roll press technology, imposes a large difficulty in the start-up and implementation of the carbonisation and briquetting process. In evaluating the organisation degree, the complete production organisation, from uprooting of the stalks to briquette storage, as well as the operation in a shift system should be considered. We conclude that the agglomeration technology is a very strong alternative and hence select one of the alternatives I to III for final evaluation and implemenation in a pilot project.

Table 4.9 Properties and evaluation of agglomeration and roll-pressing techniques for charcoal briquetting.

Property	Agglomeration	Roll pressing
Sensitivity to disturbance	low	high
Level of investment	low	high
Energy consumption	low	high
Employment	high	low
Level of technology	low	high
Scale of production organisation	low	high

Though the alternatives and III may be financially the most attractive ones, their financial advantages are only marginal. Alternative I, with briquette production which is limited to the dry season, bears the advantage of using known technologies only (open-air drying rather than forced-draught drying) and of avoiding some yet unanswered doubts about briquette handling (storage, transport) and use (ignition properties) during the rainy season. Alternative I also needs the lowest investment and has lower production cost, which leaves more room for yet unknown costs. This is shown as follows: If the margins which are put over the production cost for the briquette gate-price to wholesalers and retailers are increased to 35 and 45 % respectively, the pay-back period of the carbonisation and briquetting plant reduces to 3.4 yr. Still the margins between consumer prices and cost made by wholesalers and retaiiers are 30 and 10 %, which seem to be reasonable. These fiqures indeed only indicate the flexibility and low risk of this production alternative. In reality an entrepreneur should establish prices in his own manner in an open market.

Costs which are not yet considered

Up to this level of analysis no cost are taken into account for availibility of cotton stalks, nor for taxes. As for cotton stalks availibility, any payment must be considered in view of calculated production cost. There is limited room for such payments. However, an additional cost of 20 LS/t briquettes for purchase of the stalks seems to be possible in view of the shown flexibility. Which procedures are necessary to make cotton coal briquette production profitable for tennants and Scheme Management is discussed in Chapter V.

Payments of taxes to the Sudanese Government will influence the financial results of a carbonisation and briquetting project negatively. At this stage of the investigations tax regulations could not be taken into account. The Sudanese government should take a position in this matter in the next phase of the project. In order to not needlessly hinder a carbonisation and briquetting pilot project (See Chapter VII) for example a tax holiday may be considered.

V ORGANISATION OF COTTON COAL BRIQUETTE PRODUCTION

Starting from the main objective of the cotton stalks carbonisation and briquetting project i.e., to make use of as much cotton stalks as possible, in this chapter various organisation models are formulated and evaluated. Any party involved in the processing of cotton stalks to cotton coal briquettes should be stimulated to reach the highest possible output. In a future situation of final development of cotton briquettes production it should not occur that relevant amounts of stalks still are incinerated. Therefore, relationships between parties involved should be constructed such that these are in tune with this general interest of the Sudanese society. Within the same framework implementation strategies are discussed, since wrongly chosen strategies might lead to failures that prevent further development.

Briquetting

The running of an industrial briquetting plant, on village level or block level, involves several managerial skills acquired by both education and experience, like:

- technical management;
- marketing management;
- accounting management;
- management of personnel.

It is not likely that a tennants cooperation or the Tennant Union have these skills readily at their disposal. In a meeting with representatives of the Tennant Union the Union's willingness was expressed to consider taking part as a shareholder in the foundation of briquetting factories, as the Union presently does with some vegetable oil mills (in this stage of the investigations no commitments were made). The Rahad Scheme Management may certainly be able to cope with accounting and personnel management, but it is not familiar with manufacturing industry nor charcoal marketing. Consultations with the Scheme Management learned that it is aware of this fact and that it wants to restrict its activities to agriculture. For this reason it appears to be necessary that a briquette manufacturer is found elsewhere.

The founding of a privately owned briquette factory calls for the definition of some commercial relationships between the manufacturer and the suppliers of raw material.

Supply of cotton stalks

For the carbonisation efforts not only the mere availibility of stalks but also its period of availibility is of importance. The earlier stalks become available, the longer the carbonisation period and the lower the amount of kilns needed (See Chapter IV for the importance of the investment in kilns). Below some organisational options are summarised:

- The briquette manufacturer comes to an agreement with individual tennants about both the general availibility of cotton stalks as well as about the time of availibility.
- The briquette manufacturer arranges with the Scheme Management that it will announce the general prohibition of stalks incineration and that it will oblige the tennants to uproot and collect the stalks following a strict time schedule from March until half May.
- With the Scheme Management the briquette manufacturer arranges for the general prohibition of stalks incineration, whereas he agrees upon the coordination of uprooting and collection activities with the Tennant Union.

In all alternatives the briquette manufacturer offers a financial compensation to either tennants, the Tennant Union or the Scheme Management. Such a payment to the Union or the Scheme might be of interest, for instance to fund social programmes. In a consultation with the Tennant Union, the Union proposed to pay directly to the tennants, in case the Union coordinates uprooting and collection activities. The briquette production cost vary linearly with the cost of the unprocessed cotton coal. In view of the anticipated production cost a briquette manufacturer is able to pay about 20 LS/t briquettes for the service of timely stalks availibility. With a potential of 2.75 t cotton coal per hawasha and an amount of 0.78 cotton coal per t briquettes this would result in a payment of 71 LS/hawasha. On the Rahad Scheme level this would be 1,000,000 LS/yr under the assumption that all presently incinerated cotton stalks are carbonised and briquetted.

Dealing directly with the tennants will involve a great effort of negotiations and control of performance of the contracts, especially since the financial space is not that large. The Tennant Union is expected, even more than the Scheme Management, to be able to organise a well timed uprooting and collection schedule. Probably the last formulated alternative (see above) is the most suitable from both an organisational and economical point of view.

Supply of cotton coal: carbonisation

The next step, after availibility of the cotton stalks has been secured, is the carbonisation. Due to the high cost involved, investment in metal kilns can only be justified if made by the briquette manufacturer, not by individual tennants or the Tennant Union (See Appendix II). In order to ensure proper care for the kilns, all carbonisation activities must be supervised or, alternatively, the kilns must be hired out to those who actually carbonise. The latter alternative, in combination with the purchase of cotton coal from the carbonisers on a per ton basis is for the briquette manufacturer not only the cheapest solution but also fits well in the present Sudanese society.

If in the future open pit kilns might be used for the carbonisation of cotton stalks, the investment structure would change drastically. The main input would be the labour to dig the pits, which could be provided by tennants or professional carbonisers.

To avoid endless negotiations and extremely high prices for carbonised cotton stalks it is necessary that tennants will not acquire a monopoly on carbonisation. Carbonisation must be made subject to a free labour market. Therefore, any agreement with tennants, the Scheme Management or the Tennant Union about availibility of cotton stalks must include the stipulation of carbonisation activities by professional carbonisers along the hawasha supply roads. The cotton coal price, as payed by the briquette manufacturer, will then only depend on the labour market, rather than on the price of wood charcoal. Presently a reasonable wage for charcoal makers is about 7 - 8 LS/man day. With metal kilns 2 charcoal makers are able to produce 0.520 t cotton coal per day (2 man operating 6 kilns), which therefore should cost 26 - 29 LS/t. If, with pit kilns, the cotton coal production capacity per man would be larger, the price setting for the coal would lower accordingly.

For the carbonisation basically two organisational alternatives exist:

- Carbonisation is carried out by professional charmen. The briquette manufacturer buys cotton coal from these carbonisers on a per ton basis.
- The tennant takes care of the coal production (by either his own labour or by hired labour). The briquette manufacturer buys coton coal from the tennant on a per ton basis. Since a hawasha delivers approximately 2.75 t coton coal, a tennant could maximally receive 72 - 80 LS for the charcoal made on his hawasha (Calculation based on above mentioned per ton price).

The latter alternative bears the advantage of the cooperative attitude of the tennant which is mainly of importance for an early start of the uprooting activities and consequently timely availibility of cotton stalks. This alternative would therefore combine with both the first and the third mentioned alternatives concerning availibility of cotton stalks, i.e. a direct deal with the tennants or a deal with the Tennant Union. The amount of money payable for the service of timely uprooting (maximally 71 LS/hawasha) together with the amount payed for the cotton coal might be of interest to a tennant. However, it must be born in mind that the tennant should also pay for all labour cost involved for the carbonisation (With 2.75 t cotton coal per hawasha, 0.09 t/kiln cycle and 2 operators for 3 kilns: approximately 20 man days per hawasha).

