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REVIEW OF THE NIGER COAL CARBONIZATION PROJECT

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REVIEW OF POLICIES IN THE TRADITIONAL ENERGY SECTOR

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EXECUTIVE SUMMARY

1.0 PROJECT INTRODUCTION AND OBJECTIVES

The present report is a review of a coal carbonization project funded by the Canadian International Development agency and carried out by Cartier Engineering (La Société d'Ingénierie Cartier Ltée, Groupe Monenco, Canada) in Niger to produce carbonized coal as a substitute fuel for firewood in Niger homes and institutions.

This review is a part of a large-scale regional review of the traditional energy sector in Sub-Saharan Africa commissioned by the Energy Unit within the Africa Technical Department of the World Bank. The regional review is done in phases and the present report is part of Phase IIa which covers a group of Sahelian countries, of which Niger is one.

The objectives of the present work is to briefly review the status of the abovementioned Niger coal carbonization project entitled "Production d'un combustible domestique, projet d'usine pilot".

Summarized, the specific objectives of the review are:

1. A brief background history and rationale of the carbonization project.
2. Technical status of the carbonization plant.
3. Economic state of the project emphasizing certain aspects of the cost of carbonization, feedstock, transportation and future resource availability and markets.

The overall objective is to help verify the technical and economic viability of the enterprise.

2.0 PROJECT RATIONALE AND BACKGROUND HISTORY

Large areas of the world suffer from the lack of suitable household energy source. In their search for everyday cooking fuels, people have denuded large areas of forests. The result has been local environmental deterioration in general and, on a larger scale, an increased greenhouse effect as the forests, the most effective CO_2 sinks, have disappeared and the CO_2 level in the atmosphere has risen and the advance of desert in regions, such as the Sahelian zone of Africa.

To help reduce the overuse of wood, a number of projects have been financed to search for suitable substitute fuels for firewood. The aim of the coal carbonization project was, and is, to promote the use of clean coal, i. e. semicarbonized coal, as a substitute fuel in Niger and, if feasible, in other regions were there are coal reserves.

Cartier (Monenco), thanks to its expertise in energy use of peat, got first involved in Africa, in Senegal, in a study of using mangrove peats as a source of energy. After this, already in 1984 Cartier Engineering started to investigate the use of peat in Burundi. In 1989 a brick kiln to carbonize peat and other biomass, such as wood shavings, coffee husks and rice hulls, was built in Burundi. It produces carbonized biomass briquettes for the domestic market as a substitute for wood charcoal and firewood.

In 1986, Cartier Engineering studied the overall use of coal in Niger. The project led into another project, whereby a sample of Anou-Araren coal was carbonized in Burundi and tested in a number of families in Niamey.

The encouraging results led to the present project, which consists of a pilot plant to produce carbonized lumpy coal and briquettes for the domestic market in Niger.

The following is a concise summary of the main findings of the project, which is reviewed in more detail in the main body of the present report.

3.0 PLANT'S PRODUCTION CAPACITY

Raw coal, because it emits acrid smoke, is not usable untreated as domestic fuel in small kitchen stoves. To render the coal usable, it is partially carbonized in a kiln by anaerobic process, pyrolysis, whereby it is exposed to high temperatures to drive its volatiles out only leaving enough of them to allow it to be burned, but at a low enough level to render it smokeless.

The carbonization kiln built at Tchirozerine to carbonize Anou-Araren coal was planned to be capable of producing at least 3000 tonnes of carbonized coal per year. The tests confirmed the planned capacity of 3000 tonnes and by operating the kiln in three 8 hour shifts, a capacity of 4500 tonnes a year. For testing, the kiln operating time was limited to 20 day periods interrupted by coal preparation periods of 30 days. This mode of operation was imposed by the shortcomings of the ancillary equipment, notably by a low capacity of the vibrating screen to screen the feedstock. As a result, the total annual capacity at the present pilot plant equipment configuration is about 730 tonnes. Technically, the kiln

is capable of producing up to 4500 tonnes annually when operated 300 days a year and at three 8 hour shifts daily.

Due to a large percentage of fines in the feedstock and in the carbonized product, 35 and 40% respectively, up to 60% of the final product could be briquettes. Briquetting tests have established that the carbonized and uncarbonized fines can be briquetted at a rate of at least one tonne per hour. If the briquette press were operated also 300 days a year at three 8 hour daily shifts it could produce about 7200 tonnes of briquettes, or the kiln would have to produce 12,000 tonnes of carbonized coal a year. Thus one press is capable of handling the production capacity of 2 or 3 kilns.

Technically, the planned 3000 tonne annual production capacity can be achieved simply by acquiring the needed additional pieces of equipment. The plant at its present state is, after all, a pilot plant and never was planned to be an industrial facility without additional investment in equipment.

The total investment to attain the planned 3000 tonne annual production level is $US 115,000.

To reach a stepped-up level of, for instance 10,000 tonnes annually, the investment needs for imported equipment are about $US

238,000 and for the local materials about $US 211,000 bringing the grand total to about $US 449,000.

This is an order of magnitude estimate and does not include taxes, duties, freight costs and the influence the recent devaluation of FCFA has on the costs of imported materials.

4.0 FEEDSTOCK, AVAILABILITY, QUALITY AND COST

Anou-Araren mine has over 13 million tonnes of reserves. The original plan was to supply Sonichar power station for 30 years at an annual production capacity of 300,000 tonnes. However, for last few year the power station has run at a partial capacity consuming only about 110,000 to 120,000 tonnes of coal annually.

The coal in the Anou-Araren deposit is in two seams of varying thicknesses. Of these two seams, seam A is located closer to the surface under an overburden of about 50 metres. Seam B is below seam A separated from it by an intercalation which varies in thickness and on average is only about 0.2 m thick. Both seams A and B are on average 2.50 m thick according to the information supplied by Sonichar. Seam A is of a lower quality coal with a relatively high ash content up to 63% while seam B has an ash content about 30 to 40%. To optimize the usage of these two seams,

the power station was designed to run at about 49% ash content. To achieve the required parameters, the coal from these two seams is mixed in a suitable ratio.

At the present mining rate, there is coal for the power station for more than 60 years. As also, according to some preliminary indications, the coal in seam A appears to improve in quality as the mine advances towards west, it is probable that even seam A coal might be usable for carbonization in the future. Based on the estimated ration of A to B seam coal (1 to 1), it appears that at today's power station consumption rate there would be about a 90,000 tonne annual reserve of seam B coal for the carbonization plant for the next 30 years. To realize this would require an increase of the mining rate to the full capacity of the mine or to 300,000 tonnes annually. As a result, there would be a 90,000 tonne annual surplus of seam A coal, if it were not suitable for carbonization. These calculations are only of magnitude of order and would require a thorough study of detailed deposit data and the required mixing ratios. In any case, they give an indication of the potential of the existing site.

The coal deposit of Anou-Araren appears to extent to the north indicating further reserves. According to other exploration projects, about 40 km north of Anou-Araren, there are large deposits of good quality coal, albeit at a depth of 400 metres, or

at this time not economically minable. These deposits have been estimated to contain up to 2250 megatonnes of good quality coal.

An exploration project between Tahoua and Filingué in southern Niger has also revealed an existence of a number of coal seams at varying depths (25 to 50 m) and with a seam thicknesses from a few decimetres to several meters (up to 7 m). The quality of coal according to the preliminary analyses is in many cases better then that of Anou-Araren (lower ash content, higher carbon content). This area awaits further exploration work, but if economical, would open up possibilities closer to the large markets in the south.

Anou-Araren coal has a high ash content, 30 to 60%, depending on the seam. For power station use it is low quality, for carbonizing to produce domestic fuel it is quite acceptable. The high ash content, and low calorific value render it a suitable feedstock for carbonized coal to be used in domestic stoves. These characteristics ensure a slow burning rate and low enough temperature to allow good cooking conditions.

Presently Sonichar delivers feedstock to the carbonization plant at a total cost of 3720 FCFA/tonne composed of 2310 FCFA/tonne of mining cost and 410 FCFA/tonne for transportation cost. The unusable fines can be returned to the power station for a credit of 2310 FCFA/tonne after the return transport cost has been paid.

This cost is limited and will go up at a higher demand level, because it would create extra mining costs at the mine. The cost above about a 10,000 tonne annual demand might go up to 10,000 FCFA/tonne. The cost figures are not yet firm and will have to be discussed with Sonichar.

5.0. *CARBONIZATION COST AND SALES PRICES*

Calculated on the basis of pilot plant experience, the production costs are about 27.5 FCFA/kg. This cost is subject to changes in the cost and quality of coal as well as other coats items, such as the labour rates, as is normal. Presently, perhaps the most important factors which may change the production cost profoundly are the cost and quality of coal. The future coal mining needs depend largely on the health of the uranium mines. If they were shut down, there would be very little need for electricity in the total region. If for some reason also the power station would have to be closed down, the only coal user would be the carbonization plant. It is obvious, that in this case the coal cost would have to be adjusted to the quantity and quality needed for the plant. The quality also affects the production costs. The quantity of fines determine the percentage of briquettes of the final product. Briquetting test indicate that the production cost of briquettes is about 34.5 FCFA/kg. Obviously the sales price in this case would

have to be higher than for the lumpy coal to recover the difference in the production cost.

Carbonized coal has been sold at the plant gate at about 29 FCFA/kg. The retailers sold it (1993) in Tchirozerine and Agadez for 40 and 35.5 FCFA/kg in "small quantities" (2.5 kg containers) and in "large sacks" (45 kg) respectively. The respective prices in Arlit were 50 and 44.5 FCFA/kg.

Demonstrations and price discussions in Niamey indicated that there would be no resistance to prices over 50 FCFA/kg, even 75 FCFA/kg was suggested. This gives an indications about the price ranges. At 62.5 FCFA/ kg coal would be at the efficiency level of firewood if it were sold at 25 FCFA/kg as was done on average (1993). Carefully controlled tests have shown that one kilogram of carbonized coal does the same cooking task as 2.7 kg of firewood. The cost ratio will have changed considerably in 1994 as the price of wood has in many cases almost doubled.

According to a more recent information (1994) coal and briquettes are presently sold in Niamey at 67 FCFA/kg (3000 FCFA/sack of 45 FCFA kg).

Market potential evaluations in Niger (unnamed source, 1994) have estimated coal prices from 34 FCFA/kg in Agadez (near the plant)

to 55.5 FCFA/kg in Zinder (525 km from the plant), 67 FCFA/kg in Tillabéri. The same evaluation estimates a total potential annual consumption of 6900 tonnes by institutional users alone, initially.

6.0 PRODUCT PROMOTION AND ACCEPTANCE

Carbonized coal was promoted through well coordinated programs carried out by Cellule Technique de Coordination, Foyers Améliorés et Energie (Ministry of Mines and Energy) first in Niamey and later for the carbonization project in Agadez. The product was well received by the housewives, once they had been trained in its use and had learned its convenience and safety. By 1993 according to sales records a total of 2450 stoves had been sold to families and the military camp in Tchirozerine and the hospital in Agadez were converted to carbonized coal. The latter realized 60% savings in the energy costs over firewood.

The total number of Onersol stoves may be close to 3000 when also the unrecorded sales by the blacksmiths are added to those recorded by Socaren. In addition to this figures, about 400 to 500 ABBAZE stoves should be added to realize that the families who use or are ready to use coal may be close to 3500, if also the stoves sold directly by blacksmiths were taken into account.

Further promotion has been carried out in Niamey and Tahoua and on radio and television, as well in the schools and fairs and in front of representatives of the private sector and the Government.

This new fuel requires a special stove. One was designed by ONERSOL (Office national de l'énergie solaire) and tested and found to be efficient. Its basic price was originally (1992) about 1300 FCFA. The price was accepted by the user, although it is higher than 750 FCFA commonly paid for a simple improved firewood stove. Presently (1994) the stoves are sold in Agadez area for 1200 to 1500 FCFA each.

By the beginning of 1993 some of these stoves had been in a daily use for more than one year without showing any signs of unusual wear.

The abovementioned Niger market evaluation (unnamed source) has investigated the institutional market by using an ABBAZE (ABZ) stove type Gaya. A total of 30 of these stoves would be sold at a cost of 53,000 FCFA each plus the cost of special pot for the stove at 25,000 FCFA each in 16 centres across the country. According to the same study, the institutions taking part in the program would realize about 55% savings in their energy cost by using coal at the abovementioned price ranges.

7.0 TRANSPORTATION COSTS

Niger is a large country with a sparse population and long transportation distances resulting in high transportation costs. The carbonization plant is located at the only existing mine in the country, creating a product transportation problem. Official quotation (1992) gives a transportation cost of 14.4 FCFA/kg from the plant to Niamey (1040 km) on backhaul basis. Experience during the course of the project with independent truckers has shown that the cost can be lowered as low as to 8 FCFA/kg. However, only a few trips were done and for any long-term operations the truckers would have to include allowance for depreciation and maintenance and come up with rates to reflect these higher expenses.

Some coal has been, and is being, transported to Niamey by independent truckers. At the time of writing no cost information was available.

The willingness of the consumers to pay the present (1994) rates of 67 FCFA/kg for the product in Niamey makes transportation even at the official rates feasible even to Niamey.

The official (1992) backhaul rate to Tahoua (480 km) is 5.7 FCFA/kg, to Birni n'Konni (520 km) 6 FCFA and to Dosso (880 km) 9 FCFA/kg.

8.0 ENVIRONMENTAL IMPACT

The carbonization plant emits gases. Their concentrations were measured in the plant chimney and on the field 100 metres downwind from the plant with Gastec tubes. Compounds measured are carbon dioxide and monoxide, hydrogen sulphide, sulphur dioxide, nitrogen oxides (NO_x), phenol, acetic acid, ammonium and hydrogen. All the concentrations were below the accepted levels or even at the level not detectable. The standard acceptable levels used were those set by American Conference of Government Industrial Hygienists.

The same measurements were done at the user sites in normal kitchen conditions. No concentrations above accepted levels were detected, indicating that this fuel is safe. According to the users, it does not bother their eyes, nor does it smell like the smoke from wood fires.

The overall environmental effect has not been studied in a detailed manner. It appears, that the benefits of using carbonized coal in place of firewood are positive. Its use certainly reduces deforestation and consequently the advance of the desert in Niger. Indirectly its use should thus reduce the CO_2 emissions and the greenhouse effect. Other benefits rising from the conservation of trees are various edaphic, climatological and habitat benefits

which also benefit quality of human life. The safety and the convenience of use also reduce the workload of housewives and thus improve their life.

If a zero emissions facility is needed, it is possible to construct one. In some high production coking plants the emitted side products are incinerated and used to produce electricity for the plant.