Appraisal of one organising alternative

Based on these considerations the authors recommend to establish privatly owned companies for cotton coal briquette production. Possibilities for share holding by Tennant Unions should be considered in order to create a common interest of plant owners and tennants. The Rahad Scheme should consider the general prohibition of cotton stalks incineration (except for the small amounts used for cooking purposes in poor households). For the household use of cotton stalks certain hawashas near the villages should be allotted. Tennants should remain being obliged to uproot and collect the cotton stalks from their fields, in order to prevent unacceptable costs with respect to cotton stalks availibility. To keep investments in kilns low, the briquette manufacturers and the Tennant Unions prepare uprooting and collection schedules which the tennants are obliged to follow. The tennants receive a financial compensation for this effort. The kilns are owned by the briquette manufacturer who decides who is going to use them on the cotton fields.

VI SOCIO-ECONOMIC CONSIDERATIONS

In this chapter a concise analysis is presented on the most important socio-economic impacts of applying cotton stalks as an input to produce cotton coal briquettes. The aspects of briquette production, most relevant to the Sudanese society, are succinctly described and effects are elaborated as far as possible in the framework of the present project stage. The analysis mainly pertains to direct effects. In some cases these effects may have a further impact on society in such a pertinent way, that discussing these so called indirect effects adds considerably to the analysis.

In case the analysis has to be limited through lack of immediate knowledge and or inavailibility of data and if it is expected that the effects under consideration may be relatively important for decision making purposes, efforts are made to indicate further investigations, which can be included in the next phase of the project or be a subject of future research.

The effects on society discussed in the present chapter have to be considered in the light of the objective of the briquetting project. The aim may be summarized as follows: The application of a waste material (cotton stalks) for production of charcoal as an input for production of charcoal briquettes. This will to some extent alleviate the great demand for charcoal in Sudan and will in its turn prevent deforestation connected to the diminished demand for charcoal. The project is further directed at contributing to other main development aims of Sudan, like increase of employment, income generation and income distribution, improving the energy balance, etc. The effects of the project are considered from a national level as well as from a regional level (of e.g. the Blue Nile, Kassala and Gezira provinces).

The following aspects are considered more or less comprehensively:

- Environmental effects of briquetting;
- Labour market effects;
- Income generation and income distribution;
- Balance of payments effects;
- Contribution to the energy balance;
- Stabilizing effects on charcoal prices.

<u>Environmental effects of briquetting</u>

To stress the importance of forest conservation and (re-)afforestation, the following summarizing statements have been derived from various sources of expertise (SCHMITT/SIEM 85, EL SHEIKH/HOOD 86, BTGI 86, GTZ 85, WB 83).

A. Biomass as a source for fuels

- 80-90% Of the population of Sudan relies on biomass for their fuel requirements. This, together with a recent multi-year period of drought, has lead to a fast rate of deforestation. Regional variations exist with regard to the phenomena, especially the forest reserves in the provinces of Blue Nile, are much affected by uncontrolled cutting of trees.
- For various reasons, but also because of the important reason of fuelwood (and derived charcoal) need, desertification is reportedly shifting South with a speed of 10 to 20 kilometers a year; it is expected that at the present rate of deforestation all forest in Sudan will be depleted within a period of 20 years from now.
- The demand of wood (including charcoal) for household purposes, mainly consisting of cooking, has been reported to roughly reach a level of 500 kg/year per capita. This, related to a population of about 20 Mln., comes up to about 10 Mln. tons of wood per year. On top of this (reportedly low estimate), industry as well as building needs for wood have to be considered.
- Hydrocarbon based fuels in Sudan are scarce because of import restrictions related to the unfavorable balance-of-payment structure. Kerosine, increasingly used for lighting and cooking in the near past (mainly in urban areas) almost completely disappeared from the market. By government measure the Port Sudan refinery has ceased production of kerosene in favour of fuel for transport purposes.
- Proven reserves of hydrocarbons in Sudan (oil and natural gas) will not soon lead to a change in energy consumption patterns. An increase in production of hydrocarbon based energy sources (fuel oil and electricity) will reportedly still for many years find an ample market in transport and industry, leaving the household sector to rely mainly on biomass based fuels.
- For the same reason, also in urban areas, the demand for fuel wood and charcoal may not considerably decrease in the near future.

B. Aggravation on charcoal

- As second important energy resource (after wood) comes charcoal. This commodity covers 25-30 % of all energy consumption in Sudan.
- Regional variations in charcoal demand have been reported; the role played by charcoal is most prominent in the relatively densely populated provinces of Sudan.
- The urban population (25 % of total population) consumes 40 % of all charcoal produced in Sudan.

C. Potential of cotton stalks

- Cotton stalks may in principle have alternative applications which might compete with using the stalks as an input for cotton coal based briquette production. Potential applications, at least in theory, are for example: paper production and particle board production. In Sudan these applications have been considered and rejected, for various reasons not to be discussed here. In one case (particle board production) investments were made, but the project was abandoned.

- Actually there is a use for cotton stalks in Sudan, as they are used by tennants and squatters as firewood and, to a lesser extent, as building material in adobe buildings or dwellings. Research learned that after substracting stalk amounts consumed in said applications, ample amounts of stalks still remain on the field to be incinerated. Stalks are mostly gathered in the fields nearest to villages and settlements.
- The future of cotton production in the Sudan looks bright enough to guarantee long term stalks availability for briquetting purposes. Even if the prospects of cotton production would decrease considerably and structurally, converting cotton areas to other crops would not be that easy to realise.

Labour market aspects

The 5 remaining alternatives (I - V) for briquette production in the Rahad Scheme come with employment opportunities as shown in Table 6.1. It is clear that especially the alternatives I to III (briquette production by agglomeration) will produce much permanent employment. All alternatives rely on seasonal carbonisation labour. As for the latter: in the carbonisation period much of he work in the cotton fields has already been completed. Thus for those seasonal labourers that can be employed in carbonisation (after a training in kiln operation) an opportunity arises to increase their yearly income.

Alternative I plants dry briquettes in the open on drying tables; this restricts production to the dry season. In this alternative, most of the briquetting labour is also seasonal in nature, the season however stretches out over a period of approximately 8 months.

If briquetting proves to be succesful, production can also be stimulated in the other cotton growing areas. Especially the Gezira-Managil Scheme, located even closer to the main urban areas of Wad Medani and Khartoum than the Rahad Scheme, offers good opportunities (a total area under cotton of about 200,000 ha, compared to 55,000 ha in the Rahad Scheme). If it is assumed that all opportunities with regard to now still incinerated cotton stalks are seized in the future, and taking into account that cotton production in the Gezira-Managil area yields less per ha than in the Rahad scheme, it may roughly be estimated that employment in that scheme may rise with approximately 17,000 man months of seasonal labour (carbonisation) and with 810 to 4,700 permanent or (semi)permanent places, depending on the technical alternative considered.

Indirect employment opportunities have not yet been reckoned with. In this respect one may think of certain services like transport, repair-services, retailing etc. Usually for these indirect opportunities a multiplier of 1.25 - 1.5 is applied in areas where such services have already been developed, like in the Rahad Scheme.

The other side of the coin is that new employment related to the production of cotton coal briquettes will cut out employment in charcoal production elsewhere. Given the facts that, firstly, cotton coal briquetting involves much more labour per ton of product than wood carbonisation, secondly, that cotton coal briquettes may only for a relatively minor percentage subsitute wood charcoal and thirdly that the potential demand for charcoal (and briquettes) may still rise in the near future, the employment lost in wood charcoal production will be limited. If decline of employment in charcoal production will occur, it is more likely that it will be caused by a slack in demand due to more efficient charcoal burning in household cooking or to the general tendency of rising charcoal prices.

Income generation and income distribution

For each of the 5 remaining alternatives, income generation is considerable. At actual wage levels of about LS 7 to LS 10 per day the total yearly labour income generated in a maximum case of utilisation of all cotton stalks now burnt in the Rahad Scheme will amount from approximately LS 1,020,000 to LS 1,450,000, depending on the alternative chosen. Most of the income will accrue to poorest classes of society (field and plant labourers) leading to more income equity in the Rahad Scheme. Opportunities for additional income generation because of briquette production may also have a dampening effect (probably of relatively minor influence) on migration to urban regions. Employment on management level, will lead to a change in distribution of households over various income classes, the greater part of households at the moment being in the lowest income classes. The distribution of profit income, depends on the structure(s) in wich briquetting will be organised (Private, public, individual firms, cooperations, etc.). Organisational structures should be subject to further investigations in a next project stage.