9.0 FUTURE

At the present time, the Niger carbonization plant, although it is technically capable of producing its full capacity of 3000 to 4500 tonnes of carbonized coal per year, is limited to an annual 730 tonne rate. The reason is in the under-capacity of ancillary equipment. The plant awaits further investment to bring the auxiliary equipment capacity to the kiln's full capacity level from the pilot plant stage. According to information supplied by the on-site personnel, the plant has been idle since late 1992, except for the briquetting operation which is slowly turning out briquettes fabricated from the large stockpile of carbonized fines produced during the project. The briquettes are sold locally and also in markets as far as Niamey.

The markets are well established and the user is willing to pay a premium price for the carbonized coal over the price of firewood. The environmental impact of the plant and the product is below the applied standard for acceptable level and the overall environmental impact apparently positive in comparison with the use of firewood.

To establish accurately the investment and pricing and other economic parameters, an on site fact verification is needed. As well, equipment and freight pricing in North America is needed. With all the upgraded information on hand, a final analysis of this promising technology can be carried out.

REVIEW OF THE NIGER COAL CARBONIZATION PROJECT

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1.0 INTRODUCTION

The present review is part of a wider regional review of the traditional energy sector in Sub-Saharan Africa carried out by the World Bank. The overall review is supervised by the Division for the Private Sector Development and Economics within the Africa Technical Department (AFTPS) and commissioned by the Energy Unit, also within the Africa Technical Department. The overall objectives of the regional review are:

(i) undertaking a retrospective evaluation of the objectives, scope and approach of the traditional energy sector work done to date and its resulting policies, strategies and programs on the evidence of stated public policy, its execution by agents in the public and private sector, and activities of external assistance agencies and organizations;

(ii) identifying the principal critical inter-sectorial linkages that influence the operation of the traditional energy sector in selected countries, and developing a conceptual framework and strategy for the sector within this enlarged operational context;

(iii) preparing a set of recommendations of new policy directions for the development of the traditional energy sector, and for the establishment of implementation priorities by national institutions and economic agents, complemented by appropriate instruments of external assistance;

(iv) identifying projects and/or programs and thus to arrive in the shortest possible time at operational results; and

(v) disseminating the operational results among the donor community at large.

Due to the wide scope of the overall review, the World Bank has divided it into a number phases. One phase (Phase IIa) covers a group of five Sahelian countries, Senegal, Gambia, Mali, Niger and Burkina Faso, which have been perceived to have severe energy problems and in which extensive work has been already carried out and which have experience in alternative policy approaches and whose environments are similar to each other and whose neighbouring areas possess complementary data bases.

The present work is part of the review and covers the technical and economic feasibility of producing partially carbonized coal in Niger as one of several possible substitutes for household fuels, with an emphasis supplying the Niamey household market. The project was carried out by Cartier Engineering (La Société d'Ingénierie Cartier Ltée, Groupe Monenco, Canada) and funded by the Canadian International Development Agency. It is hoped that the present report will allay the perceived doubts as to the viability of the carbonized coal and coal briquets as substitute fuels in Niger.

2.0 SCOPE AND OBJECTIVES

The objectives of the present work are to shed more light into the background and the present state of the production of partially carbonized coal and briquettes as a substitute fuel for the Niger households.

The objectives of the report in detail are as follows:

(i) A summary review of the background, implementation and current status of the coal carbonization briquetting plant at Tchirozerine (Anou-Araren).

(ii) A review of a number of questions on the cost of carbonization

(iii) A review of questions on the cost of raw coal and its availability for carbonization depending on factors such as the quantities needed and the status of other conditions affecting the mining operations at Anou-Araren coal mine (e.g. the state of the uranium mines in Arlit)

(iv) The effect of the transportation costs on the viability of the process (carbonization).

(v) A brief review of the results of the Tahoua-Filingué region coal exploration project and its possible effect on the process.

3.0 PROJECT BACKGROUND HISTORY

3.1 Introduction

Cartier Engineering (La Société d'Ingénierie Cartier Ltée) got involved in Africa in the early 1980's in projects aimed at alleviating the problems caused by the lack of sources of domestic fuel, i.e. cooking and heating fuels. This lack is felt very acutely in various parts of Africa including countries such as Burundi in eastern Africa and Niger in the Sahelian zone of western Africa. The following is a brief history of the development that led to the establishment of a coal carbonization pilot plant to

produce partially carbonized (devolatilized) coal as a substitute fuel to firewood in Niger.

3.2 Study of Peat as a Substitute Fuel

The first step in the investigation to search for a substitute fuel for firewood and wood charcoal was carried out by Monenco Consultants through Cartier Engineering in Senegal in 1983. Monenco got involved in this study as it had a wide expertise in the use of peat for a number of purposes, one of them as a source of energy. At that time, La Compagnie des Tourbières du Sènègal was promoting the use of peat a as possible power station and domestic fuel in the country. The expertise of Cartier Engineering (Monenco) was engaged to survey and discuss the possibility of using mangrove peats of Senegal as a source of energy.

At this time Burundi surfaced as a country that already was mining small quantities of peat for horticultural uses and also had carried out studies on energy uses of peat through Finnish and Irish companies financed by various international agencies such as USAID and FINNIDA. In Burundi, peat had been promoted as a domestic fuel in its raw form. However, it contains large quantities of volatiles (up to 60%) and upon firing emits large quantities of acrid smoke. This characteristic rendered it unacceptable to the Burundian housewives as a domestic fuel, since most cooking is done

in small stoves without chimneys allowing the smoke to linger around the cooking area. In fact, peat acquired a reputation as an unsuitable fuel in Bujumbura. This reputation was further strengthened by the wood charcoal lobby which saw peat as a threatening competitor.

Cartier entered the energy picture in Burundi already in 1984. In 1987 further contacts were made with the representatives of ONATOUR (Office National de la Tourbe), the producer of peat in Burundi, to investigate the possibility of producing partially carbonized peat in the form of briquettes as a substitute fuel to wood charcoal. It was felt, that by eliminating the problem of smoke, peat would be an acceptable fuel for the Burundian households.

As a result of the interest, a project to produce carbonized peat fuel was financed partly by CIDA (Canadian International Development Agency) and partly by IDRC (International Development Research Centre, Ottawa). For the purpose of this project a pilot plant kiln, made of clay bricks, was built in Bujumbura and the required briquetting equipment imported from Canada.

This plant is still producing carbonized briquettes made not only of peat but also of mixes of other biomass, including wood shavings and coffee and rice husks.

In Burundi, there still is resistance (psychological) to the use of peat, even carbonized, because of its initial bad reputation as a smoky fuel and from the wood lobby. But as long as peat is not mentioned as an ingredient, it appears that the carbonized biomass fuel is accepted.

3.3 Initial Coal Utilization and Carbonization in Niger

Cartier carried out a study on the use of coal in Niger in 1987. The project was entitled " Etude sur les impacts de développement industriel à partir de d'exploitation du charbon". During the course of this project, it became apparent that coal could be considered as a substitute fuel for firewood which was getting scarcer in Niger, where the advance of the desert is felt very strongly. However, the characteristics of untreated coal do not lend it usable in the small stoves used in the Niger households. Also, at this time it was evident, that additional exploration to search for better quality coal, than the one found in the existing Anou-Araren mine, was necessary.

There were indications, that the same deposit could contain better quality coal towards Solomi-Sekiret about 40 km north Anou-Araren. To verify this possibility, a limited exploration project was undertaken in the Solomi-Sekiret area in 1988. Three holes were dug manually without any success. In addition to them, three holes were

drilled and sampled. The coal sampled and analyzed from these sites gave approximately the same quality results as for the Anou-Araren coal.

While the exploration work was underway, it was decided to test the possibility of carbonizing coal from Anou-Araren. For this purpose a channel sample covering the entire coal seam with the two existing seams (seams A and B) was extracted from Anou-Araren and sent to Canada for testing. The test, since it was done on a very limited quantity of coal, indicated only that it was possible to carbonize this coal and probably to produce a product usable in domestic stoves.

To follow up the possibility of producing carbonized coal as a domestic fuel, a larger scale carbonization test on the Anou-Araren coal in the brick kiln in Bujumbura, Burundi was undertaken. For this purpose, about 15 tonnes of coal from seam B, which is of a better quality than that of seam A, were manually passed through a 100 mm sieve, packed in 200 litre oil drums and sent by a Niger Air Force Hercules aircraft to Burundi.

The coal was successfully carbonized in Burundi. Part of the product was in the form of lumps. The fines were briquetted by using molasses as a binder. About three tonnes of the produce were shipped back via commercial airlines to Niamey for testing.

The testing was carried out by CTFED (Cellule Technique de Coordination, Foyers Améliorés et Energie Domestique; Ministère des Mines et de l'Energie) under the technical supervision of Cartier Engineering.

Testing was done in a traditional area of Niamey (Yantala bas) inhabited by what can be specified as "traditional" families, and in a military section inhabited by the families of the "garde républicaine", considered to be more modern in their lifestyles than the traditional families. In each area 10 families were selected for testing.

The testing agency CTFED, mentioned above, started the project with scepticism believing that it would be very difficult to win housewives over to use a totally new fuel. This scepticism was based on their earlier experience with the resistance they had met when introducing improved stoves. However, to their surprise the families tested accepted the new fuel almost totally without any reservations. This result prompted the Niger government to seek further testing of carbonization of the Anou-Araren coal locally in a new setup; interest which led into the project under review.

3.4 Niger Coal Carbonization Pilot Plant and Marketing Project

Prompted by the encouraging results of the first limited consumer tests on the use of carbonized coal as a domestic fuel in Niamey, the Niger government initiated the procedure that eventually led the Industrial Cooperation arm of the Canadian International Development Agency to contract Cartier Engineering to carry out an in-depth coal carbonization project in Niger. The aim of the project was to construct a coal carbonization pilot plant at Tchirozerine, to produce carbonized coal in lumps and, if possible, in briquettes, to carry out an acceptance test in a large number of families in Agadez, and to market the produce in a number of selected locations, and to study the economical feasibility of the project. Also, as a prerequisite to funding, CIDA exacted acquisition of a number of letters of intent from the Niger private sector to show their willingness to invest into a commercial enterprise and to continue the project later on if it, during the testing, would prove to be commercially viable. In fact, the local private sector showed more enthusiasm than anticipated, and over twenty participants formed a company, named SOCAREN (SARL), and invested 200,000 FCFA each in it, thus more than fulfilling the CIDA prerequisites and opening up the financing of the project, which started in the fall of 1990.

Sonichar joined SOCAREN investing also 200,000 FCFA with an agreement that their share would be allowed to increase up to 20% of the total in the future.

4.0 TECHNICAL REVIEW

4.1 Introduction

The following chapters will review certain technical aspects. The idea is not to reiterate the data available in the final project report released in 1993, but rather to compliment it and reinforce the technical feasibility of the methods as well as offer solutions to the shortcomings any pilot plant normally has in comparison with a commercial installation. Most of the shortcomings are due to the incompatibility of certain pieces of equipment. It was caused by factors, such as the availability of equipment, project budget limitations and certain unknown characteristics of the feedstock. The project budget and time limitations necessitated compromising the equipment acquisitions to ensure that the work could be done on time and within the budget.

4.2 Feedstock Considerations

4.2.1 In Situ Quality and Quantity

The raw feedstock coal is extracted from the Anou-Araren mine with standard mining methods utilised at this mine and hauled directly to the plant by dump trucks without any special preparation. The total haulage distance is about 5 km.

The coal in the deposit is in two seams: Seam A and Seam B. These seams are covered by about a 50 m overburden and separated from one another by an intercalation of varying thickness and on average only about 0.2 m thick.

Both seams A and B are on average 2.50 m thick according to the information supplied by Sonichar. This gives a ratio 1 to 1 of coal in seams A and B.

The earlier laboratory carbonization tests indicated that the coal of seam A with its high average ash content of up to 62.8% was not very suitable for carbonization. However, the lower ash content of about 30- 40% of seam B makes it usable. The ash content values vary widely. However, the analyses carried out during the plant operation gave the average ash content value of 30% for the coal delivered to the plant. This reflects the influence of controlling the quality of coal extracted at the mine for carbonization. The overall average ash content appears to be over 40%. In fact, the

Sonichar power station mixes coal from seams A and B in suitable ratios to keep the ash content of the feedstock at 49%.

The total reserves in the Anou-Araren deposit are estimated at 13.7 million tonnes. The mine has been designed for a 30 year life and for an annual production capacity of 300,000 tonnes. However, for years the power station with its 32 MW capacity has operated only at 40 to 60% of its total capacity consuming only about 110,000 to 120,000 tonnes of coal per year.

At the abovementioned mining rate there would be coal for the power station for more than 60 years. As also, according to some preliminary indications, the coal in seam A appears to improve in quality as the mine advances towards west, it is probable that even seam A coal might be usable for carbonization in the future. Based on the ratio of A to B seam coal (1 to 1), it appears that at today's power station consumption rate there would be about a 90,000 tonne annual reserve of seam B coal for the carbonization plant for the next 30 years. To realize this would require an increase of the mining rate to the full capacity of the mine or to 300,000 tonnes annually. As a result, there would be a 90,000 tonne annual surplus of seam A coal, if it were not suitable for carbonization. These calculations are only of magnitude of order and would require a thorough study of detailed deposit data and the required mixing ratios. In any case, they give an indication of the potential of the existing site.

The coal deposit of Anou-Araren appears to extent to the north indicating further reserves. According to other exploration projects, about 40 km north of Anou-Araren, there are large deposits of good quality coal, albeit at a depth of 400 metres, or at this time not economically minable. These deposits have been estimated to contain up to 2250 megatonnes of good quality coal.

4.2.2 Quality of Coal Delivered to the Plant

Initially, the quality of coal delivered to the plant varied greatly. Quite frequently it contained large quantities of blocks of steriles and obviously material also from seam A. This created a situation, where too much time was used to remove the unwanted material by hand. Also, the high ash content caused by impurities lowered the quality of the product. Another problem was a very high content of fines in the coal delivered to the site. The kiln can handle particles down to 10 to 25 mm in size. Anything smaller creates flow problems inside the kiln and cannot carbonized. There were occasions when the proportion of the fines exceeded 80% of the total quantity delivered.

To correct these problems, caused by the inferior quality of delivered coal, a more strict quality control at the mine was established. At the mine site, the operators of heavy equipment are used to loading large quantities of loosened up coal into 25 to 35 tonne trucks and only roughly separating seam A and B materials for their final mixing at the coal receiving station for feeding the

power station. However, for the carbonization plant a more careful selection is needed. To ensure that only seam B material and as little contaminants as possible were delivered to the plant, an engineering geologist, who also was being trained as the Niger technical director for the plant, was present at the mine site whenever coal was selected for the plant. He directed the equipment operators to select the best quality coal for carbonization. This activity is only periodical and in relation to the total mining quantities insignificant consisting of only half a dozen truckloads a week and causing no deviation in the normal mining activity. Normally it takes only 2 to 3 hours and is easily handled by the plant engineer within his other duties and does not require hiring of a special individual.

Establishment of a strict quality control at the mine site ensured a good quality feedstock at the plant site and eliminated most of the coal quality problems. The ash content fell to an average of about 30%, or in fact below the average ash content of over 40% usually measured in the coal of seam B delivered the power plant. Also the percentage of fines fell from the high of 80% to a more manageable percentage of about 40%. The initial high percentage was caused mainly by delivering coal ground up by the tracks of heavy equipment at the mine. By avoiding travelling over the coal to be delivered to the carbonization plant, more intact blocks were obtained thus reducing the percentage of fines delivered.

Also, the calorific value of the feedstock was improved from the average of about 4000 kcal/kg normally obtained for the coal of seam B delivered to the power station to an average of up to 5400 kcal/kg. This increase is mainly due to a decrease in the ash content since the calorific value is inversely proportional to the ash content. For the overall product efficiency of the product the calorific value is not as important as it is for the power station, since the domestic cooking stoves are not any high efficiency appliances, and in actually perform best with a fuel of a relatively low calorific value.

The fines are returnable to the power station and credited against the total billing, although at a discounted rate. The greatest drawback in having initially to deal with large quantities of steriles and fines is that their handling greatly reduces the efficiency of the process and adds to labour cost.

4.3 Kiln and Ancillary Equipment Performance

4.3.1 *Introduction*

The term "ancillary equipment" refers to the equipment needed to handle the feedstock before and during loading and unloading it from the kiln as well as its handling and preparation for briquetting. The pilot plant ancillary equipment consists of three belt conveyors, one bucket elevator, two screw conveyors, one

vibrating screen, one mixer, one crusher, one briquette press and an array of electrical kiln controls.

Briquetting process is discussed under its own heading, since it appears that in the future a sizable proportion of the produce might come in the form of briquettes.

Kiln was originally designed for a potential annual production capacity of about 3000 tonnes of carbonized coal. Most of the ancillary equipment has a capacity of up to several tonnes per hour and was believed to exceed substantially the production capacity of the kiln. Due to both budgeting and time constraints the number of conveyors was minimized from he total number required and concerning the crusher, a compromise piece was acquired. The following is a brief review of the performance of the equipment used and an explanation of any shortcomings and solution to problems that has to be taken into consideration when planning for additional equipment for a commercial operation. It should be pointed out, that at the present equipment configuration, the plant is capable of producing about 730 tonnes of carbonized coal annually, and that with very limited acquisition of additional pieces of equipment it can reach its planned capacity of 3000 tonnes. In any case, it is a pilot plant and rarely, if ever, a pilot plant can be turned into a full-fledged commercial operation without any modifications.

The kiln consists of the actual retort used to carbonize the feedstock. Its performance will be reviewed in the light of the performance of the ancillary equipment and the coal quality and its characteristics.

4.3.2 Ancillary Equipment

4.3.2.1 Conveyors

Belt conveyors have caused no problems as their capacity is several times higher than that of the kiln and they could handle a load for a number of kilns. The limited number (3) of belt conveyors caused some delays, since they had to be moved from one location to another depending on the tasks being performed. The reason for not acquiring more belt conveyors was to optimize their number to meet the budget limitations. However, their number was sufficient to allow the kiln to run at its full capacity long enough time periods to properly test its capability and thus no handicap was created for the purpose of a pilot plant and for the expected test market requirements. The need of additional conveyors will be discussed in the chapter on the future requirements of the plant for a full-fledged commercial operation.

Loading of the kiln is done by a bucket elevator. Also its capacity of several tonnes per hour largely exceeds the kiln's production capacity of 3000 tonnes per year. Initially, particles of coal up to 65 mm in diameter were carbonized. However, the buckets of the elevator are slightly too small to handle this size and the

material tended to get stuck in the system. As in addition to this it was observed that the optimal maximum size of blocks that performed efficiently in the local stoves was 45 mm, the maximum size of particles was reduced to 45 mm. This adjustment remedied the handling problem. In case larger particle size is needed, it can be achieved simply by acquiring a larger sized bucket elevator.

The kiln was designed to be emptied by a continuously operating screw conveyor. During the operation it became obvious that this method of discharging the produce was not suitable if the produce was to be in the form of intact blocks, since it tended to grind up a large proportion of the carbonized coal. In fact, up to 60% of the produce was less than 25 mm in diameter, or below the minimum size the local stoves could efficiently handle. The increased amount of fines would require a larger portion of the produce to be briquetted resulting in a more expensive but a more convenient and homogenous fuel.

Because of this shortcoming, the screw conveyor was replaced by a manually operated double door mechanical discharge system designed and constructed at the site by the operating crew under the supervision of the project manager. The manual discharge system reduced the portion of the fines to about 35%.

A screw conveyor is usable, if a larger portion of briquettes is required and is a viable option for the future depending on the market preferences.

The second screw conveyor, used to convey the fines to be briquetted from a storage bin into the mixer, operated without any problems.

4.3.2.2 Screen and Crusher

The coal delivered from the mine to the pilot plant site is composed of a material of a large variety of grain sizes from fine dust to blocks measuring up to half a meter in diameter. Originally, the material was passed through the power station's first stage crusher to reduce it to a size of 100 mm or less. However, this process produced too much fines not usable for the carbonization process and was discontinued. The largest blocks, up to almost one metre in size, are manually broken into smaller ones before screening. Since they comprise only a small percentage of the total, and are relatively easily broken into smaller size, they have not caused any appreciable delay or manpower problems during the pilot plant operation. For the industrial phase a crusher capable of crushing particles up to 0.5 m in diameter to 45 mm or less, but not producing too much fines, is needed to assure a continuous and rapid flow of feedstock to the kiln. For the pilot plant stage, a small crusher was acquired, but it also produced too much fines at this stage where briquetting was not carried out at

a full-scale and its use was discontinued for raw material crushing.

The raw coal and the manually crushed particles are fed manually onto a conveyor belt for screening in a double deck screen. The screening is done through 45 mm and 25 mm screens. Presently about 35% is passed through as smaller than 25 mm and is stockpiled for the return to the power station and credited against the total bill. This portion will be carbonizable only after a suitable crusher is acquired to allow its grinding into fines less than 6 mm in diameter. These fines can be first briquetted and thus formed raw coal briquettes carbonized. The process is described later in the chapter on briquetting.

About 10% is oversize, i.e. more than 45 mm in diameter and is again manually crushed for further screening. The rest, about 60% is carbonized directly. The same screen is also used to screen the produce to separate the fines from the usable fraction. The intention was to alternate the screening of the raw coal and the produce and keep the kiln producing continuously. However, due to the large quantities of fines, the screen has proven to be too small to allow a fast enough screening of the raw material to stockpile it for to last a long enough time to allow screening of the produce while the kiln continues operating. As a result, once the small stockpile of screened feedstock is depleted and the screening of produce continues, the kiln has to be shut down until

enough raw material has been screened again. From this it may appear that the kiln produces batches, although actually during the process cycle its operates continually as planned. The remedy for this pilot plant shortcoming is simply the acquisition of a screen(s) large enough to handle all the screening requirements and the acquisition of a suitable small size crusher(s) to crush both incoming feedstock as well as any fines (raw or carbonized coal) destined to be briquetted.

4.3.2.3 Kiln Controls

The process (carbonization) control is done partly manually and partly by semi-automatic controls. Controls include a number of thermocouples to monitor the temperatures in various sections of the kiln. The temperatures are kept within certain limits to ensure a proper degree of carbonization and to avoid any excessive combustion of the feedstock in the kiln. Some combustion is needed, especially in the early stages of the carbonization process, and occasionally during the process, if the temperatures fall below the exothermic reaction level (about 280° C).

The temperatures in the chimney and in the main body of the kiln are monitored by a six-channel chart recorder.

The control is performed by using automatic temperature controlled airflow valves and manually adjusting the chimney damper to control the draft and the exhaust gas temperatures which are a good

indicator of the process conditions. The control is also done by adjusting the speed of production according to the carbonization temperatures and the residence time in the kiln. All these adjustments are made in response to the same-day analytical results on the volatile matter content of the produce.

The cooling zone of the kiln is used to precool the product by injecting water inside the cooling zone of the kiln and by cool water circulating in the double-walled discharge mechanism. Further cooling is done by spraying the hot product by water whenever necessary and by letting it cool some time in the receiving containers to ensure that no spontaneous combustion takes place.

By using simple low technology for the controls it is ensured that the operation is easily run in the local conditions without any expensive and complicated high technology equipment that would make the operation dependent on the outside expertise and would cause operating and cost problems. There have been no problems with control mechanisms. Certain small adjustments would be made in the materials and mechanisms for a larger scale industrial operation.

4.3.3 Kiln Performance

4.3.3.1 Production Capacity

The existing pilot plant kiln was designed to be able to produce about 10 tonnes of carbonized coal per day, or about 3000 tonnes per year. During the testing, production rates of up to 625 kg per

hour were reached equalling 10 tonnes per day while working two 8 hour shifts. Based on this rate, a production rate up to 14 to 15 tonnes per day could be achieved, if the work would be carried out 24 hours continuously. Taking into consideration downtime, it is assumed that the plant could work 300 days per year. At a rate of 10 tonnes per day, the total annual production per kiln would be 3000 tonnes as was originally planned. For a number of reasons, such as untrained crew, insufficient ancillary equipment (screen) capacity and minor equipment breakage and the overall pilot nature of the installation, the theoretical capacity of 15 tonnes per day (equivalent of 4500 tonnes per year) was not achieved. However, maintaining the 10 tonnes per day rate was feasible at the pilot plant configuration for short periods of time and 7.2 tonnes per day over extended time periods. It appears technically possible to attain up to a 4500 tonne annual production by optimizing the ancillary equipment.

Initially, a screw conveyor was used to discharge the carbonized product from the kiln. However, it was quickly discovered that the screw had a tendency to crush the product resulting in production of up to 60% of fines. At this stage they were not briquettable in any large quantities because of the lack of a suitable crusher to reduce their grain size to the required 6 mm maximum size. Thus only about 40% of the total product was usable in practice. The installation of a manual mechanical discharge mechanism reduced the percentage of fines down to about 35 to 40% bringing the usable

production rate up to about 5 tonnes per day for each operating day. This equals 1500 tonnes per year of total production if the plant could operate the planned 300 days per year. However, due to the inefficacy of the screening system, it was possible to produce only about 20 day continuously and then shut down the production for about 30 days to screen the produce and feedstock. This cycle could be repeated 7.3 time in a year. Thus the actual equivalent capacity of usable production, that is carbonized produce above the size of 25 mm in diameter, was about 730 tonnes. It was slightly larger since small quantities of the fines produced were successfully briquetted.

All this shows, that the kiln is capable of producing at a production rate equalling a total 3000 tonnes of carbonized coal annually when operated on two shifts and up 4500 tonnes on three shifts, but at the present combination of equipment this level is reduced to about 730 tonnes of usable produce per year. It also shows, that actual usable production rate can be raised to the planned level by the acquisition of a few pieces of ancillary equipment to step up from the pilot plant level to a proper industrial level.

While one kiln is capable of producing even up to 4500 tonnes per year, two kilns would be required to ensure an uninterrupted production to ensure a stockpile of produce in case of any technical or other production problem. The cost, however, would not

be doubled because only a few additional pieces of equipment would have to be added to the existing full compliment of ancillary equipment to keep two kilns operating. Also it is foreseen, that having two kilns, it could be possible to extend the effective equivalent one kiln operating period of 300 days to 365 days per year and thus easily ensure at least a 3000 tonne annual production rate.

4.3.3.2 Kiln Performance Considerations

Carbonization of wood and other biomass materials is an ancient technique to alter the nature of fuel. Techniques vary from small earth mound kilns, with an annual capacity of few hundred kilograms and a 5 to 10% yield, to huge multimillion dollar high technology plants with a capacity of 100,000 tonnes or more and yields up to 80%. While the high technology plants may look attractive in an industrialized country, they pose both unsurmountable financial and technical problems to most developing countries and thus not feasible for their needs - at least in the first stages of developing the techniques and markets.

For these reasons Cartier Engineering developed a technology that is at the same time simple and cost effective and can be handled both technically and financially by the targeted region and which also attains a good yield thus increasing economy and is environmentally friendly as well. High yield translates into saving

natural resources, reducing pollution and cost of raw materials and their transport to the plant.

The kiln designed by Cartier Engineering has been locally constructed, albeit from imported materials since it is made of steel. Steel construction was selected over the bricks used in the first kiln (in Burundi) which was built from locally made bricks. The main reasons are the durability and low maintenance requirement of a steel kiln and the ease and accuracy of the process control. The brick kiln had proven to be more difficult to control, mainly due to it not being airtight enough to ensure proper conditions for a pyrolysis and to avoid combustion of the feedstock. Steel kilns can be manufactured in sections in one location and transported to the plant site, making their construction more efficient in case a number of kilns in a number of locations are needed. For instance, the Niger project kiln was constructed in Niamey and transported by a truck to the site where it was erected and finished to its final readiness.

The performance of the project kiln is affected by the quality of the feedstock and, to some extent, by the ambient temperature as well as the direction of the prevailing wind.

As to the quality of the feedstock, its grains size is of importance in achieving proper level of carbonization. A number of tests were carried out on different size fractions to determine the

limits within which the kiln was capable of producing homogeneous product. The tests revealed that this kiln can carbonize size fractions down to about 15 to 22 mm in size. When the size was diminished to contain particles less than 10, it was observed that the fines tended to start agglomerate and form large agglutinated chunks of coal, which then often got attached to the walls of kiln and impeded the flow of feedstock. This increased the residence time and eventually led into both over-carbonization and combustion of the feedstock. As a result, the percentage of volatiles dropped to very low of 3-4%; far too much below the preferred level of 7 to 8% and thus too low for the produce to be used as a domestic fuel, since at such a level it is very difficult to light and does not sustain continued combustion in the stoves. Also its ash content rose to 50-60% and in many cases the product was a mixture of highly carbonized coal and chunks of burned out coal.

As to the maximum size, there were no problems carbonizing fractions up to 60 mm in size. The only limitation was caused by the bucket elevator which does not easily accommodate particles over 55 mm in size. Since the local cooking stoves perform best on the fuel between 25 and 45 mm in size, the operation was limited to this fraction.

Control of the temperatures in the kiln is very important for the process to progress properly. Both the carbonization temperature and the speed are the principal factors controlling the process.

With the steel kiln it was possible to control the temperatures accurately enough to be able to produce quite uniformly carbonized produce. Only the fluctuations in the ambient temperatures and the direction and the force of the wind created variations in the internal temperatures in the kiln and had to be taken into consideration when controlling the process to avoid either over- or under-carbonization.