Table 6.1 Employment from utilisation (carbonisation and briquetting) of cotton stalks in the Rahad Scheme.

Alternative	I	II	III	IV	V
Number of plants in the Rahad Scheme	63	44	44	14	9
Employment related to all Rahad plants:					
- carbonisation (seasonal)	1,600	1,600	2,600	1,600	2,600
- briquetting (incl. management)	1,800	1,600	1,600	260	270

Balance of payments effects

In discussing the balance of payments effects of briquetting, the agglomeration process and the roll-press process have to be strictly separated, the former being a more labour intensive, the latter a more capital intensive process. A general picture of differences will now be presented.

If briquetting by agglomeration develops well in Sudan, many agglomerators of the same type have to be gradually procured. On the level of the Rahad scheme, just to give an impression, it concerns about 400 to 700 machines of Dfl 2000,00 a piece, depending on the alternative chosen. If other cotton areas are included, the number of machines of course will be much higher. Probably, the number of machines needed in Sudan will not be large enough to consider their production in Sudan. Even if production in Sudan would seem a good decision because of balance of payment advantages, then still most of the components for these machines are best procured abroad at competitive prices. The best solution, taking everything into consideration, is to select one or a few foreign companies to develop the machines in such a way that compact knock-down deliveries can be made to some Sudanese companies specialising in assembling, tuning and maintenance of the machines. Apart from the agglomerators other machines like grinding mills and mixers are needed. Those are needed in such limited amounts that procurement abroad is the most economic solution.

Investment figures in Tables A2.9 and A2.11 (Appendix II) show that sophisticated roll-press machines, are expensive. Those machines must be procured abroad, and, what is more, they have to be installed and maintained under supervision of specialists. Rolls, which indeed are the most expensive part of the machine, have to be replaced quite regularly.

Without entering into details, the considerations presented above clearly suggest that the capital output ratio of the agglomeration alternatives is more favourable from a balance of payment point of view, than that of the roll-press alternatives. Alternative I, from a balance of payments point of view, probably is most attractive on a per plant basis, because in this case import of drying equipment is not necessary. On the other hand, in alternative I plants, more agglomerators are needed than in alternatives II and III, because of the shorter production period. This reduces the relative advantage of alternative I.

Material inputs (or their intermediates), apart from energy (fuel, electricity), lubricants and bags, are all from local origin and thus don't put much strain on the balance of payments. Bags to sack briquettes have to be imported in considerable quantities. These woven plastic bags are re-usable. Consequently, after initial imports, only modest imports for gradual replacement of worn out bags has to be taken into account. Kilns which are needed in considerable quantities in all alternatives (the numbers depending on the lenght of the carbonisation period) can be procured in Sudan. However, steel to produce kilns has to be imported.

One of the local inputs concerns the molasses, which is needed in modest amounts. An alternative outlet for molasses is export; consequently balance of payment effects are involved. If these effects are considered to be of importance (which is not likely), more details have to be gathered in a next project phase.

Contribution to the energy balance

Production of briquettes from cotton coal consumes energy for running the various machines and, in some of the alternatives, for forced drying of briquettes. This amount can be ignored since on the other hand much diesel oil presently used for wood charcoal transport can be saved. The cotton growing schemes are much closer to the urban charcoal markets than the wood charcoal producing areas. This saving equals possibly more than 15 l diesel per ton of wood charcoal (replaced by cotton coal briquettes). Keeping in mind that ideally 315,000 t/yr of cotton coal briquettes can be produced, this would result in a saving of approxiately 4,725,000 liters (3,780 t) of imported diesel fuel per yr. The more briquette production will be realized in Sudan, the more the energy balance on national level will be equilibrized.

Stabilizing effect on charcoal prices

Price hikes of charcoal are a major concern to the Sudanese society. High prices for charcoal put a considerable strain on household budgets, especially those of low income groups. These price hikes are mainly caused by depletion of wood reserves in the vicinity of urban markets, leading to increasing cost. The charcoal market in Sudan in its rigidity will immediately and completely pass cost increases on to the end user. Any opening in this market by introduction of a good substitute, like in this case the cotton coal briquette, may have a stabilizing effect on charcoal prices.

Screening of alternatives on socio-economic effects

Table 6.2 summarizes socio-economic effects for each of the alternatives. Starting from the assumption that in any of the five alternatives considered the same production level of briquettes will be reached in the future, scores have been applied for the various effects tied to aspects and to alternatives. The scores are of restricted value; they offer a dimensionless ordering without any weights attached for differences in importance of the various socio-economic parameters. Applying weights is reserved to the final decision maker (in this case the Sudanese Government). The decision maker firstly has to decide on wether or not to persue the concept of cotton coal briquetting and secondly has alternative ways of implementation to choose from.

Table 6.2 Score card of socio-economic effects.

	I	II	III	IV	V
	(Agglomeration)			(Roll-press)	
Environment	1	1	1	1	1
Labour market	1	1	1	0	0
Labour income generation/distrib.	1	1	1	0	0
Balance of payment	-1	-1	-1	-2	-2
Energy Balance	2	1	1	1	1
Stabilization of charcoal prices	1	1	1	1	1
Total unweighted score	5	4	4	1	1

VII RECOMMENDATION FOR NEXT PROJECT PHASE: RESEARCH AND IMPLEMENTATION

In view of the promising results of the present field test, the expressed interest of the Sudanese people, the result of the evaluation of financial feasibility and of the socio-economic evaluation, it is proposed to continue the programme on carbonisation and briquetting of cotton stalks.

Since the present study shows clearly the necessity of small-capacity charcoal briquetting equipment, it is proposed to continue development of such equipment as started by BTG. The agglomeration equipment should be further developed as pointed out in Appendix I. It is proposed that BTG takes the lead for mechanising the feed of cotton coal fines to the agglomerators. The Sudanese climatic conditions impose special demands on the briquette quality (E.g. resistance to air-humidity in relation to transport and handling). RERI could perform the necessary tests. Employment of low-cost permanent kilns should be considered in order to investigate possibilities for reduction of the costs made for unprocessed cotton coal.

Demonstration project

In the view of the authors of the present study a demonstration project should be started in the Rahad Scheme next season on a village scale. In this demonstration project the feasibility of the whole process of carbonisation, briquette production and marketing should be shown to potential investors and traders. Both from an organisational and technical points of view the production should be monitored closely to make improvements and adaptations as necessary.

To enable continuation of the programme in the next season, it is proposed that the interested donor agencies send a mission to the Sudan for the necessary co-ordination activities. The general mission objectives are to discuss and evaluate the findings of the first project phase with the relevant Sudanese parties (Energy Research Council, Rahad Scheme management) and to draft project documents for the second phase of the programme in co-operation with the ERC and the Sudanese Ministry of Finance and Planning;

The mission will study the possibilities of commercialisation in this project phase. To demonstrate the feasibility of cotton coal briquetting to Sudanese investors and to elaborate proper extension and training programmes, a comprehensive insight in the commercial and financial setting of this target group is required. In this context the mission will also discuss the necessity and possibilities of tax regulations for briquette production during the pilot phase of the project with the the Sudanese Government (See Chapter IV). During this visit a working-group, consisting of representatives of the Rahad Scheme Management, RERI and BTG, will be established in order to easen the co-ordination of project related activities. In order to be able to start the demonstration project in the next season (March 1988) this mission should visit Sudan as soon as possible, preferably before the end of November.

As a pilot plant meant for the demonstration of viability to potential investors, the project should as far as possible be commercial. The proposed mission will study the present possibilities. Preferably all investments are made by a Sudanese entrepreneur. Since the carbonisation and briquetting of cotton stalks using this technology is a novelty in biomass processing, some technical assistance might be necessary. In order not to disturb the commercial character of the pilot project services to the briquetting plant should be payed the normal Sudanese compensations (Foreign services should be topped up to the necessary levels by the donor agency involved). Training of the carbonisers to operate the kilns can certainly not be borne by the briquette manufacturer and should therefore be financed externally.

A part of the mission's activities is the selection of an entrepreneur willing and able to run the demonstration project. Selection criteria should be defined and an announcement (Call for qualifications) could be published in the Sudanese newspapers as a means to identify interested potential entrepreneurs. The mission must also prepare a financing schedule in co-operation with Sudanese investment banks and relevant donor agencies and the selected entrepreneur.