Before the produce is discharged from the kiln it enters the so-called cooling zone of the kiln. It is located below the carbonization zone and is the section which is not clad with refractory cement on the inside as is the rest of the kiln. The simple steel wall allows a large heat loss and essentially stops the process and starts to cool down the product. At this stage cooling is enhanced by injecting water into the produce inside the kiln and spraying on the outside. Initially, only this method was used. However, due to air leaking into the kiln thorough the discharge mechanism, it was improved by enveloping it with a double wall allowing the entire mechanism to be cooled down. This improvement solved the cooling problem and also allowed the reduction of the quantity of water needed from about 300 m^3 per month to about 100 m^3 per month. The consumption can be further reduced to a negligible quantity for the industrial stage by recycling the cooling water - an important consideration both for environmental (no discharge of water, water resource conservation) and economical (cost of producing water) reasons.

4.3.4 Product Review

4.3.4.1 Chemical Characteristics

A total of 342 samples of product were analyzed in a laboratory to determine the basic chemical characteristics of the produce. The most important characteristics are given in Table 1 below. The values both for the product and the feedstock as well as the change (±) are shown to give an indication of the changes that take place in the material during the process.

The table shows that the volatile content is reduced down to about 7.5% . During the tests in the homes it was observed that, if the volatile content was over about 8-10% in the unbriquetted coal, there still was some smoking that irritated the user. It appeared that at this higher volatile content level there were still

TABLE 1
BASIC CHEMICAL PROPERTIES OF PRODUCT AND FEEDSTOCK

Material	Product	Feedstock	Change %
Ash content (%)	35.0	30.0	+5.0
Volatiles (%)	7.2-7.7	23.0	-15.6
Total C (carbon)	51.7	53.0	-1.3
Calorific value (kcal/kg)	4770-5170	5408-5583	-525.0

individual particles of coal at up to a 18% volatile content. These particles released enough fumes to be an irritant to the user. Once the level was down to below 8-10 percent on average, the highest

volatile contents in individual particles fell below about 13-14%, or to a level at which no smoke is released.

Other changes are the decrease of calorific value and total carbon and the increase of ash content. Since the efficiency of the carbonized product for the domestic use is not critical at these property levels, these changes do not cause any efficiency problems and are within acceptable limits.

The above listed basic chemical properties indicate also that the production of a suitable carbonized domestic fuel from coal does not require good quality coal. In fact a high volatile, low ash content coal might not be suitable for the production of this kind of fuel without an addition of some inert material, such as bentonite, to increase its ash content and to reduce its calorific value to ensure a slower burning rate.

4.3.4.2 Physical Properties

The most clearly noticeable changes in the coal, after it has been carbonized, are the changes in its colour to silvery from almost black, weight loss and it cleanliness (does not smudge). Table 2 gives the bulk densities of both the uncarbonized feedstock and carbonized product. Table shows that during the carbonization process the bulk density is reduced by 11-12%. The resulting carbonized coal is lighter in weight and harder than the original feedstock. The lightness is caused by the increased porosity of the

material. The product is also durable and does not break on dropping it onto a concrete floor from the height of about 3 feet (90 cm) as does the raw feedstock.

The durability is also well demonstrated in that upon a long distance transport by trucks from the plant to Niamey less than 1% was lost through the breakage of lumps to fines.

TABLE 2

BULK DENSITY OF DIFFERENT FRACTIONS OF FEEDSTOCK (RAW COAL) PRODUCT

	kg/m³		
fraction (mm)	Feedstock	Produce	% weight los
25-45	736	655	11
>45	669	591	11.7

At the discharge, the product contains a quantity of fines which are not usable as fuel and have to be stocked for briquetting. The granulometric analyses have shown that up to 35 to 40% are fines and about 10% oversize, i.e. more than 45 mm in size. The quantity of fines may increase during handling, if no care is taken not to travel (walk, drive vehicles) on the stockpiles. The oversize (over 45 mm) fraction is usable in the large institutional stoves.

4.3.4.3 Utilization Properties

The chemical and physical properties of the produce affect its utilization properties in a number of ways. Initially, there was a certain reluctance for the user to accept this new fuel as it was perceived to be difficult and uncomfortable to use.

Some of the critical doubts concerning the product were its cleanliness concerning the hands, soiling the pots on the fire, smoke emissions, smell and ash residues, the ease of lighting, recovery and re-use of extinguished materials, quantity of heat, length of fire and possible imparting of flavour to the food.

All these suspicions were alleviated already during the first user test on the small quantity of Anou-Araren coal carbonized in Burundi and returned to Niamey for testing. The final acceptance materialized during the consumer testing in connection with the present project.

The first misconception was the belief that coal is difficult to light. This belief has its roots mainly in that, while carbonized coal is quite easily lighted, it takes a relatively long time to proceed to a level where enough heat is generated to start cooking. Firewood in a hot and arid country, such as Niger, is extremely dry and can be lighted directly with match without any other kindling such as paper. In fact, Tuaregs commonly start a fire by rubbing carefully selected pieces of dead wood together creating enough

heat through friction to start a fire in small slivers of wood and dry straw. Coal, on the other hand resembles, to an uninitiated, a piece of rock and seems to be non-combustible. Uncarbonized coal can be lighted quite easily, if it has a high volatile content. A much cleaner looking carbonized coal, with its low volatile content, only requires a little of skill and patience to get it lit.

Originally the user was advised to place a small quantity (100 g) of wood slivers on the gate of the stove, cover them with about one kilogram of coal and finally splash one or two bottle capfuls of petroleum on the charge, wait a couple minutes and light it. Normally, the fire starts in a minute or two and enough heat is generated in about twenty minutes to start the cooking. The objections some users raised was the additional expense and inconvenience caused by the need to buy petroleum and wood. However, the quantities needed are minimal and considering the higher efficiency of the coal, the total fuel cost is still kept below the cost of wood. Also, as the users got familiar with the carbonized coal they learned to light it without petroleum with only small scraps of paper or some other waste.

The experience quickly taught the user that the product is very clean, it does nor create any deposits on the pots as does firewood fire, it does not soil the hands, releases very small quantities of dust in handling, does not impart any additional flavour to the

food, and it is possible to re-light the partially used and extinguished remnants. Above all, it burns very cleanly without any irritating smoke or smelly emission contrary to firewood and the fire is long-lasting; one kilogram of coal burning up to five hours. Also the fire is hot enough to allow easy cooking and a convenient control of fire, but not too hot to damage cook ware. In the tests temperatures up 700° C were measured within the burning coal. Nevertheless, neither the grate nor the stove in general, made of recycled oil drum steel, withstood the temperatures well, and stoves did not show any appreciable damage after a year's use.

The users also learned to put out the fire at the end of cooking to conserve the fuel. They did re-use the old partially burned material and mixed in a rough ratio of 1/3 of old fuel to 2/3 of new material.

4.4 Stove Technology

4.4.1 Traditional Stoves

Traditionally cooking was, and still is to some degree, done by placing the pot directly on three stones on the ground. The firewood is placed on the ground between the stones.

Second step in the techniques is to make a simple cylindrical stove out of recycled sheet metal with a door on one side. The pot is

placed on this "stove" and the firewood on the ground inside the stove. A number of different "improved" (foyers améliorés) designs by modifying this simple stove have been used in various parts of Africa. Most of them still rely on firewood placed directly on the ground.

As a part of the marketing and user testing, carbonized coal and briquettes were tested in these stoves as well as on three stones. The three stones method did not work at all and most other simple wood stoves gave very poor results for a number of reasons. The most obvious drawback was the lack of grate and draft control.

Raw coal is being used by e.g. the catholic missionaries in Tchirozerine as a cooking fuel in their mission school. The stoves are made of 200 litre oil drums and some masonry work and supplied with a 2 to 3 metre chimney to carry the smoke away. They seem to work satisfactorily in this isolated location, where it is possible to dissipate the smoke into the open country, but they hardly could be used in any densely populated area.

4.4.2 New Designs

4.4.2.1 Cherchar Stove

As a part of the Foyers améliorés project, a stove called Cherchar was developed by ONERSOL (Office National de l'Energie Solaire). It is constructed of virgin sheet metal and supplied with a grate and simple method of draft control. It was believed to be usable also

with carbonized coal and was tested with it in connection with the first experiments on the coal carbonized in Burundi.

The stove performed quite well with both the lumpy coal and the briquettes. However, its price, about 15,000 FCFA (1989), was too high for all but the affluent citizens and it was discarded as a stove candidate for later tests. A regular improved firewood stove costs about 750 FCFA, setting a bench mark for a simple stove.

4.4.2.2 Project Stoves

The early tests had shown that the carbonized coal or coal briquettes do not perform satisfactorily either with three stones or with the stoves designed for firewood. To overcome this shortcoming, a new stove to suit coal was designed by ONERSOL/CTFED personnel. The stove can be made of recycled oil drums or any suitable sheet metal at least one mm in thickness. Its manufacture does not need any high technology such as welding and it can be easily made by local blacksmiths who, in fact, were trained to make them in a number of locations. The stove consists of a pedestal foot as a base, a cylindrical fire box, a pot holder in the shape of an inverted cone, a grate to raise the fuel from the ground and a door under the grate for ash removal and draft induction. The pot support in the first model was capable of accommodating pots sizes up to # 3, or the most common sizes (pots are numbered according to the size).

Later on, a few larger models were constructed to accommodate larger pots used by very large families and by institutions as supplementary cooking utensils.

These stoves can be also manufactured by industrial methods of sheet metal and instead of bending, welding can be used to fit the sections together.

The stove prices vary depending on the location, availability of metal and the demand. Initially, they were sold in Agadez for 1500 FCFA each and later for 1200 to 1350 FCFA.

During the project, a pottery maker was hired in the village of Say, about 10 km east of Niamey, on the banks of the Niger River, to make a similar stove of pottery clay. This stove performed very well and was durable and withstood very well the abuse of being transported in a vehicle for months without breaking. It also withstood the actual use well without any signs of breakage. The use of pottery clay and local artisanal talents would further enhance the economic feasibility of carbonized coal as a domestic fuel.

The stoves were tested by ONERSOL and performed well. By the end of 1992, some of these stoves had been in a daily use for about 14 months without showing any significant signs of wear. Even the grates, which are exposed to the highest temperatures, had

withstood the use very well. These stoves can be used with wood charcoal and, if the grate is removed (it is removable), with firewood.

4.4.2.3 ABBAZE Stoves

A group of SONICHAR power station technician formed a small cooperative to produce locally manufactured stoves designed to accept wood, wood charcoal, coal and some larger models, used for heating water, also petroleum. The name ABBAZE is an acronym derived from the initials of the founders of the cooperative. These stoves are manufactured from commercial grade sheet metal in a local artisanal workshop. The process involves rolling and welding the components and lining of the stoves' firebox with pottery clay and preferably even with refractory cement.

Although some models perform well with the carbonized coal and briquettes, their performance is not any better than the ONERSOL stoves' performance. The main problem is the price. The least expensive models cost over 6000 FCFA (1992) and the larger water heaters up to 50,000 FCFA (1992). As a result, these stoves have a limited market mostly among more affluent families.

Recently (1994) ABBAZE has promoted a larger stove for institutional use at the price of 57,000 FCFA.

4.4.2.4 Institutional Stoves

One large segment which can benefit from the use of carbonized coal as a fuel is the institutional segment including the military, schools, hospitals and some industrial enterprises.

After visits to a number of institution to investigate their energy requirements, four locations were selected as suitable for testing the carbonized coal as a cooking fuel. These are the military camp at Tchirozerine next to the Sonichar power station housing a few companies of infantry, the large military camp in Agadez, the Agadez hospital and EMAïR (Ecole des Mines de l'Aïr) in Agadez.

The first stove made of banco, cement and a few pieces of angle iron was built at the Tchirozerine Camp. It is supplied with a two metre chimney and can hold a large pot (about 40 litres) used to cook for the soldiers. This installation has been in use since late 1991. Initially, coal rejected at the plant site as not marketable was used in this stove without any problems. The reasons for the rejection were too high an ash content or level of carbonization. Later on, when the production at the plant had stabilized, good quality material was used.

The stove performed very efficiently and saved the soldiers from arduous trips up to 100 km to search for scarce firewood in the area. The use of coal benefits the camp economically and the environment in the reduced use of wood.

The second stove was built at the Agadez hospital where all the cooking was done in a poorly ventilated small detached kitchen building. The stoves, originally used with firewood, were a large masonry stove vented outside through a short chimney and improved stoves (foyers améliorés) inside the kitchen building without any special ventilation or chimneys exposing the personnel constantly to irritating smoke, carbon dioxide and monoxide and other emissions.

The new stove is of the same design as the one at Tchirozerine. it is vented outside and has a tightly fitting pot support to keep smoke from entering the kitchen. The standard small stoves were replaced by ONERSOL stoves. Only carbonized coal in lumps is used to cook. Even though the small stoves still are inside and not vented outside, no irritating emissions were present. The basic air quality tests did not reveal any unacceptable levels of emissions even inside the kitchen.

According to the hospital administrator, due to the high efficiency of the fuel and stoves, the savings in the kitchen fuel cost are about 60%.

Two other stoves were under planning or under construction, one in EMAïR and the other one at the Agadez military camp, at the end of 1992. Presently no information is on hand about their state of readiness.

Other locations showing interest are some schools and the Niamey hospital, and can be considered as suitable locations in the future.

4.5 Production of Briquettes

4.5.1 Introduction

Because considerable quantities of fines are both in the feedstock and in the produce, and because the fines of the feedstock are not carbonizable as such, it was deemed necessary to carry out briquetting experiments on both types of fines. The briquettes produced from the carbonized fines are directly usable as a fuel while the those produced with the feedstock fines were first briquetted and then carbonized. The following chapters discuss briefly certain principal aspects of this process.

4.5.2 Equipment and Preparation of Materials

The main piece of equipment is the press with a 1-2 tonne capacity per hour, or considerably higher than the production of fines suitable for the briquetting process.

Other pieces are belt conveyors periodically taken from the carbonization operations for briquetting process, a mixer to mix the fines with water and a binder, a metering bin for metering the water/binder mix into the coal fines, a fines metering bin and a

crusher modified for crushing coarser particles. The fines crushed or produced in the carbonization kiln as well as the fines separated from he feedstock at the screening station are eventually screened manually through a 6 mm screen to obtain a fraction that can be briquetted.

In order to obtain coherent briquettes it is necessary to add proper quantities of water and a suitable binder into the coal fines before briquetting. Both molasses and manioc flower were used as a binder in this case and both worked well. Initially molasses appeared to be more efficient as a binder and 3.5% by weight of molasses were used versus 4.5% of manioc flower in preparation of the mix of carbonized fines for briquetting and 2 to 4.5% of manioc flower for the uncarbonized feedstock.

Due to limitation caused by the equipment available, only small quantities of briquets were produced for testing with the consumer.

Presently (1994), briquetting of the stockpiled carbonized fines has been resumed. The process tries to minimize sieving to avoid high ash content in the briquettes. The produce is sold and is well obviously well received by the user, since there probably is a shortage of carbonized coal products because the plant is not operating at this time. The percentage of binder, manioc flower ("gari") has been reduced to about 3% from 4.5% used in the earlier tests.

4.5.3 Properties of Briquettes

For the consumer, the briquettes appear appealing because they are uniformly shaped and smooth in the outer appearance. Due to the binder and high compression during the process they are durable and clean to handle. They also withstand exposure to the rain well, excepting the briquettes made of uncarbonized coal which, before having been carbonized, are readily destroyed by any extensive rain.

Table 3 gives the ash and volatile matter content of the two different types of briquettes in comparison with the non-briquetted lumpy coal. Both these values for the briquettes are considerably higher than for the lumpy coal. In the consumers tests it was

TABLE 3
BASIC CHEMICAL COMPOSITION OF BRIQUETTES COMPARED WITH CARBONIZED COAL

		Briquettes A	Briquettes B	Coal C
Ash Content %	55.0	47	35	
Volatile matter %	9.5	13	7	

A = Briquettes made of uncarbonized coal and then briquetted
B = Briquettes made of carbonized fines
C = carbonized unbriquetted coal

observed that the briquettes were preferred by the consumer for their appearance and handling over the lumpy coal. Although the volatile matter content was as high as 13% the briquettes did not emit any fumes. It is believed, that during the crushing and mixing process all the particles containing high percentages of volatiles are ground up into small grains and then in the mixing process homogeneously distributed in the mass and thus not being burned as distinct blocks emitting large quantities of smoke. From this it appears that the average volatile content of the briquettes can be as high as 13% in contrast to that of 7% for the lumpy coal, and still be acceptable to the consumer.

A look at the ash content reveals that in these tests it was from 47 to 55% for the briquettes and only 35% for the lumpy coal. In the tests it became obvious that the high ash content rendered the briquettes quite unreliable in that while they were easily enough lit they did not burn long enough and were not re-usable after the fire had gone out. The residue contained mainly ashes. For these reason, although otherwise the consumer expressed a preference for the briquettes, their acceptance was conditional.

The reason for the increase in the ash content is in that the fines were screened to exclude anything over 6 mm in size. The screening allows a large percentage of fine grain sterile to pass through while a proportionately large percentage of small coal particles is retained by the screen. The solution to this is to replace the

existing inefficient crusher with a different model capable totally crushing everything to a grains size of 6 mm or smaller thus ensuring that no change in the ash content occurs. The good quality of briquettes as substitute fuel was verified in the early tests on the coal carbonized in Burundi. The briquettes in that case were made of fully crushed materials without any further screening resulting in good quality briquettes.

Based on the results of the Burundi briquetting tests and on the general fact that briquetting is a well established technology, it is can be stated that no extensive further testing is required at the Tchirozerine plant to attain a reliable output of good quality briquettes once all the required pieces of equipment are in place and personnel trained in their use.

Due to the equipment-caused inefficacies briquetting was discontinued pending acquisition of more efficient equipment and to ensure that the consumer would not be prejudiced against briquettes.

4.5.4 Quantities; Briquettes vs. Lumpy Coal

The ratios of fines, in both the feedstock delivered to the plant and in the produce exiting from the kiln as well as in the stockpiles, to the coarser material indicates that a considerable proportion of the final product would be in the form of briquettes, if all the raw material were to be utilized.

Initially, the feedstock contained up to 80% of fines returnable to the power station. Later with a more efficient quality control at the mine, the percentage of fines was reduced to about 40%. If all these fines were to be first briquetted and then carbonized and assuming a kiln yield at 73%, the final percentage of the briquettes would be about 40%. The product exiting from the kiln contains about 35% of fines. If all these too were briquetted, the total of briquettes in percentage of the total product would be about 60%. Since the tests have shown that the uncarbonized coal can be successfully briquetted and then carbonized, this picture could be quite close to the actual end result.

However, if the marketing and economic reasons do not warrant such a large portion of briquettes, the uncarbonized fines can be always returned to the power station against credit. In this case the percentage of briquettes would be about 35% of the total quantity.

5.0. SUMMARY OF TECHNICAL REVIEW

5.1 Introduction

The following summary recapitulates concisely the present technical state of the project according to the knowledge on hand, the need for upgrading certain pieces of equipment and possible preparations to be made and a brief preview of the possible future technical

development envisaged for the production of domestic fuel derived from coal.

5.2 Present State of the Project

Present state refers to the technical status of the project at the beginning of 1993, when the project was left at the hands of Nigers pending further financing by lending agencies and/or possible further investment by the Niger stockholders of SOCAREN. The plant was operated till the end March 1993 still under Cartier contract. Since that, it operated till the end of July 1992, after which only briquettes have been produced from the stockpiles of carbonized fines produced during the earlier carbonization operations. At the same time, both briquettes and the remaining lumpy coal have been marketed in a number of locations including Niamey. These activities have been financed both by the revenues from the sales and by a small (6 million FCFA) operating grant allocated by l'ACCT (l'Agence de coopération culturelle et technique; Bureau régional pour l'Afrique, Lomé, Togo)

At the time the project was left in the hands of the Nigers it was technically operational at pilot plant capacity, as recapitulated below.

5.2.1 Kiln Production Capacity

The kiln is capable of continuous production, as planned. Presently, due to the pilot plant configuration of equipment, it can be used for continuous production for only periods of about 20 days interrupted by about 30 days for screening of the product and feedstock and stockpiling of the screened feedstock.

Kiln has produced 10 tonnes of carbonized coal per day working two 8 hour shifts. Theoretically, it could reach a 15 tonne daily production rate. Due the inefficacies of ancillary equipment forcing to break the kiln operation into the abovementioned periods of interruption of production, the actual long term production capacity is about 730 tonnes per year of lumpy coal. With a set of full capacity equipment this limit can be raised to 3000 tonnes per year and working on three shifts, to 4500 tonnes per year.

5.2.2 Briquetting Capacity

The briquetting press has a capacity of up to 2 tonnes per hour which translates into a theoretical capacity of at least 7,200 tonnes per year. Because, at the most about 60% of the total product would be briquettes, the annual capacity of 7,200 tonnes is equivalent of almost the production capacity of three kilns, or equivalent of a total annual production of 12,000 tonnes of carbonized materials.

Also the mixer has the same extra capacity as the press. Presently, other pieces of equipment required for briquetting are alternately used also for other kiln operations and would have to be supplemented with new pieces for an industrial scale operation. Due to the inefficacies inherent to a pilot plant concept. The full briquetting capacity has not been achieved, although briquettability both the carbonized and uncarbonized fines and their subsequent carbonization has been technically proven.

5.2.3 Quality of Feedstock and Product

5.2.3.1 Feedstock Availability and Quality

Presently, there is only one operating coal mine in Niger. In connection with a number exploration projects large probable coal deposit have been found in various parts of the country. However. as of today no other full-fledged exploration project to accurately estimate total coal reserves has been finished in Niger. The existing mine contains about 13 million tonnes of coal reserves. This reserve was initially earmarked to support the Sonichar power station for thirty years at an annual mining capacity of 300,000 tonnes. Due to the reduction of the uranium production at the Arlit area uranium mines, the power station has been operating only at a partial capacity and using only about 110,000 to 120,000 tonnes of coal annually. The coal in the Anou-Araren mine is in two separate seams - seams A and B. Due to quality reasons, only the coal of seam B is usable for carbonization. It is calculated (page 11) that the ratio of the coal of seam A to B is 1 to 1. Thus there

would be, at today's mining rate, about 90,000 tonnes of coal of seam B annually available for carbonization at this location for the next 30 years. This means that the rate would have to be increased to the original maximum of 300,00 tonnes per year and that about 90,000 tonnes per year of seam A coal would be a surplus.

The quality of coal in the existing seams vary from each other. Due to its high average ash content of about 50 to 60%, seam A coal it is not suitable for the production of carbonized domestic fuel whose maximum acceptable ash content is 30 percent. Other parameters such as the average volatile content of 23%, low sulphur content of less than 1% and the calorific value of 5400 to 5583 kcal/kg of seam B have been found to be quite optimal for the production of carbonized fuel from this coal.

5.2.3.2 Product Quality

Table 1 gives the basic quality parameters of the product compared with those of the feedstock. The ash content of the product (lumpy coal) was about 35%, volatile content 7.2-7.7%, total carbon 51.7% and the calorific value 4770 to 5170 kcal/kg.

The relatively high ash and low calorific values are, contrary to common belief, beneficial for the product by slowing down its burning rate and release of heat as well as keeping the

temperature of the fire low enough not to damage neither the cooking pots nor the stove grates. The low volatile content ensures that no visible or otherwise irritating or unhealthy fumes are released by the fuel upon use. At the same time it is high enough to allow easy enough lighting of the fuel and sustaining the fire.

The handling qualities of the fuel are excellent. It is durable and withstand easily long distance transport by truck without any significant breakage (less than 1%). Its does not soil the hands of the user neither does it dirty cooking pots. In the everyday use, carbonized coal has also proven to be very efficient and carefully organized cooking tests have shown that one kilogram of carbonized coal is equivalent to 2.7 kg of firewood. This clearly shows its high efficiency. Furthermore, at the price of 29 FCFA/kg (1992) for the coal Agadez hospital realized up to 60 percent savings in its kitchen energy costs over the cost of firewood.

5.2.4 Stove technology

The first consumer tests were done on three stones, improved stoves (foyers améliorés) and a stove called Cherchar, designed for use with coal. Only Cherchar performed well, and was consequently used for the rest of the testing. The results were positive, and indicated that simple stoves accommodate carbonized lumpy coal and briquettes efficiently and in an acceptable manner.

Because of the high price (about 15,000 FCFA, 1989) of Cherchar, it was not used for the larger testing for the Niger coal carbonization project. Instead, CTFED (Cellule Technique de Coordination, Foyers Améliorés et Energie) and ONERSOL (Office National de l'Energie Solaire) of the Ministry of Mines and Energy in Niamey designed a specific stove for the use with carbonized coal products. This stove can be manufactured either from recycled sheet metal (e.g. recycled oil drums) or industrial quality sheet metal from one to a few millimetres in thickness. It can be manufactured either by artisanal blacksmiths or in an industrial plant, depending on the quality, quantity and price requirements.

A successful test of using a ceramic stove made by a local pottery maker of local clay was also carried out, further opening up artisanal and more economic stove market which would not require any imported materials paid for by foreign currencies.

As well, institutional ovens for the use of carbonized coal were built at a military camp in Tchirozerine and for the Agadez hospital. The materials were mostly local except a few pieces of angle iron to reinforce the structures. The test were successful and mark the way for the future techniques indicating that by a judicious use of the local materials and skills, the new fuel, although it requires a new stove, does not impose any extra costs to the user or the country in the long run.

5.3 Upgrading Prerequisites

As has been shown, at the present pilot plant stage the plant on the whole is capable of producing about 730 tonnes of usable product per year. In order to reach the kiln's full capacity, a number of pieces of equipment are needed. Acquisition of these pieces also ensures that the briquetting capacity will reach its maximum, provided a suitable binder is available.

The additional equipment needed includes the following:

1. **Six belt conveyors** to ensure efficient and uninterrupted utilization of all the other pieces of equipment.

2. **One large capacity double deck vibrating screen.** Its capacity has to be about three time larger than that of the existing screen.

3. **One large capacity pulverizer** capable of crushing the fines to 6 mm or smaller in size to ensure briquettability both of the uncarbonized fines to prepare them for briquetting and carbonization and of the carbonized fines for briquetting.

4. **Spare parts.** The type quantity and number required is not known at this time without obtaining detailed information from the site of the condition of the equipment.

5. **Product and feedstock storage hangars.** One 12 X 6 m hangar exists on the site. It is estimated that additional 9 hangars of this size would be needed to protect the product.

It is possible that other items might be required for upgrading the plant. Determination of any additional items has to be done on site and is subject to the decision to continue the support of this endeavour.

5.4 Future Technology

The present kiln is designed to produce about 3000 tonnes of carbonized coal annually. This quantity would only fill partially the total need of Niger which could be as high as 100,000 tonnes per year. Any demand larger than 3000 tonnes per year would require building additional kilns. It could be possible to have a number of these low technology kilns grouped together with all the required ancillary equipment in a number of location in Niger, if suitable coal deposits were found in other locations. The economics of a large production need might make it more feasible to establish one or two higher technology high capacity kilns capable of producing up to 100,000 tonnes each. These plants, which are no more in extensive use e.g. in North America, where the demand for coal briquettes has fallen off since gas operated barbecue grills have become popular, are obtainable at a relatively low cost. They could be dismantled, transported to the Niger and erected at suitable locations.

6.0 REVIEW OF COST AND MARKETING ASPECTS

6.1. Introduction

This section on the review of the marketing component deals with aspects other than technical, and will shed light into the

economical feasibility of producing carbonized coal in Niger for domestic use in general. Since the end of the project early in 1993, FCFA has been devaluated and the market for the carbonized coal has been developed further. Consequently, certain details would have to be verified to adjust them to today's conditions, if it is deemed that the project is economically viable.

6.2 Pilot Plant and Production Cost Aspects

6.2.1 Equipment Investment Cost to Attain a 3000 Tonne Annual Production Level

As it is evident, in order to increase the present production capacity of 730 tonnes annually to the planned 3000 tonne annual production capacity, certain pieces of equipment have to be acquired. Table 4 lists the minimum additional equipment and their estimated cost required to keep the plant running continuously. This equipment is to be imported. The cost estimate excludes probable duties and taxes to be paid if the endeavour is not exempted. Exemption is usually granted for projects or endeavours in the early developmental stages until they become profitable. The freight costs are not included at this stage, because they depend on the mode and distance of transport and on the weight of each shipment. E.g. airfreight is of the order of $10 to $12 per kilogram ($4.5 - 5.5/lb). Surface freight costs are considerably

TABLE 4

Minimum equipment to be imported to run the carbonization plant continuously
(Equipment service life is estimated to be 10 years)

Equipment	Quantity	Total Price $US x 1000
Belt conveyor	6	48.0
Vibrating screen	1	12.5
Pulverizer	1	17.5
Miscellaneous spare parts		12.0
Hangars	650 m^2	20.0
Reparation of the existing facilities		5.0
	Total:	115.0

lower depending on the container size and weight. However, the delivery time via surface may be up to 6 months and in a case of urgency not feasible. For an accurate actual freight cost estimate a quotation is needed, and to obtain it a relatively accurate description of the consignment is obligatory.