Longer term implementation strategy

The programme should finally lead to large scale implementation of this technology in the various cotton growing schemes for the reasons explained in Chapter I. For stimulation and supervision it is proposed not to limit the activities of above mentioned working-group (with representatives of the Rahad Scheme Management, RERI, experts from relevant donor agencies and others) to activities related to the demonstration project, but also to make discussion and evaluation of the project a part of its duties.

Requirements for large-scale implementation are reviewed below. In due course it is proposed that a number of administrative decisions are taken by the managements of cotton growing schemes to satisfy these conditions.

- In order to strengthen the position of the briquette manufacturer with respect to the tenants who, instead of making uprooted stalks available to carbonisers, might decide to have them burnt, the scheme managements should generally prohibit the incineration of cotton stalks in all areas where cotton stalks carbonisation and briquetting has been implemented. Meanwhile the tenants should remain being obliged to do the land clearing (uprooting and collection of the stalks) (See Chapter V);

- To ensure that a free labour market controls the price setting of cotton coal, the scheme managements should make it possible that the briquette manufacturer rather than the tenants, decides who is going to execute the carbonisation on the hawasha's (See Chapter V);
- Since water is needed for the operation of the open-ring type carbonisation kilns, the hawasha's water supply ditches should be filled with water in accordance with carbonisation activities on the hawashas. After an uprooting and carbonisation plan has been established by the briquette manufacturer and the Tenant Union for a particular village, the Scheme Management should be prepared to cooperate (See Chapter III);
- Presently part of the uprooted cotton stalks are not incinerated but rather used by poor people who cannot afford buying wood nor charcoal. Production of cotton coal briquettes should not disturb this important use of cotton stalks. For protection of the poor, the scheme managements should allot certain hawashas near the settlements to these users.

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APPENDIX I RESULTS OF THE LABORATORY AND FIELD TEST PROGRAMMES

BTG and RERI laboratory programme

A. Briquette technology

In the laboratory programme of the Biomass Technology Group a cotton coal briquetting technology has been designed. The cotton coal briquettes show combustion characteristics similar to wood charcoal. The briquette also is resistant to water so that it can be extinguished after the cooking is ready (this method of extinguishing is often applied in case wood charcoal is used in order to save fuel). With respect to transport characteristics (friability and strength) the briquette shows a much better performance than charcoal made from wood, so that losses due to transport are minimised.

B. Briquette production process

While the briquetting process consists of grinding, binding and forming, BTG research focussed on grinding rate (particle size distribution), binder types (tested binders are: gum arabic, starch, cement and cane sugar molasses), binder content and the formation process. The considered production processes were piston extrusion, screw extrusion, roll pressing and granulation. Both roll pressing and granulation turned out to be promising alternatives. For reasons of economics of scale, granulation was developed further.

The research resulted in a prototype of a granulator and in a prototype production line, with a design capacity of 50 and 200 kg wet briquettes per hr respectively.

Results of the field test programme

A. Carbonisation

During 2 months approximately 30 tons of charcoal were produced on cotton fields located near Village 10 in the Rahad Scheme. The actual in-the-field carbonisation started April 20 and lasted until June 7. The kilns used were constructed from oil drums, sheet metal and angle-bar (This type has been described in ZORGE 85). 3 kilns were operated by 2 men, which were payed on a per day basis (7 LS/day). The men worked 7 days per week, fridays were payed double. These relationships once being established, it was decided not to change them although technically it appeared to be possible to operate more kilns per labourer. The tenants were not payed any compensation for making the stalks available, however not every tenant was willing to cooperate on this basis. If tenants were cooperative, the uprooting labourers were not. They wanted to be payed for bringing the stalks to the sides. The use of the kilns appeared to be efficient and easily understandable by the charmen, although being payed on a per day basis they needed close supervision. The carbonisation has been described in more detail in ZORGE 87.

8. Briquetting

The briquetting plant was built near Village 10 in the Rahad Scheme. Its lay-out is schematically presented in Figure A1.1. During the 2.5 month period of the project, the plant could only be operated for 23 days. Main problems were the time necessary for transportation and custom's clearance, a 15 days power cut and a fire accident. After these start-up problems smooth operation was possible with 2 of the 4 briquetting machines. Production data are listed in Table A1.1.

Table A1.1 Production data

Period of operation (hr)	284
Total amount of processed cotton coal (kg)	3,950
Proximate amount of processed molasses (kg)	1,000
Average production per agglomerator, on basis of the whole production period, airdryed briquettes (kg/hr)	17.4
Idem, on basis of the day of maximum performance (130787), airdryed briquettes (kg/hr)	29.1
Maximum hour production of one agglomerator, operated by staff member, on basis of airdryed briquettes (kg/hr)	43.8

The designed capacity of 50 kg wet briquettes per hr (36 kg/hr, on an air dryed basis) was excelled by 20 %, though by a Sudanese staff member rather than by the operators. Several shortcomings and opportunities for improvements of both quality control and production capacity have been identified. One of the reasons for the low average production is that the Sudanese operators preferred to produce the briquettes in batches rather than in a continuous process. The start-up procedure (the formation of nuclei which grow until they reach the right size), often repeated in batch-wise production, needs close supervision and costs a relatively long time. The largest production rate, mentioned in Table A1.1, was actually reached in continuous operation. If the equipment is adapted along the lines identified below, the agglomeration technology appeares to be very promissing from a point of view of production capacity to investment ratio:

- In order to attain the highest possible production rate, the agglomeration equipment should be operated continuously rather than batch-wise. For continuous operation, however, the agglomerators must be provided with a mechanical charcoal fines feeding device. The briquette collection system should be adapted accordingly.
- The potential increase of the production capacity by changing the disk inclination should be investigated.
- Possibly related to the former ones is the problem of dust

formation in the production area. It should be solved both for reasons of briquette quality control and working conditions.

Apart from the development of the production equipment more tests should be performed to assess the briquette quality in terms of strength, moisture resistance and friability. These properties are especially important in relation to the Sudanese climatic conditions.

C. Marketing

Based on an estimate of annual charcoal consumption given in BTG 86 (approximately 2.8 Million ton of charcoal) and a potential of cotton coal briquettes of approximately 0.3 Million ton per year, it can be concluded that in a final stage of development of cotton coal briquette production maximally 11 % of the charcoal market can be penetrated with these briquettes.

In order to find a niche in the household fuel market (charcoal) the qualities of the briquette must be identified thoroughly. Some marketing aspects have been mentioned elsewhere (See Chapter II and Appendix II): with a higher bulk density and absence of fines and brands the briquettes form a product which differs from wood charcoal. These marketing properties should lead to specific ways of offering the briquettes to the end users (Size and form of sacking). Also in cooking performance the briquettes differ from wood charcoal. For example:

- During the ignition phase of the fuel (5 - 10 minutes) the briquettes produce some smoke and a sweet odour;
- After a short period an ash layer is formed around the briquettes which tempers the fire, leading to a longer burn-out time at a smaller heating rate;
- The lower heating value on a weight basis is smaller (22,000 - 24,000 kJ/kg, wood charcoal: 28,000 - 30,000 kJ/kg);
- With the rather heavy briquettes, the fuel load of a cookstove can be higher than with wood charcoal, which leads to a longer burn-out time of the load.

Although some physical characteristics can be assessed in the laboratory, it is not immediately sure how these features influence the actual cooking performance as experienced by the users. In fact consumer's experience should be evaluated over longer periods. Due to the fact that production started late in the dry season, only a limited impression of appreciation of the product could be obtained. Consumer's comments on the quality of the briquettes were collected in 5 villages of the Rahad Scheme. For 3 days 139 families, representing 5 % of the inhabitants of these villages, and 5 restaurants were supplied freely with briquettes. The 4^{th} day the housewives and restaurant owners were questioned about their experience. The questions adressed some typical features of the briquettes in comparison with wood charcoal: the ease of ignition, the amount of ashes, the presence of smoke or smells and their appreciation. These questions and their answers are presented in Table A1.2. Also questions about the duration of combustion and combustion rate were asked. In order to estimate the consumer's appreciation of the briquettes, they were asked to give an indication of the prices they were willing to pay (See Table A.3). The price indications given by the restaurants as well as housewives, close to the price of wood charcoal (See also Table A1.4), show that the briquettes are considered as a serious alternative to wood charcoal. The amount of ashes as well as the presence of smoke and smell in the ignition phase of the briquettes, are properties of this type of briquettes which cannot or only slightly be improved upon. We consider it positive that most consumers experienced no ignition problems. The comments on burn-out time and heating rate indicate that market introduction could stress the favourable combustion characteristics. An aspect which was overlooked in the questionaire was the ease of handling of the briquettes (the ball shape, the absence of fines). However, such comments were given by many people.