The additional equipment ensures that the kiln can be run continuously to produce at least the planned 3000 tonnes annually, assuming that the kiln proper can be run 300 days per year without any other major problems. However, if a 100% insurance of the kiln

performance is needed, a second kiln would have to be constructed on the site to operate during the downtimes of the first kiln and to supplement its production at other times. Construction of a second unit would also involve acquisition of additional equipment, and increased labour and operating costs, which should be recoverable by the revenues generated by the increase of the production above the planned 3000 tonnes per year for one kiln.

As Table 4 reveals, the investment costs, excluding possible duties and taxes in Niger and the freight costs, would be in the order of $US 115,000 to increase the present pilot plant production capacity of about 730 tonnes per year to the planned capacity of 3000 tonnes per year.

6.2.2 Investment Cost for a Stepped-up Production Capacity

The maximum feasible capacity of the actual plant is 4500 tonnes per year if the operation is run on three eight hour shifts and 300 days per year and if it assumed that the kiln does not experience any other downtime periods. Stepping up to a higher production capacity would involve either the construction of a number of kilns or installing a large capacity high technology kiln, as was previously mentioned in the section on technical review. At this stage, it is still more feasible to stay with a low technology installation requiring minimal outside input, more readily mastered by the local talent and also for financial reasons of which the economics of foreign currency is one of the most important. As

well, a low technology approach is more appropriate for the needs of Niger, and developing countries in general, because it also creates employment and other social benefits. This approach is often goes by the name "appropriate technology".

The stepped-up level could eventually lead up to a 100,000 tonne annual production capacity which would meet most of the need of the entire country. It could be achieved only in a number steps over a number years. The basic design kiln is to a large degree modular, and without very significant economies of scale. The likely investment cost for an annual production capacity of 10,000 tonnes is given below for a multi kiln unit which can be considered more stable and efficient than a single kiln unit.

The equipment and cost estimates at this stage are of the order of magnitude. In order to go beyond this level to produce a more thorough estimate, proper quotations on the equipment prices, delivery times to overseas, duties and taxes in Niger and freight cost would be needed.

The modular nature of the plant is largely restricted to the modular characteristics of the kiln proper. Most of the ancillary equipment, as well as the briquetting section have high capacities

TABLE 5

Additional Equipment and the Cost to Attain a 10,000 Tonne Annual Production Capacity from the Planned 3000 Tonne Level
(Imported equipment)
(Equipment service life is estimated to be 10 years)

Equipment	Quantity	Total price $US x 1000
Bucket elevator	3	25.0
Belt conveyor	8	36.0
Scraper conveyor	1	20.0
Vibrating screen	2	30.0
Small front end loader	2	50.0
Large front end loader	1	65.0
Small screw conveyor	1	15.0
Instrumentation	3 (sets)	12.0
Kiln controls	3 (sets)	5.0
	Total:	238.0

TABLE 6
Additional Equipment and the Cost to Attain a 10,000 Tonne Annual Production Capacity from the Planned 3000 Tonne Level
(Local equipment and other costs)

Description	Quantity	Total cost $US x 1000
Kiln	3	51.0
Miscellaneous items: plumbing, electrical, kiln and equipment supports, cement works, briquette baskets, erection labour costs etc. etc.		120.0
Hangars	1300 m^2	40.0
	Total:	211.0
	Grand Total (Tables 5 and 6)	449.0

and can handle the production capacity of a number of kilns and thus, when properly configured, give some economies of scale.

All the local costs are based on the 1992/93 rates and have to be verified for any higher accuracy, especially considering the effect the devaluation of FCFA has had. The estimates include only the transport costs of the locally manufactured and transported materials such as the kiln and its sections.

Table 5 gives the cost of imported equipment. It amounts to $US 238,000. Table 6 gives the cost of local equipment and some other local costs amounting to $US 211,000, and the grand total of tables 5 and 6 amounting to $US 449,000.

High technology multi-hearth kilns, capable of producing up to 100,000 tonnes of carbonized coal annually, cost several million dollars and could be considered for a large-scale production at a stage where exports of the product to the adjacent countries would be considered.

6.2.3 Coal Quantity and Quality vs. Its Price

Feedstock quality affects the overall economics of the operation in a number ways. In the beginning of the project, Sonichar delivered coal free of charge until total quantity of 4000 tonnes had been reached. The fines returned to the power station were excluded from the total of 4000 tonnes. This arrangements was agreed upon by the

Ministry of Mines and Energy and the Project to ensure that the testing phase of the project could proceed without any additional budget limitations. After the threshold, coinciding with the onset of the sales of the product rather than it being given to the test families free of charge, Sonichar commenced to charge for the coal delivered to the plant. The charge is composed of two elements: the marginal cost of extraction at 2310 FCFA/tonne , and the cost of transport from the mine to the plant at 410 FCFA/tonne. The transport cost is composed of hourly cost of the dump truck and the loader at the mine. Thus the total short run marginal cost of coal delivered at the site was 2720 FCFA/tonne.

In the event the fines are not used, Sonichar is ready to take them back to the power station at the cost of 2720 FCFA less 410 FCFA/tonne for the return transport or for a total credit of 2310 FCFA/tonne.

In the negotiations with Sonichar, it was established that Sonichar at that time (1992) would have been willing to deliver at the short run marginal cost up to 10,000 tonnes of coal per year, since up to that level the small quantity in question would not have any effect on the mine's day to day operation. However, beyond the 10,000 tonne limit the feeling was that the quantities would start to have some effect on the operation, although still negligible initially. More important was, that Sonichar appeared to consider the operation at the level of 10,000 tonnes or higher, to

be such a well established commercial enterprise that delivering coal at the SRMC level would be subsidizing the project and that Sonichar should be able to start benefitting from the operation. Sonichar indicated that the price would have to be higher at this level and reflect the real costs of mining and transporting of the coal to the plant. However, regardless of several attempts to extract a price, Sonichar was not willing to commit itself and only some vague references to 10,000 FCFA/tonne were given. Thus the level of production, and to a large extent the quantity of fines and their treatment, can have significant impact on the cost of coal and consequently on the cost of production.

In the beginning, the fines comprised up to 80% of the total quantity delivered to the plant. As no briquetting was done, all the fines were returned to the power station. However, the high percentage of fines slowed down carbonization to almost a standstill, because the equipment was not sized to handle all the fines delivered. After a proper control at the mine, the level of fines was in the best case reduced to 40%. Based on the calculations of 40% of fines in the feedstock and 35% in the carbonized product, an approximate ratio of briquettes to lumpy coal is about 60/40, if all the raw fines were briquetted and carbonized and also all the carbonized fines briquetted. In this case, if the overall losses were estimated at 5%, the total amount of coal required for the production of 3000 tonnes per year, at a rate of yield of 73%, would be 4300 tonnes at $US 37,400 (1992)

applying SRMC. Small variations in this figure are possible depending on at which state the losses occur. For this calculation the losses are calculated to occur before carbonization. For the production of 10,000 tonnes annually, about 14,400 tonnes of feedstock would be required costing at SRMC $US 140,000 per year (1992). However, the last 4400 tonnes might have a different price tag. It could be e.g. the earlier mentioned 10,000 FCFA/ tonne, and increase the total to about $US 254,000.

If all the raw fines were returned, the total tonnages required to produce 10,000 of carbonized product would be 24,200 tonnes (5% losses, 73% yield) at $US 235,000 at SRMC or $US 604,000, and if the tonnage above 10,000 tonnes were billed at 10,000 FCFA/tonne. If the credit would be calculated at the present basis, it would amount to 10,000 FCFA - 410 FCFA = 9,590 FCFA/tonne. Considering a 5% loss, a total of 9,200 tonnes would be returned for a credit of $US 328,500 leaving the total cost of coal in this case at $US 275,500 or about 8.5% higher than if all the fines were carbonized.

This calculation, albeit based on 1992 exchange rates and partly only surmised coal cost figures, indicates that the quantity of fines in the feedstock could have very significant effect on the total costs depending on their fate. It also indicates that briquettes may have to be considered as a major product component.

Another factor, that will have a bearing on the coal cost, is the selective mining probably required, because the carbonization plant does not accept the high ash content of seam A coal. At a high production capacity, say around 50,000 tonnes per year, the effect of using seam B coal for the carbonization plant would have a profound influence on the mining activity, because the power station also needs seam B coal which is mixed together with seam A coal to obtain a mixture suitable for the power station. Too high or too low an ash content, or large variations in it, cause operating problems. Consequently, a separate effort would be needed to supply the carbonization plant with seam B coal. It would mean that the coal mined for the carbonization plant has to be billed at a rate which covers the extra effort. However, there are indications that, while the mine face moves west, the characteristics of the two seams appear to be changing. There are indications that the quality of seam A may be improving and approaching that of seam B. If this were the case, the specific coal quality prerequisites of the carbonization plant could be satisfied by either of the seams and no extra effort would be needed to mine only one seam for it. This information was obtained in informal discussion with some of the technical personnel, and would have to be verified, as would any other unanswered questions concerning the coal pricing.

The entire mine and the power generation complex was built to supply the Arlit area uranium mines located 180 km north of

Tchirozerine. During the cold war era, uranium mined in this area had a high strategic importance to France and at that time the power requirement was calculated at about 32 megawatts and the coal mine was designed to be able to produce 300,000 tonnes per year for 30 years. Due to the vagaries of the world uranium markets, the mine has operated only at a partial capacity as described earlier. The collapse of communism and the end of the cold war has lowered the price of uranium and thus affected the economic significance of the uranium mines. As a result, the mines in Arlit have experienced considerable redressing pressures and resulted in, as it is said in French, "compressions" of the personnel - a sign of the future fate of the uranium mines? Depending on factors other than economics, the uranium mines may continue operating, and consequently also the coal mine. In case the uranium mines were closed, the Sonichar power station might become uneconomical and face a shutdown or a severe "compression" followed by a reduction in the need for coal.

During the discussions on the supply of coal to the carbonization plant, while no official opinion was expressed, it seemed to be apparent, that Sonichar would consider coal supply and pricing methods, which would help the carbonization plant to become a strong and economically viable enterprise and thus in retroaction help Sonichar survive. Sonichar is one of the shareholders in SOCAREN, perhaps an indication of their interest in the enterprise and in its survival as a mutually beneficial entity. Presently Sonichar is an equal partner with the other investors (200,000 FCFA

each), but with an agreement that it could become a major shareholder and obtain up to 20% of all the shares in the future.

6.2.4 Various Carbonization Cost Aspects

6.2.4.1 Indirect Effect of Fines on the Carbonization Costs

It has been calculated that the production cost for the lumpy coal is about 27.5 FCFA/kg (27.5 - 29.2 FCFA/kg) and for the briquettes of the order of 34.5 FCFA/kg.

These cost may change once the briquetting operation is fully operational. As the previous chapter indicates, they are also sensitive to the fines content of feedstock. Overall, a lower content of fines means a lower production cost. On the other hand, production of briquettes, once the market is well established, could mean larger return on a higher product (briquette) selling price. It depends on the acceptance of briquettes as a more convenient and efficient fuel at a higher price than the lumpy coal. If all, or most of the production were to be briquetted, the production costs could be lowered, since for the briquettes a higher volatile content is acceptable than for the lumpy coal. A lower level of carbonization decreases the residence time of the coal in the kiln thus potentially increases both the yield and production capacity. As well, the process control is simplified because briquettes are not as sensitive to the fluctuations in the volatile content as is lumpy coal.

The abovementioned production cost figures are based on pilot plant capacity indications. It can be safely assumed, that at an industrial plant equipment compliment, there would be a gain in the efficiency and consequently economies in the production costs. This would be true especially when carbonization crews are fully trained ensuring a highly efficient operation.

6.2.4.2 Consumption of Electricity

The plant consumed about 500 kWh/month of electricity during its operation or about 8.5 kWh/tonne. To produce 3000 tonnes per year at a full set of equipment and at a full briquetting capacity, the electrical consumption could rise to 5000 to 6000 kWh/month. At a 10,000 tonne annual production level it could be of the order of 15.000 to 18,000 kWh/month. At the present billing rate, the project has paid 50 FCFA/kWh. At higher production levels, the rate could be adjusted down.

Carbonization releases combustible gases and liquids. Typically, a tonne of coal carbonized at a low temperature (less than 650° C) can release 75 to 95 litres of tars, 10 to 16 litres of light oils, 11 to 13 m^3 of gases and up to 130 litres of pyrolytic liquids. These figures would be somewhat lower for Anou-Araren coal at its high ash and low volatile content. During the process, the small quantities released so far have mostly burned in the chimney and no significant condensations of any liquids or tar were observed.

Considering the consumption of electricity at a high production level, the emitted combustible side products could be considered as a source of fuel to generate electricity for the plant. This is being done e.g. in Finland at a peat coking plant producing 30,000 tonnes of peat coke annually. The combustible side products emitted by the plant are used to fuel a generating plant. By this method, enough electricity is generated to satisfy 95% of the plant's electrical needs. It should be noted in this context, that peat going into the plant has a moisture content of about 35%, an ash content of about 5% and up to a 60% volatile content. The combined ash and moisture content of peat can be compared to the ash content of Anou Araren carbonization plant feedstock. However, the high volatile content of peat gives a larger portion of combustible gases than would coal. Consequently, the combustible side products released by coal at a low level production rate hardly could be considered as a source of energy to alleviate the energy needs of the existing plant. At a very high (say over 50,000 tonnes /year) production rates their quantities may become large enough to consider installing a generating system. This is a question that would require some work to be done before any economic analysis is feasible.

6.2.4.3 Effect of Pollution Control on the Cost

One kiln, even at its rated production level of 3000 tonne per year releases very low levels of pollutants. In the tests the levels were below all the internationally accepted levels and in many

cases undetectable. No tar or pyrolytic water condensation were observed in the kiln. It appears, that most released side products are burned in the chimney resulting in minimal emissions. Considering the low levels of emissions even from a high volatile bituminous coal, their absolute quantities from the low volatile Anou-Araren coal in this plant would be even lower, and for up to 4 kilns too low to justify any comprehensive removal methods. In case of production capacities higher than 10,000 tonnes per year, a system to thoroughly incinerate the emitted matter might be feasible if a zero emission level were required. Such a system would increase the cost of operations. To estimate the increase, a separate study would be needed.

6.3 Transportation Cost Review

Perhaps the most controversial cost item has been the transportation cost. Niger is a large country with a sparse network of roads. The major market is in the southern part of the country. The largest population centres are around the city of Niamey and along the southern border of the country from Niamey to Tahoua and Zinder. The total transportation distance from Tchirozerine to Niamey is 1040 km; the distance a major part of the product might have to been transported, if no other source of raw material is found closer by. Table 7 below gives transportation distances from

the carbonization plant at Tchirozerine to major potential market areas.

The product destinations in the table are: Arlit, Agadez, Tahoua, Birni n'Konni, Zinder, Maradi, Dosso and Niamey and any suitable community en route.

Several scenarios have been proposed to solve the transportation problem. It appears that transportation costs have a major effect on the product price on the market. Sociètè Nationale des Transports Nigériens (SNTN) is the major transporter of materials to and from the uranium mines in Arlit. According to SNTN, about 120,000 tonnes of materials are transported by SNTN to Arlit. Some of the trucks return back via Dosso to Cotonou in Bénin carrying yellow cake, while others are available for backhaul. In addition to the SNTN trucks, there are a number of independent truckers who in most cases return empty to the south. These vehicles are potentially available to haul carbonized coal as a backhaul to the southern market. It is apparent that there would be no shortage of vehicles.

Recent slowdown at the uranium mines has affected trucking industry, and SNTN has been forced to reduce the size of fleet. Its total capacity still should be large enough to satisfy the needs of the carbonization plant, and transporting coal might even be a welcome substitute for the uranium mine business and could change

the pricing policy. The actual size of SNTN fleet should be verified by contacting SNTN in Niamey.

The type of trucks vary. SNTN uses normally 25 tonne tractor trailers. Independent truckers have a whole gamut of trucks from five to 25 tonne sizes.

When contacted (1991), SNTN was interested in the backhaul business. In comparison with the independents, SNTN officially would appear quite expensive. In the African context there always is room for negotiations. Officially SNTN gave the quotation (see Table 8) for backhaul by 25 tonne trucks for small quantities. For a larger quantity continuous shipping, the company was reluctant to give a quotations, which at that time to them may have seem to be speculative, since the production was not at a high enough level and the markets were not yet well developed.

The high cost to Zinder reflects the distance added to the regular backhaul route directly to Niamey. Direct distance to Niamey is 1040 km. Via Zinder the distance is 1425 km or about 400 km longer than directly. Although the haulage distance to Zinder is only 525 km from Tchirozerine the cost is higher than to haul directly to Niamey, in order to compensate for the total distance to travel.

To go to Maradi, the truckers prefer to travel via Birni n'Konni and then return via Birni n'Konni to return to Niamey. This back and forth routine is selected to avoid unpaved roads and increases

TABLE 7
Transportation Distances

From	To	km
Tchirozerine	Tahoua	480
-"-	Birni n'Konni	520
-"-	Dosso	880
-'-	Niamey	1040
-"-	Zinder	525
Tchirozerine	Zinder	525
Tchirozerine - Birni n'Konni	- Maradi	730
Tchirozerine	Agadez	70
-"-	Arlit	180

TABLE 8
SNTN Transportation Cost Quotation (1991-1992)

	FCFA/tonne	FCFA/kg	FCFA/lb
Tchirozerine - Tahoua	5650	5.7	2.8
-"- - Birni n'Konni	6600	6.6	3.0
-"- - Dosso	9000	9.0	4.1
-"- - Niamey	14400	14.4	6.5
-"- - Zinder`	15200	15.2	6.0
-"- - Maradi	16900	16.9	7.0

the total travel distance from Tchirozerine to Niamey to 1400 km, or slightly less than via Zinder. Because the total product haulage distance in this case is 730 km the price is even higher than for Zinder in compensation for the total distance travelled. These calculations are the official SNTN quotations and assumably the trucks do not pick up any other loads at Zinder and Maradi or other locations en route. If the trucks can pick up extra loads, the backhauls, especially to Zinder and Maradi, should not be costlier than to e.g. Birni n'Konni and Dosso respectively.

A regular trucking fee for a 25 tonne SNTN transport to go from Niamey to Tchirozerine and return with a load of coal would be 780,000 FCFA or about 31.2 FCFA/kg.

These are official quotations and may have been used for certain cost calculations in the final project report. For the project, various pieces of equipment and supplies were transported from Niamey to Tchirozerine, and from Tchirozerine to Niamey and to Arlit by independent truckers at varying costs. The first shipment was to carry 15 tonnes of coal to Niamey for shipping to Burundi. It was carried by a 25 tonne tractor trailer. The truck was hired at a full price. The total cost was 200,000 FCFA and if a full 25 tonne load had been transported it would have amounted to 8 FCFA/kg; an indication of lower transport rates. However, only a few trips were done and for any long-term operations the truckers

would have to include allowance for depreciation and maintenance and come up with rates to reflect these higher expenses.

Kiln and 8 tonnes of refractory cement and various pieces of equipment also were shipped from Niamey to Tchirozerine at a total cost of 400,000 FCFA or 16 FCFA/kg (16,000/tonne) at a full rate. This is only about 50% of the cost for a similar transport quoted by SNTN without any guaranteed backhaul to Niamey.

Some carbonized coal was shipped out of Tchirozerine to Agadez and Arlit. For both cases 5 and 10 tonne trucks were used. The smaller loads only to Agadez were priced at 5 FCFA/kg due to the small size of the truck (5 tonnes) and small quantities shipped. The shipment to Arlit was done at about 4 FCFA/kg. At the time of shipping, the area experienced unrest caused by Tuaregs rebelling against the government policies. Because of the safety considerations, truckers were reluctant to travel over any longer distances and were enticed to do so only by increasing the price. In other conditions the cost would have been lower.

From the experience it appears, that by using local independent transport system, the cost of transport should not ,in fact, be an unsurmountably high cost item. Further, discussions with the representatives of "Association du Bois", or the firewood distribution and sales network in Niamey indicated that there would be no resistance to carbonized coal. I fact, new regulations on the

cutting rights of wood had been proposed as well as new taxes to lure people to use substitute fuels. The wood distributors saw in all this signs of a bleaker future for their business, and some among them, as owners of trucks, indicated interest in transporting and distributing carbonized coal even over longer distances. To them, it did not matter what kind of fuel they were dealing with, as long as they could substitute wood with another produce and carry on with their business.

The interest of wood distributors in carbonized coal indicates, that there are different ways to beat high transportation costs and that a judicious utilization of local unofficial networks may allow avoiding costly standard methods.

Another possibility would be for Socaren to acquire a fleet of their own trucks and use it to transport produce to the markets in the south and supplies and whatever other freight might be available back to the north.

There are also a number of smaller communities in the north which are interested in coal, and some of them are located in desert areas where there is no firewood, or wood is too scarce and valuable commodity to be burned. Such are Elméki, 150 km north of Agadez, Timia, 250 km northeast of Agadez, Iferouane, 180 km east of Arlit and Bilma about 700 km east of Agadez; to mention a few.

These communities rely on scarce wood and sometimes petrol, transported over long distances and often at subsidized prices. Transport to some of the locations could be realized by backhaul, because some of them, such as Timia do produce vegetables and dates and bring them to other markets, e.g. to Agadez. The trucks belong to cooperatives and take other goods as backhaul freight in return.

Briquettes are still being manufactured at the plant site from the stockpiled carbonized fines and transported to markets by private trucks. The cost of trucking was not available at the time of writing.

6.4 Marketing Review

6.4.1 Product Promotion

The product promotion for the present project was done in Agadez by CTFED which was contracted by Cartier to do an in-depth product promotion/user training/acceptance testing. For the promotion a total of 100 families were selected. The very professionally conducted testing established acceptance of the new fuel. The promotion put a lot effort into training people in the use of the new fuel. The aspects of lighting and slow start up of the fire initially presented problems. However, once the trainers (animatrices) had taught the housewives to change their procedure of cooking adopted for the characteristics of firewood which

catches fire very quickly, no more serious user problems existed. Normally, when using firewood, the housewife finishes all the necessary preliminary food preparation before lighting the fire. Once everything is ready, she lights the fire and start cooking. When using carbonized coal, she starts the fire first and leaves it alone while finishing the preparations. By the time everything is ready, the fire is hot enough and cooking can commence. So in reality no time is wasted, only the order of tasks is changed.

Once CTFED had established the user acceptance and that the fuel in reality was superior to firewood, promotional activities were continued by project personnel in Agadez, Arlit, Tahoua and Niamey. Normally, the presidents of town sections (quartier) and various women's associations were contacted to arrange a meeting of groups of women, to whom the fuel and its user characteristics were demonstrated. The women, who thus had been exposed to the fuel, in their turn promoted it in their respective "administrative" areas. As a result, a keen interest was created and in Niamey, when enough coal was not available for everyone, a comment was made that "you are creating a need but you do not have the product". This comment, of course, can be taken either positively or negatively and a hen-and-egg question can be asked: should we have a lot of produce before there is no market potential? -or, should we create a market before producing?

Promotion was continued also in the schools and other institution, at fairs such as "La Fête de l'Arbre" which is arranged annually to promote substitute fuels and the conservation of trees and forests, as well as on radio and television. In Agadez also a roving crier was hired to promote the produce and to advertise demonstration occasions of its use. As well, promotional demonstrations were performed for the representatives of private sector and the government.

6.4.2 Product Pricing

Perhaps the trickiest marketing question was, and still may be, what price carbonized coal? Initially, it was thought that the price of carbonized coal should not be higher than that of firewood, because it was believed that the user would resists buying it at a higher price. Wood prices varied at the time of project, depending on the season and the location, from a low of 17 to a high of 35 FCFA/kg, when bought at various market places. Although it is scarce in the north, there sometimes appear to be no shortage of wood. Niger is a vast country and large areas are very sparsely populated and, although quite elaborate and strict wood cutting policies are in place, it is virtually impossible to control the cutting. As a result, markets are sometimes even flooded with firewood, which then is sold at artificially deflated prices. At the end of 1992, new measures were taken to try and reduce illegal cutting and the use of wood in general. These

measure should create an economically more favourable climate for substitute fuels, such as carbonized coal.

The production cost of carbonized coal at the SMRC pricing of coal was calculated at about 27.5 to 29 FCFA/kg. Originally the price of coal at the plant gate was set at about 28 FCFA/kg. Later, the selling price to the wholesalers at the plant was set at 1300 FCFA/sack of about 45 kg of coal or equivalent to 29 FCFA/kg (28,9). The retailers were selling coal in Agadez and in Tchirozerine at 35.5 FCFA/kg in large sacks (45 kg) and at 40 FCFA/kg in small quantities (in loose piles of 2.5 kg). The respective prices in Arlit were 44.5 and 52 FCFA/kg. Based on the efficiency value, measured in actual carefully monitored cooking tests, the price of coal could be up to 2.7 times higher than that of firewood. Thus a price of 52 FCFA/kg would correspond to about 19 FCFA/kg for wood, or still lower than wood (commonly around 25 FCFA) in any larger population centre at the time of testing.

Once the users had understood the high efficiency and the convenience of using coal, there appeared no price concerns when the matter was discussed in private with individuals. In Niamey, testing and discussion with housewives revealed that they would have no hesitation to pay over 50 FCFA/kg. Some even suggested 75 FCFA/kg. There were several reasons, one of the first was the economy of coal. Others were its convenience and even safety - no large flame or sparks are visible and it is impossible for children

to grab a burning piece of coal and start a fire in the house; too frequent an occurrence with firewood.

The advent of wood becoming scarcer and more expensive, and some other substitute fuels proving to be too expensive, makes the carbonized coal ever a more attractive fuel. Even at a quoted high official 14.4 FCFA/kg transportation cost, the price in Niamey at an apparently acceptable level of over 50 FCFA/kg makes this fuel economical. Enter into the picture unofficial transportation system and see the transportation costs plunge and the level of economics of using carbonized coal rise.

A recent (Sept. 94) communication from Tchirozerine indicates that a sac of briquettes (45 kg) in Niamey sells for 3000 FCFA (67.7 FCFA/kg). The same communication informs that the devaluation of FCFA increased the labour cost at Tchirozerine 12% and the cost of firewood doubled. This indicates that the carbonized coal is becoming a more attractive fuel in comparison with firewood. The high selling price in Niamey should offset the increased labour cost and improve the transportation situation, although it remains to be seen what is the effect of the increase in the fuel cost on transportation costs.

6.4.3 Stove Pricing

Usually cooking in Niger is done on traditional stoves. These stoves are manufactured locally from recycled low cost materials. and cost about 750 FCFA. The introduction of carbonized coal to the market raised the question of its suitability for traditional stoves. They were found to be inadequate. As a consequent a stove was developed for coal. The question of price was raised. The argument was, that the user would resists the need of purchasing a new stove for the new fuel. When the new stoves, after they had been tested and found efficient, were introduced to the market initially at 1500 FCFA, and after the potential users had used them with the efficient carbonized coal, there was no serious problem with price. Since then, a number of blacksmiths have been trained in the construction of the stoves and some of them have started to run stove manufacturing at their own and setting their own prices. In Agadez the price for the basic Sonichar stove model was at the end of 1992 about 1300 FCFA. The blacksmiths manufacturing them set the price depending on the availability and price of raw material which commonly is used oil drums, and on the market demand. Recently, the stove prices have varied from 1200 to 1500 FCFA

Certain larger models in Niamey have been sold at 2500 FCFA. An industrial manufacturer, who also produced TCHIP stoves, in Niamey estimated, that if the volume is large enough, say 1000 unit per year, he might be able to lower the price of industrially manufactured units to about 1200 FCFA. A pottery maker, after

having made one of the local clay, estimated a price of no more than 1000 FCFA/unit, or even lower.

Some of the stoves have been in use for more than a year without any appreciable wear and tear and thus proven to be economical regardless of their initially higher price. All in all, stove prices have not diluted the interest in carbonized coal as a substitute fuel.

For the more affluent clientele, such as the personnel of Sonichar and the uranium mines in Arlit, a small co-operative called ABBAZE manufactures stoves in Tchirozerine at prices from 6000 FCFA up.

By the end of 1993 about 2450 stoves had been sold according the records and about 300 had been distributed free of charge in the course of the demonstration project. Some families bought two stoves and some others, despite the inefficacy continued to use other stoves also with coal. Thus the number of stoves sold does not necessarily give the number of customers. To this number we have to add also those who have bought ABBZE stoves, Their sales, according to ABBAZE information, may have reached 400 to 500. In addition, blacksmiths have sold stoves independently without keeping any records. Taking into consideration all these known and unrecorded sales it is probable that total number of families using carbonized coal at the end of 1993 may have risen to about 3500 families.

A Niger market evaluation (unnamed source) has investigated the institutional market by using an ABBAZE (ABZ) stove type Gaya. A total of 30 of these stoves would be sold at a cost of 53,000 FCFA each plus the cost of special pot for the stove at 25,000 FCFA each in 16 centres across the country. According to the same study, the institutions taking part in the program would realize about 55% savings in their energy cost by using coal at the abovementioned price ranges.