After the collection of consumer's comments on the briquette quality the willingness to actually buy the briquettes was tested. It was decided to offer the briquettes to the potential consumers in 30 kg bags or in the traditional malwa for a price which effectively (on a weight basis) equalled 90 % of the wood charcoal price. A bag of wood charcoal usually weighs 35 kg, of which only about 28 kg consists of useful charcoal. Table A1.4 reviews the price settings used in the marketing test.

During 2 days (13 and 16 July 1987) briquettes were sold on the market of Village 10. The sacks were sold to 24 people, the malwas to 117. In Village 10 live approximately 600 families (tenants and labourers). In total 1290 kg (30 sacks and 390 malwas) of briquettes were sold (an average of 645 kg/day), whereas it may be estimated that the daily consumption of wood charcoal, and therefore the daily sale of wood charcoal, in Village 10 is approximately 2000 kg. Consequently 32 % of the charcoal market was reached. From this test it can not be concluded that on the long run the appreciation of the briquettes will remain the same. However, the market niche must not necessarily exceed 11 % of the wood charcoal consumption. From the fact that also the second marketing day was a success and from the consumers comments we conclude that there is a good possibility for the briquettes to find its place in the market.

Table A1.2 Results of the market survey for the cotton coal/molasses briquettes.

Question	Answer (%): A	B	C
Is the lightning speed quicker (A), the same (B), or slower (C) than for wood charcoal?	87	2	11
Is the amount of ashes smaller (A), the same (B), or more (C) than for wood charcoal?	10	3	87
Is the amount of smoke smaller (A), the same (B), or more (C) than for wood charcoal?	14	6	80
Did you observe a smell differing from smells produced by wood charcoal (A: Yes, B: No)?	71	29	na
If so, do you like it more (A), the same (B) or less (C) than smells from wood charcoal?	15	4	81 (*
Does combustion last longer (A), as long as (B), or shorter (C) than for wood charcoal?	37	14	49
Is the heat produced more (A), the same (B), or smaller (C) than for wood charcoal?	53	13	34

*) Of 71 %.

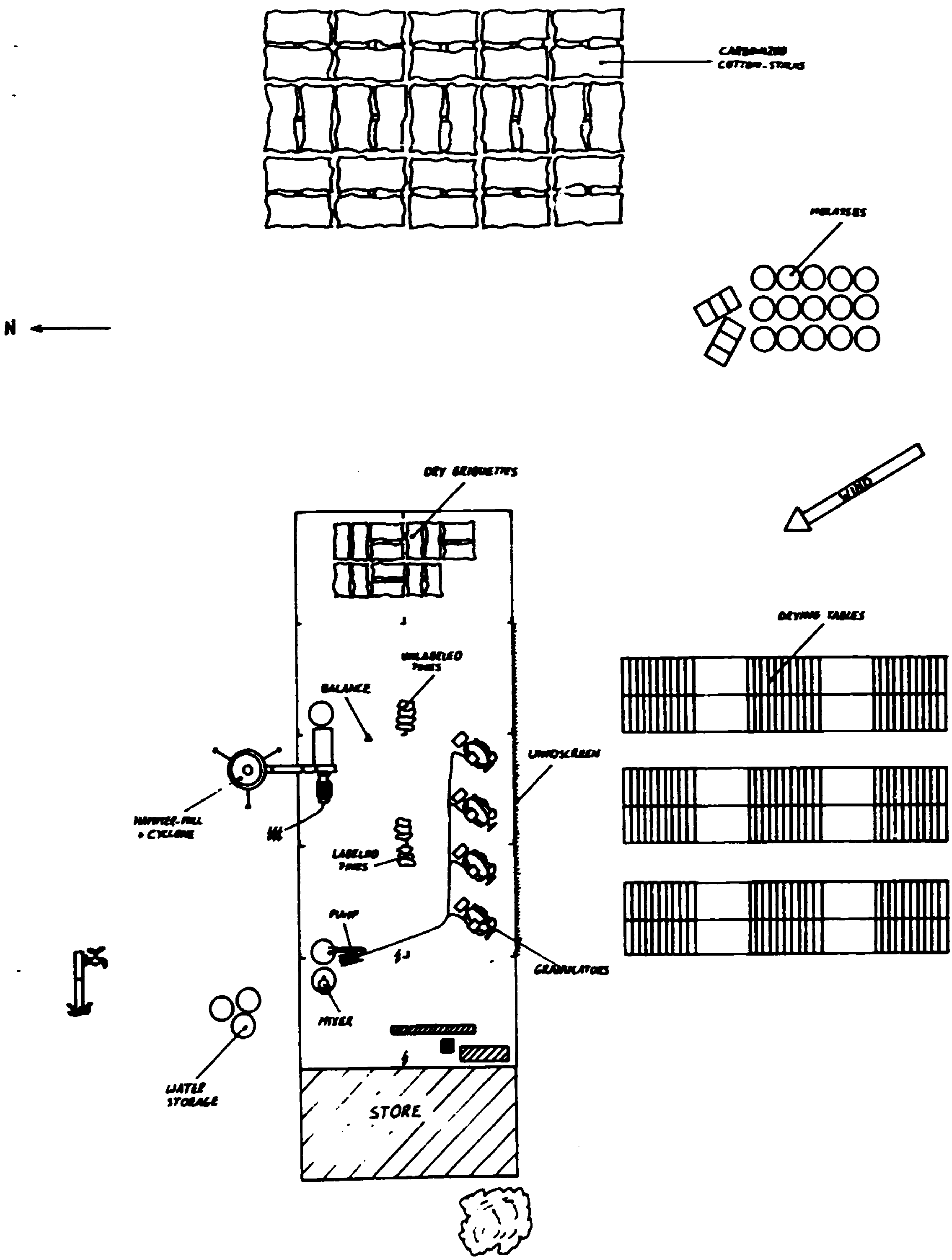
Table A1.3 Price indications by consumers.

Housewives, price per malwa (LS):	0.50	0.75	1.00	1.50	2.00
Percentage	53	21	12	4	10
Housewives, price per sack (LS):		5-7	8-10	12-16	18-20
Percentage		13	44	38	6
Restaurants, price per sack (LS):			5-10	11-15	16-20
Percentage			40	60	0

Table A1.4 Test price settings for cotton coal briquettes and actual prices for wood charcoal in the Rahad Scheme (June 1987)

	Price (LS)
Cotton coal briquettes	
Sack (30 kg)	17.50
Malwa (2.4 l)	0.75
Wood Charcoal	
Sack (35 kg)	18.50
Malwa (2.4 l)	1.00

Figure A1.1   Plant lay-out (Drawing by R. Schuuring)



APPENDIX II THE FINANCIAL BACKGROUND OF PRODUCTION ALTERNATIVES

First aim of the financial analyses is to estimate production cost of the briquettes. Secondly the relation between production cost, factory gate prices and wood charcoal market prices is analysed as described in Chapter IV.

Production cost

The production cost calculations are based on estimates and measured values of: the briquette composition (coal, water and molasses), the cotton stalks yield per ha, the charcoal yield of the kilns, charcoal transport cost, storage cost, investments in equipment, labour costs, etc. The Alternatives A - C are first rough approaches which are refined in Alternatives I - V. Data on the briquette composition, cotton growing and carbonisation hold for all alternatives. They are listed in Table A2.1. Besides those general data there are data which are specific to the production alternatives. These mainly concern labour cost, load factors, energy cost and investments. Apart from the investment costs those factors are summarised in Table A2.2. for the Alternatives I to V. When a shift system is applied (Alternatives II and III) this means that only the agglomerators are operated by the 2 shifts. The grinding mill, builds up a sufficiently large stock for the agglomerators to operate during two shifts in a working period of 8 hours. In Alternatives II and III, where a forced-draught dryer is used, sacking and storage is also carried out in 2 shifts.

As for the investment costs, the Alternatives I to III are designed such that approximately all cotton stalks produced near 1 village can be processed to cotton coal briquettes. With the various operational characteristics, this results in differences in briquetting capacity and related investments (See Tables A2.3, A2.5 and A2.7). Unlike Alternatives II and III, in Alternative I the plant is only operated during the dry season, from November until July. Therefore 16 agglomerators are installed (in Alternative II and III only 10). Instead of forced-draught drying, open-air drying is applied and for this purpose special tables are installed. The necessary cotton coal stock in Alternative I is much smaller than in Alternative II and III. Cotton coal storage cost is smaller accordingly. An important difference between Alternative II and III is in the number of kilns that are needed. This number is related to the length of the carbonisation season (8 respectively 13 weeks/yr). The same holds for the storage cost of the cotton coal after the carbonisation season.

Marketing

After the briquettes are dryed, they must be sacked before they can be sold. A first estimate of sacking cost is made by using ordinary jute charcoal sacks (2 LS/sack). However, since the bulk density of the briquettes is somewhat higher than that of wood charcoal and since, after transportation, the amounts of fines and brands in a sack of briquettes is considerably smaller than in a sack of wood charcoal, the briquettes are a completely new product from a marketing point of view, which in fact calls for a different way of packing. Bags preferably should be of a another size.

Sacking is a matter which should be considered very carefully, because success or failure of marketing depends strongly on presentation of the product to the consumers. One consideration is that consumers pay a refundable sum for the bag in the same way as presently done for bags of wood charcoal. If such a strategy were to be followed, both an alternative to the jute charcoal bag as to the malwa could be found. Consultations with European bag manufacturers learned that it is possible to import a plastic woven bag in Sudan which can contain 30 kg cotton coal briquettes, for the price of 1.80 LS/sack.

As explained in Chapter IV other marketing costs have not been taken into account. Instead, they have been accounted for in the factory gate prices to wholesalers and retailers.

Table A2.1 General data for all production alternatives.

Briquette quality	
- Cotton coal/briquette ratio (%) (coal as produced, briquette air dryed)	78
- Molasses/briquette ratio (%) (Molasses as received, briquette air dryed)	20
- Bulk density (t/m^3)	500
Cotton growing	
- Stalks yield (t/ha yr)	2.38
Carbonisation	
- Kiln volume (m^3)	5
- Kiln cost (LS/kiln)	1000
- Cotton stalks density (t/m^3)	0.072
- Cotton coal yield (%)	25
- Operation days per week (day/week)	7
- Load factor (%)	100
- Cotton coal cost (LS/t)	28
- Cotton coal transport cost (LS/sack of 50 kg);	
Within area of 1 village	2
Between area of 2 villages	4
Briquetting	
- Cotton coal storage in 50 kg sacks, cost (LS/sack)	7
- Molasses storage in 0.22 m^3 oil drums, cost (LS/drum)	100
- Molasses cost, at sugar factory gate (LS/t)	90
- Molasses transport distance (km)	300
- Molasses transport cost (LS/t km)	0.85
- 30 kg Briquette sacks, cost (LS/sack)	1.8
- Diesel fuel cost (LS/l)	0.90
- Plant operation days per week (day/week)	6
- Labour hours per shift (hr/shift);	
Single shift system	8
Double shift system	6
- Load factor (%)	
Single shift system	85
Double shift system	90
Financial analysis	
- Discount rate (% Investment cost/yr)	10
- Profit margin over production cost (%);	
Sale to wholesalers	20
Sale to retailers	30
- Briquette consumer price (% of wood charcoal price)	90
- Briquette price in Rahad Scheme (LS/t)	579
- Briquette price in Khartoum (LS/t)	724
- Village market absorbtion (t/yr)	325

Table A2.2 Specific data on which the calculations of production alternatives are based.

Alternative	I	II	III	IV	V
Briquetting plant operation period (week/yr)	34	49	49	49	49
Nr. of installed agglomerators (@ 50 kg wet briquettes/hr)	16	10	10	-	-
Management and labour					
- Production manager (man yr)				1	1
Associated cost (LS/yr)				24,000	24,000
- Maintenance engineer				1	1
Associated cost (LS/yr)				15,000	15,000
- Maintenance mechanics (man yr)				2	4
Associated cost (LS/yr)				4,000	4,000
- Briquetting plant supervisors (man yr)	2	2.5	2.5		
Associated cost (LS/man day)	18	18	18		
- Charcoal purchase super visors (man yr)	1.4	4	2	12.6	9.4
Associated cost (LS/man week)	110	110	110		
- Unskilled labour (man yr)					
Charcoal storage (seasonal)	2*8/34	4*4/49	2*8/49	8*4/49	6*8/49
Grinding	4	4	4	4	8
Briquetting	16	20	20	2	4
Sacking and storage	4	8	8	8	16
Associated cost (LS/man month)				200	200
Idem (LS/man day)	7.8	7.8	7.8		
Storage period for molasses (week)	4	4	4	1	1
Energy consumption by the briquetting plant (kWh_m/t)	2	2	2	18	18

Table A2.3 Investment cost for Alternative I.

Cost item	Investment (LS)	Life time (yr)	Annualised cost (LS/yr)
Briquetting plant			
- agglomeration system	64,500	10	10,497
- cotton coal grinder	40,000	10	6,510
- 20 kW_e generator	40,000	5	10,552
- drying tables	5,000	10	814
- 2 hand carts	4,000	10	651
- molasses tanks	4,973	2	2,866
- building	50,000	15	6,574
Kilns	76,588	5	20,204
Raw cotton coal sacks	48,314	5	12,745
Freight and installation (20 % of foreign investment)	28,900	10	4,703
Design (5 % of total investment)	18,114	15	2,381
TOTAL	380,389		78,496

Table A2.4 Analysis of production cost for Alternative I.

Cost item	LS/yr	% of total annual cost
Annualised capital cost	78,496	26
Operation cost		
- Supervision briquetting plant	7,344	3
- Labour briquetting plant	44,696	15
- Charcoal cost (Incl. purchase supervision)	18,482	6
- Charcoal transport	25,090	8
- Molasses	55,399	19
- Briquette sacks	48,173	16
- Energy	1,014	0
- Maintenance (5 % of investment per yr)	24,252	6
Total	297,704	
Annual production (t/yr)		803
Production cost (LS/t)		371

Table A2.5 Investment cost for Alternative II.

Cost item	Investment (LS)	Life time (yr)	Annualised cost (LS/yr)
Briquetting plant			
- agglomeration system	40,300	10	6,559
- cotton coal grinder	40,000	10	6,510
- 20 kW_e generator	40,000	5	10,552
- forced-draught dryer	15,000	10	2,441
- 2 hand carts	4,000	10	651
- molasses tanks	4,663	2	2,687
- building	50,000	15	6,574
Kilns	109,565	5	28,903
Raw cotton coal sacks	88,594	5	23,371
Freight and installation (20 % of foreign investment)	27,060	10	4,404
Design (5 % of total investment)	20,959	15	2,756
TOTAL	440,141		95,406

Table A2.6 Analysis of production cost for Alternative II.

Cost item	LS/yr	% of total annual cost
Annualised capital cost	95,406	22
Operation cost		
- Supervision briquetting plant	13,230	3
- Labour briquetting plant	84,360	20
- Charcoal cost (Incl. purchase supervision)	26,439	6
- Charcoal transport	35,894	6
- Molasses	79,253	14
- Briquette sacks	68,916	16
- Energy	1,451	0
- Maintenance (5 % of investment per yr)	22,007	5
Total	426,956	
Annual production (t/yr)		1,149
Production cost (LS/t)		372

Table A2.7 Investment cost for Alternative III.

Cost item	Investment (LS)	Life time (yr)	Annualised cost (LS/yr)
Briquetting plant			
- agglomeration system	40,300	10	6,558
- cotton coal grinder	40,000	10	6,510
- 20 kW_e generator	40,000	5	10,552
- forced-draught dryer	15,000	10	2,441
- 2 hand carts	4,000	10	651
- molasses tanks	4,663	2	2,687
- building	50,000	15	6,574
Kilns	178,043	5	46,967
Raw cotton coal sacks	102,838	5	27,128
Freight and installation (20 % of foreign investment)	27,060	10	4,404
Design (5 % of total investment)	25,095	15	3,299
TOTAL	526,997		117,772

Table A2.8 Analysis of production cost for Alternative III.

Cost item	LS/yr	% of total annual cost
Annualised capital cost	117,772	26
Operation cost		
- Supervision briquetting plant	13,230	3
- Labour briquetting plant	84,360	19
- Charcoal cost (Incl. purchase supervision)	26,439	6
- Charcoal transport	35,894	8
- Molasses	79,253	18
- Briquette sacks	68,916	15
- Energy	1,451	0
- Maintenance (5 % of investment per yr)	26,350	6
Total	453,664	
Annual production (t/yr)		1,149
Production cost (LS/t)		395

Table A2.9 Investment cost for Alternative IV.

Cost item	Investment (LS)	Life time (yr)	Annualised cost (LS/yr)
Briquetting plant			
- roll press	280,000	10	45,569
- cotton coal grinder	70,000	10	11,392
- feeder silo with extraction system	10,000	10	1,627
- mixer	30,000	10	4,882
- 40 kW_e generator	50,000	5	13,190
- forced-draught dryer with feeder	30,000	10	4,882
- 4 hand carts	8,000	10	1,302
- molasses tanks	4,640	2	2,674
- building	20,000	15	2,629
- briquette store (@ 850 LS/m^2)	54,313	15	7,141
Kilns	344,615	5	90,909
Raw cotton coal sacks	290,304	5	76,581
Freight and installation (20 % of foreign investment)	94,000	10	15,298
Design (5 % of total investment)	64,294	15	8,453
TOTAL	1,350,166		286,530

Table A2.10 Analysis of production cost for Alternative IV.

Cost item	LS/yr	% of total annual cost
Annualised capital cost	286,530	23
Operation cost		
- Supervision and labour of briquetting plant	82,040	7
- Charcoal cost (Incl. purchase supervision)	83,160	7
- Charcoal transport	188,160	15
- Molasses	249,274	20
- Briquette sacks	216,760	17
- Energy	18,482	2
- Maintenance (10 % of investment per yr)	135,017	10
Total	1,259,423	
Annual production (t/yr)		3,613
Production cost (LS/t)		349

Table A2.11 Investment cost for Alternative V.

Cost item	Investment (LS)	Life time (yr)	Annualised cost (LS/yr)
Briquetting plant			
- roll press	280,000	10	45,569
- cotton coal grinder	70,000	10	11,392
- feeder silo with extraction system	10,000	10	1,627
- mixer	30,000	10	4,882
- 40 kW_e generator	50,000	5	13,190
- forced-draught dryer with feeder	30,000	10	4,882
- 4 hand carts	8,000	10	1,302
- molasses tanks	6,960	2	4,010
- building	20,000	15	2,629
- briquette store (@ 850 LS/m^2)	81,469	15	10,711
Kilns	840,000	5	221,590
Raw cotton coal sacks	495,936	5	130,827
Freight and installation (20 % of foreign investment)	94,000	10	15,298
Design (5 % of total investment)	100,815	15	13,255
TOTAL	2,117,184		481,166

Table A2.12 Analysis of production cost for Alternative V.

Cost item	LS/yr	% of total annual cost
Annualised capital cost	481,166	24
Operation cost		
- Supervision and labour of briquetting plant	124,600	6
- Charcoal cost (Incl. purchase supervision)	124,740	6
- Charcoal transport	304,819	15
- Molasses	373,912	19
- Briquette sacks	325,140	17
- Energy	27,723	1
- Maintenance (5 % of investment per yr)	211,718	11
Total	1,973,818	
Annual production (t/yr)		5,419
Production cost (LS/t)		364

APPENDIX III PROJECT PROPOSAL: PRODUCTION OF CHARCOAL FUEL FROM COTTON STALKS USING SMALL SCALE, DECENTRALIZED TECHNIQUES (PHASE 2)

I BASIC DATA

Programme structure	A) Research programme for the final development of small capacity charcoal agglomeration equipment. B) Research programme for the development of low cost earth or pit kilns for the carbonisation of cotton stalks. C) Commercial pilot project for the demonstration of the economical feasibility of cotton stalks carbonisation and briquetting.
Scheduled start	November 1987
Duration	Until December 1988
Executing agencies	BTG Biomass Technology Group B.V. Universtity of Twente P.O. Box 217 7500 AE Enschede The Netherlands Energy Research Council P.O. Box 4032 Khartoum The Republic of the Sudan

II BACKGROUND AND JUSTIFICATION

Cotton stalks, an agricultural waste product, are a potential energy source for the domestic sector in Sudan and other developing countries. In Sudan it may replace up to 5 percent of the total fuelwood consumption (including wood resources for charcoal production). For agricultural reasons (combatting pests), cotton stalks must be destroyed or conserved (sterilised) within a short period after the cotton harvest. At present the stalks are burned in the field. Prefeasibility studies, carried out by the Sudan Renewable Energy Research Institute in co-operation with UNIDO, GTZ and the Biomass Technology Group, have identified small scale on-site carbonisation as an acceptable alternative option.

The cotton coal produced in this way involves high transportation costs and possesses burning characteristics which make it unsuitable for domestic use (owing to the low density and high reactivity). Hence it is not yet a viable alternative to wood charcoal. Briquetting is the necessary step for improvements in both fuel characteristics and economics.

In the research programme of phase 1 of the programme, the general features of a briquetting technology were developed, aimed at applications in situations where only small investments can be made, machine break-down risks are large and only small production capacities are required. Prototype machines were used in the field test of phase 1 of the programme in order to enable a detailed feasibility study on the complete production process, starting from cotton stalks as standing in the fields up to the marketing of the briquettes, to be made. The agglomeration technology appeared to be very promissing both from financial and technical points of view, although several shortcomings and opportunities for improvement were identified. The report ("Field test programme for the production of charcoal fuel from cotton stalks using small scale, decentralized techniques", Ref. 2) also identifies feasible production scales and organisational options for the manufacture of cotton coal briquettes and suggests administrative measures to be taken by the cotton growing scheme managements, necessary to create economic relationships which make cotton stalks carbonisation possible. The report concludes that a pilot plant is needed to demonstrate the financial feasibility to potential investors.

III OBJECTIVES

Development objectives

The longer term development objectives of the project are:

- To develop an alternative to wood as a source of charcoal fuel thus relieving pressure on the rapidly degrading forest resources;
- To encourage the use of agricultural residues as a source of energy and to supply rural people with domestic fuel at an acceptable cost;
- To develop 4 small-scale, rural industries involved in i) the fabrication of charcoal kilns, ii) the maintenance and assembly of briquetting equipment, iii) the production of charcoal from cotton stalks and in iv) the production of charcoal briquettes from the resulting charcoal;
- To generate employment in carbonisation and briquetting of cotton stalks;
- To obtain experience with a technology of small production capacities and complicated organisational production structures in Sahelian countries.

The first 2 objectives have already been formulated in the first phase of the project (Ref. 1). The third objective originally mentioned also the development of local industries for the fabrication of briquetting equipment (See Ref. 1). In view of the complexity of parts of the agglomeration equipment designed in phase 1 of the project (e.g. spray nozzles, electrical power supply), this goal is now considered not to be realistic on the medium term. Local maintenance, which is a necessity for reliable operation of a factory, is quite possible with this level of technology, since the production process is simple. Also local assembly seems a realistic option, although the economics of local assembly as compared to foreign assembly do not yet appear to be favourable. It is a matter which should be considered thoroughly in a next project phase. The objective of employment is a result of the feasibility study prepared in phase 1, where it has been concluded that although the use of cotton stalks will only lead to a small income generation of the cotton growing tenant farmers, the production of cotton coal briquettes will eventually lead to large employment opportunities in the cotton growing schemes (Ref. 2).

The use of wood as domestic fuel is a contributory factor to uncontrolled deforestation in the Sudan and in several of the neighbouring Sahelian countries. Cotton is grown in most of these countries and cotton stalks are an agricultural waste which becomes available in considerable amounts and for which there is no clearly defined use. Thus, the results of the programme will be applicable to several other countries in this region.

Project objectives

The programme consists of research parts (A, B) and a field programme (C).

A. Briquetting equipment

The objectives of the briquetting research programme are:

- To finally develop commercially applicable agglomerators;
- To research briquette quality.

The evaluation of the employed technology in phase 1 of the programme (See Ref. 2) identifies several points where the agglomeration equipment needs further development before it can be used on a commercial scale.

Apart from these technical aspects of briquetting equipment design, research on briquetting will focus on briquette quality aspects. In phase 1 it has appeared that coal/molasses briquettes are sensitive to long term exposure to humid atmospheres. More precise data are necessary to evaluate possibilities of seasonal or whole year around briquette production and storage. Especially the influence of air humidity and sacking material will be investigated.

B) Low-cost earth or pit kilns

The aim of this part of the programme is:

- To investigate the technical and economic characteristics of low-cost earth or pit kilns for cotton stalks carbonisation in view of the whole production process of cotton coal briquettes.

The importance of the large investment in carbonisation equipment (kilns) has been shown in the phase 1 feasibility study. As a possibility to reduce on this investment the use of earth or pit kilns has been suggested in that report. Research on the use of such kilns will concentrate on their performance and operational characteristics under the field conditions prevailing in the cotton growing schemes.

C. Field programme

The field programme's goals are to:

- Demonstrate the financial feasibility of briquette manufacture to interested investors, by means of workshops, training and public information;
- Monitor the briquetting with respect to production organisation, financial performance and the technology;
- Evaluate recommendations concerning the employed technologies, production scale and economic relationships made in phase 1 in view of the longer term development objectives.

IV PROGRAMME STRATEGY

Satisfactory development of agglomeration equipment (See part A of the research programme) is a prerequisite for initiation of the field programme.

The programme will be managed and co-ordinated by the Biomass Technology Group (BTG) of the University of Twente, the Netherlands, in co-operation with the Energy Research Council (ERC), Khartoum. A working-group, with (anticipated) representatives of BTG, ERC and the Rahad Corporation, will be established in order to review project related activities.

A pilot briquetting plant will be constructed, able to process approximately all cotton stalks coming available around an average Rahad Scheme village. Such a scale appeared to be the most suitable for briquette production (See Ref. 2). It is the production alternative referred to as Alternative 1 in Ref. 2. Approximately 800 t of briquettes will be produced seasonally, witth a stop during the wet period (July - October). This amount cannot be consumed in the village alone where the briquetting plant is situated.

Hence export to other villages or to urban areas is necessary (E.g. Khartoum, Wad Medani, Gedaref).

As far as possible in the present stage of the project, as will be assessed by the mission mentioned below, the plant will be commercial with respect to:

- Investments;
- Relations with tenants, carbonisers and briquetting labourers;
- Briquette marketing.

The plant owner will therefore be free to market the briquettes as he likes. This does not negatively affect the project objectives, since the cotton coal briquettes allways replace wood charcoal, wherever they are sold. A Sudanese investor will be identified, willing to invest in a pilot plant of village scale. His duties will be to organise the complete production, starting from the co-ordination of uprooting activities by tenants and of the carbonisation up to the marketing. A condition for technical assistance by the project is his willingness to co-operate in monitoring and public information activities. Preferably, this investor will be looked for in the private sector. The Sudanese Government, however, will not be excluded before hand.

In the start-up phase of this new technology not all anticipated costs will be borne by the investor (briquette manufacturer). Especially the training of operators of carbonisation kilns and briquetting agglomerators will be external inputs from BTG and ERC. Other ERC or BTG supervision activities of briquette production (equipment maintenance and repair) will be part of a financial agreement between the investor (briquette manufacturer) and BTG or ERC.

V PROGRAMME ACTIVITIES

A. Co-ordination mission and working-group

In November 1987 a programme co-ordination mission will be sent to Sudan in order to discuss this project proposal with:

- The Ministry of Finance and Planning;
- The Energy Research Council.

The mission will discuss the commercial character of the pilot briquetting plant with the ERC. If agreement has been reached on this matter, the mission will identify an investor for the briquetting plant by means of publications and briquetting demonstrations at ERC's test center in Khartoum. To support the investor the mission will also prepare financial arrangements in co-operation with the Sudanese Government and investment banks. The possibilities of share holding by the Tenant Union (See Ref. 2), of leasing and of foreign loans in relation with counter value financing will also be considered.

The mission will supervise the formation of a working-group which will co-ordinate the demonstration activities in a later stage of the project.

B. Briquetting

The research and development activities of briquetting equipment by BTG will focuss on the items identified in the report on the firt phase of the project (Ref. 2), i.e.:

- The agglomerator will be provided with a mechanical charcoal fines feeding device. Options which will be considered are screw feeders, hoppers and belt feeders in relation to the flow characteristics of charcoal fines of varying moisture content and cotrolability aspects for stable briquette production.
- The briquette collection system will be improved (Adaptation of gutter size).
- The potential increase of the production capacity will be investigated. Parameters which will be considered are drum axis inclination, rotation speed and feeding rate.
- The rate of dust formation will be reduced to acceptable levels.

All improvements will be made with a view to low investment cost, ease of operation and maintenance as required in developing countries, using design methods developed by the University of Twente with inputs from the Department of Mechanical Engineering. One complete agglomerator will be built and maintained by BTG for ongoing research activities. Complete construction drawings will be made.

C. Low-cost earth or pit kilns

During the 1988 cotton stalks uprooting season (March - July) carbonisation tests with two or three promissing kiln types will be undertaken near the village where the briquetting plant will be situated. The tests will be executed by ERC under supervision of a BTG carbonisation expert.

If such kilns perform satisfactory (w.r.t. coal yield, construction cost and lifetime), the potential building of permanent kilns will be considered in close co-operation with the Rahad Scheme management and the Tenant Union. In that case also the training (adressing construction and operation) of ERC personnel will be undertaken in order to make implementation possible in the next season (1989).

D. Demonstration project

The complete briquetting plant with equipment and infrastructure (electricity, water supply, building) will be designed by BTG. The agglomeration equipment will for the major part be manufactured in The Netherlands. Carbonisation kilns will be made in the Sudan by one or more local workshops after a call for tenders. A location for the briquetting plant will be identified in the Rahad Scheme. The plant will be erected in February 1988. In this phase technical assistance to the briquette manufacturer will be provided by BTG: Plant management, agglomeration operators. BTG will also train ERC personnel, in order to enable ERC to provide the technical assistance in a later stage of the project. Training of kiln operators will be carried out by both BTG and ERC. The carbonisation and briquetting project will be demonstrated by means of public information campaigns and workshops. Table 5.1 lists all training activities.

E. Planning schedule

A planning schedule is presented in Chapter 7 of this proposal.

VI PROJECT INPUTS

The donor organisation will provide financial inputs for the services of BTG, incentives for ERC and Rahad Scheme personnel taking part in the project and for material costs made in the research co-ordinated or carried out by BTG to a maximum as will be agreed upon.

The Government of the Republic of the Sudan is expected to provide national counterpart staff and facilities for implementation of the project as described in this project document.

Table 5.1 Training activities

Activity number	Course title	Target group	Nr. of participants	Summary	Duration
A	Briquetting plant management	Pilot plant owner	1	plant construction, financial management, plant operation, marketing inputs, etc.	1.5 month
B	Cotton coal agglomeration	Pilot plant supervisors and operators	35	on the job training: operation and maintenance of agglomeration equipment	1 month
C	Cotton stalks carbonisation	Kiln operators	25	operation and maintenance of metal kilns, price calculations for cotton coal.	2 weeks
D	Background of the cotton stalks carbonisation and briquetting project	Public in the Rahad Scheme (5 selected villages), rural and urban areas (TV broadcasting)	na.*	meetings with project information, raise interest in employment, product information	1 day each
E	Cotton coal briquettes manufacture and trade	Manufacturers, traders (Potential investors)	25	workshop on financial aspects of cotton coal briquetting, marketing strategies	3 days
F	Cotton stalks carbonisation and briquetting	Cotton growing scheme managements, National Energy Administration, NGO's, International development agencies (UNIDO, FAO, UNDP)	25	workshop on socio-economic aspects of cotton coal briquetting, general technological aspects of cotton coal agglomeration	3 days

*) public meetings

VII PLANNING SCHEDULE

	1987 11	12	1988 01	02	03	04	05	06	07	08	09	10	11	12
Investors attitude survey	xxxx													
Programme co-ordination mission (for activities see App. I)		xxxx												
Research:														
- agglomerator improvements	xxxxxxxxxxxx													
- preliminary kiln tests	x...........x													
- kiln types field tests					xxxxx									
Equipment manufacture														
- agglomeration system, incl. grinder			xxx											
- kilns		x.......x												
- building and infrastructural facilities			xxxx											
Equipment transport				xxxx										
2nd Mission:				(xxxxxxx)										
- plant erection					xx									
- training and technical assistance (A,B,C)*					xxxxxx									
- village information (D)*					x....x									
- kiln types field tests					SEE ABOVE									
Monitoring					xxxxxxxxxxxxxxxxxx								xxxxxxxxx	
3rd Mission (at end of dry season):							(xxxxxx)							
- technical assistance (seasonal closing-down)								xx						
- training (D,E,F)*								xx						
- monitoring supervision							x.x							
4th Mission (at start of dry season):													(xxxxxx)	
- technical assistance (seasonal start-up)													xx	
- training (B,D,E,F)*													x..x	
- monitoring supervision														
- evaluation														xx
Evaluation report														xxx

*) For items A - F see Table 5.1.

REFERENCES

1. "Charcoal Briquettes from Cotton Stalks", BTG, 1987.
2. "Field test programme for the production of charcoal fuel from cotton stalks using small scale, decentralized techniques", UNIDO, 1987.