6.4.4 Private Sector Participation

Private sector was a participant in the project right from the start by investing into SOCAREN, However, the participation continued rather as that of a passive onlooker than an active partner. It appears that the investors, before committing more neither of their time nor their finances, preferred to await the project's fate - success or failure. At the present state the project has been proven to be feasible, and would be a total success with some more vigorous participation from the private sector. The project has all the moral and even some financial support of the Niger government. It should be enough to encourage the private sector to put some real effort into the production, since the potential to produce at least 3000 tonnes per year has been proven. There are various ways the private sector can efficiently participate in the continuation of the endeavour. One is, to arrange the transport of the produce to the south. Several private sector participants have good ties with transportation

"brotherhood" in Niger, and one appears to be actively in the transportation business. By utilizing this capacity, the private sector participants could ensure distribution of the product onto markets in the south at a reasonable price. This in turn increases the size of the market and in the final analysis the investors' profits, both through an increase in their direct share of the project and indirectly through their transportation interests.

Other ways of participation would be promotion of the product and its sales and distribution through the investors' own outlets and existing facilities.

7.0 NIGER COAL RESOURCE POTENTIAL

7.1 *Introduction*

The hope of finding coal in Niger was born in 1909 after the discovery of large coal deposit in Enugu in Nigeria in the Niger River valley. The extension of the same geological conditions from Nigeria to Niger gave good grounds to believe that there would be coal also on the Niger side of the river. A number of geological studies and their findings reinforced this belief as indications of the presence of coal were found in a number of locations in Niger. These indications as well as the interest in other mineral resources have led into a number of exploration project which

either indirectly or directly have confirmed that there are considerable coal deposits in Niger both in the north and in the south.

7.2 Coal Resource Potential in the North

The existing coal mine uses a well explored deposit at Tchirozerine (Anou-Araren, carrière Sonichar). This deposit contains about 13 megatonnes of coal and could, as has been said earlier, supply the mine at its full annual capacity of 300,000 tonnes for 30 years. It is also known, that the Anou-Araren deposit extends north of the existing mine and that the coal in this extended section is of about same quality and at about same or slightly greater depth from the surface (50 m+). In 1988, Cartier-Monenco carried out a preliminary verification of the presence of coal in Solomi-Sekiret are about 40 km north of Tchirozerine and verified the indications given by earlier exploration done by Japanese for uranium in the area. Analyses of the coal indicated that it was of about the same quality as that found at Tchirozerine, but at a greater depth being overlain by an overburden up to 70 metres thick.

The Japanese exploration company, Power Nuclear Company (PNC) had already in 1982 and later on in connection with their uranium exploration found coal in the general area of Solomi-Sekiret at the depths up to 400 meters. PNC carried out uranium exploration at a

drilling network of 5 km and in a number of locations hit coal seams up to 7 meters in thickness. Since coal was not one of the company's exploration object little information is available on the quality of the coal. Results of analyses of one of their samples whose, exact location is unsure, indicated that coal in the depth appears to be of very good quality with and ash content of 13.8%, volatile matter content 36.2%, total carbon 50%, calorific value 7295 kcal/kg and sulphur 0.9%. However, more information would be needed for a proper quality analyses. A very rough calculations estimates that this deposit could contain up to 2250 megatonnes of coal. However, it would be accessible only by underground mining, a method hardly economical at this location at this time. Depending on the economic climate and if other industries needing large quantities of energy were established in the area this deposit could become minable, and in this case a good source of coal also for carbonization.

7.3 Coal Resource Potential in the South

Geological and other studies on the possibility of finding coal in Niger, prompted by the earlier mentioned discovery of coal in Nigeria, led into a discovery of indication of coal deposits already in 1948 between Tahoua and Filingué, in southern Niger.

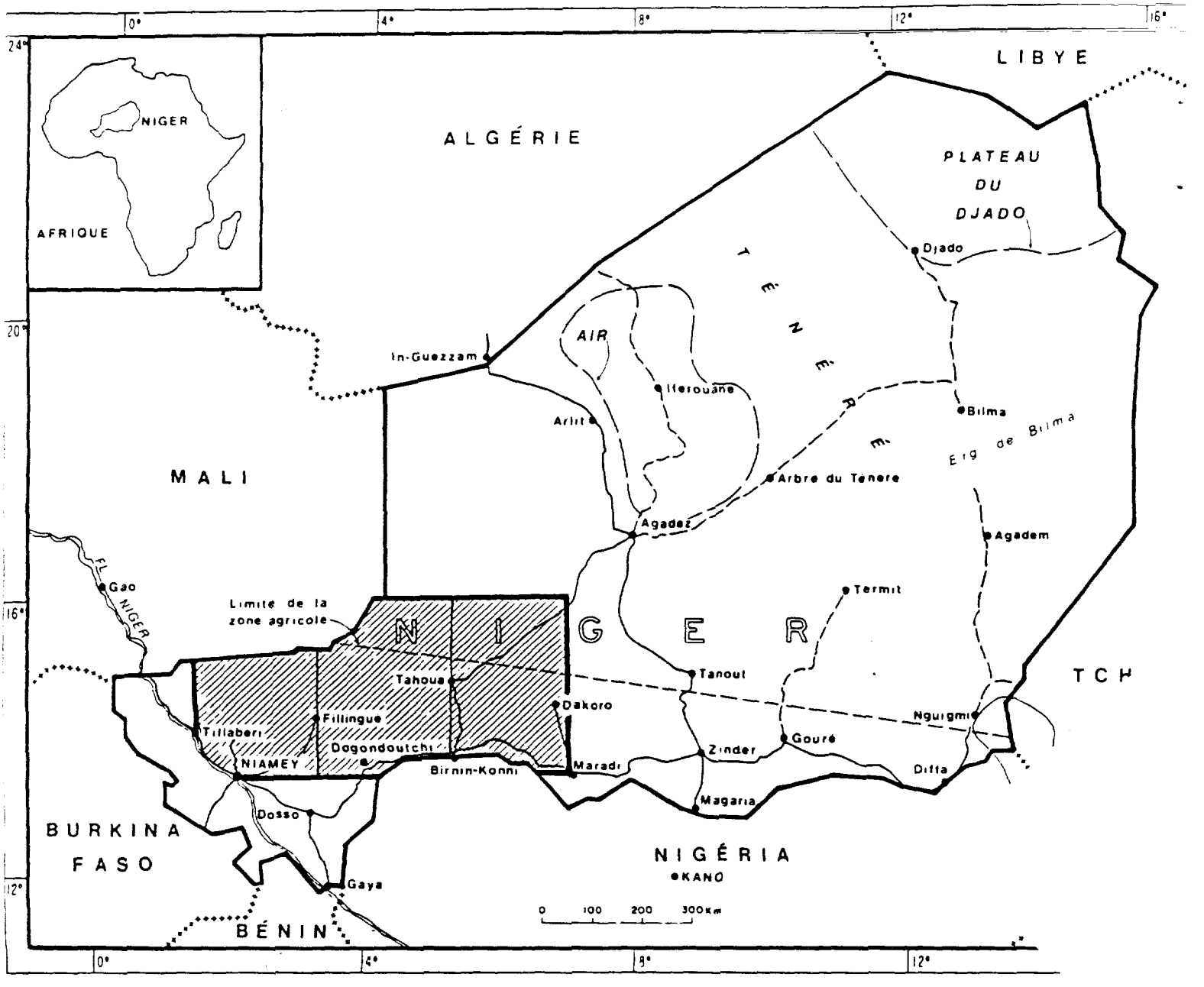

Figure 1. Southern Niger Coal Exploration Zone. (Source: Projet développement énergétique: Mise en valeur du charbon, Phase I. Projet ACDI - 700/14465. Coopération Niger-Canada, Juillet 1989)

Since then, worldwide energy problems have created a rebirth of interest in coal in southern Niger and since early 1980's a number of investigations have revealed further possible coal deposits in the south and have led into more recent and more thorough studies in the area outlined in Figure 1. Surface area of the region shown in the figure covers over 225,000 km^2.

The investigations were funded by CIDA and were based both on purely geological investigations and also on the data obtained from deep wells drilled or dug for access to drinking and irrigation water, on site visual inspection of the well walls and also by a number of actual drilling and sampling of strata to determine the extent and quality of coal in the region.

The initial investigations of the sector from Tillabéri to Filingué gave very little indications of coal regardless of a large number of wells and hydrological drilling present in the area.

Similar investigations of the data between Filingué and Tahoua gave very interesting results and those between Tahoua and Dakoro moderately interesting results. Based on the findings, CIDA funded a project entitled "Projet développement énergétique: Mise en valeur du charbon, Phase I" on the area covered by Figure 1, but concentrating in the Zone Tahoua-Filingué, where strong indications of existence of economically significant coal deposits had been found.

A total of 201 wells were investigated and logged during the first stages of the project. Later a total of 19 drillings by ONAREM were carried out for the project in the region of Takanamat and a in addition to the drillings a well was dug in the region. The drilling sites are spread from Salkadamma about 58 km NW of Tahoua where 14 holes were drilled at a spacing of about 1 km to Sarou (two holes; 14 km S of Salkadamma), Sabon Yayi (one hole, half way between Sarou and Salkadamma), In Takana (one hole; 52 km W of Salkadamma) and In Abagargar (one hole; 20 km W of Salkadamma). A well was dug in In Merizen, located about 140 km NE of Filingué.

The field work carried out in 1997-89 revealed an existence of two to three coal seams under an overburden which varied from 25 to 50 metres. The coal seams varied from about 0.5 m up to 3.8 metres in places. There appeared to be a general tendency for the seams and the overburden to get thicker in a northerly direction.

A total of 112 samples of coal were analyzed in laboratory both in Niger and in Canada. Analyses for In Merizen area indicated that the quality in different seams varied. The best quality at the depth of about 30.5 metres gave ash content on dry weight basis of 28.4%, volatile content 40.5%, sulphur 2.75% and colorific value at about 4400 kcal/kg.

The analyses carried out on other samples gave in some location excellent values; ash content being as low as 6.5%, volatile matter

as high as 60%, fixed carbon 30%, total carbon 62%, calorific value up to 10,000 kcal/kg and sulphur as low as 0.24%.

The positive results of the work carried out gave CIDA an impetus to initiate a more detailed coal exploration project in the region of Tahoua Filingué. The aim of this project was to carry out a drilling program to define the coal reserves in the region in a greater detail and to determine their economical potential as a source of energy. This project also included inspection of wells. Some were studied e.g. in Ouallam about 100 km north of Niamey, where indications of coal were found.

The drilling gave more positive results in the Takanamat-Salkadamma-Filingué area. At that time plans were made to extract about 100 tonnes of this coal from suitable location by manual excavation to be sent to Tchirozerine for carbonization tests. Also the possibility of establishing a small low technology mine to supply a locally constructed carbonization plant was discussed pending the establishment of large enough reserves for a future full-size coal mine to supply a power station in the south.

Unfortunately, the ongoing Tuareg rebel put a sudden end to all these plans. Rebels attacked the main exploration party in the field and forcefully captured most of the vehicles and some other supplies. As the security of further exploration could not be ensured, CIDA decided to discontinue the project temporarily. All

the remaining equipment was stored in Niamey in containers for a period of two years to await amelioration of the situation. However, although a formal truce between the Tuaregs in the neighbouring Mali was established, the border region remained troubled.

Earlier in 1994, the remaining equipment was released to the use of the government and the contract, it appears, formally discontinued. At the time of writing this report, the contracted parties sued CIDA for the loss of the contract. Due to the litigation process access to the information was made subject to approval by the legal branch of CIDA and was not made available immediately. For this reason a number of question remains unanswered until the reception of the information.

It is apparent, that in very high likelihood there is a deposit of good quality coal in the general direction of Filingué awaiting only exploration to determine its size and exact location. The situation in Niger appears to be calm and perhaps an exploration project in this area would be feasible at this time. It could be carried out by the Niger personnel using the existing material, an experienced drilling company and supported by a suitable financial arrangement.

8.0 MISCELLANEOUS CONSIDERATIONS

8.1 Training and Motivation

The carbonization plant workforce was originally made up of unskilled individuals hired on site. Although it would have been possible to get some skilled labour for the project, due to high salary ranges of the organized labour, used in the areas of Niger were there are technical institutions such as mines and the power station, the budget limitations did limit hiring to unskilled labour. Most of the workers had never worked on a job requiring punctuality and steady work from day to day. Nevertheless, most of the original crew remained on the job and presently there are enough well trained individuals to fill more than two shifts and capable of running the plant without being constantly supervised. A Niger engineering geologist has been trained as the future potential technical director. The quality control has been assumed by a professional chemist working full time for Sonichar and taking care of all the required analyses for the carbonization project on a part-time basis. One individual, with the equivalent of high school education, has been trained as a general foreman and the chief carbonizer, three other individuals have been trained as carbonizers (process controllers), two others as briquetting technicians and one individual, with an extensive experience as a mechanic for a number of project, (among others chief heavy equipment mechanic for the Japanese exploration project) has been

trained as the chief general mechanic. In addition to these positions, a number of labourers have been trained in all the labour aspect of the plant and also in the process control to ensure smooth operation of the process.

The crews are well motivated, and they were taught to understand that the project was theirs and for their community, not one of the numerous projects that so often come and go and are regarded as "foreigners' follies". As a result the teams work well together and believe in the future of the product and the endeavour. Most of the workers are local Tuaregs.

For the marketing, a number of persons were trained also. The principal marketing individual is a Niger engineering geologist, who originally was attached to the technical team but later became the principal promoter of the produce. Others include shopkeepers in Agadez, Arlit and Tahoua, where small shops distributing and selling both stoves and the product were established.

8.2. Security and Political Conditions

The long simmering discontent Tuaregs feel in Niger, as well as in other Sahelian areas, about their living conditions and status, has led to on-and-off skirmishes with the authorities. In Niger, Tuaregs claim an area which covers almost 60% of the country while

they consist of only about 15% of the population. Niger, as so many other African countries, had its borders drawn by the former colonial powers without any regard to traditional African social entities. It resulted in artificial countries where the frontiers run through ethnical and linguistic and other culturally more natural boundaries. This situation has, as can be expected, caused numerous conflicts. Tuaregs, always were, and still to a large degree are, nomads who do not respect any boundaries in the desert regions were they have always wandered. The new administrative borders and restrictions never sat well with their free roaming nature, and has led into many a confrontation. The recent events in Niger have disrupted a number of internationally funded projects, and created a situation of insecurity and withdrawal of foreign experts. The coal carbonization project never was a target for the rebels and has continued to operate, albeit under a certain uncertainty. The reason for this may be the commitment of the local workers to the project and understanding what it is all about, and whom it would profit in the future.

The question has often been raised: Will this "Tuareg rebellion" lead into a something more serious. The answer is not clear. The writer's own feeling is, that it may continue as an on-and-off problem for some time, but as the Tuaregs become gradually more sedentary and if the economic situation of the country can be improved, the uprisings, which already now do not have the support of a large proportion of the village elders, will die down.

Because of the size of the country and the open nature of the desert area, it would be difficult to carry on a civil war in the north. Furthermore, for a successful uprising in the north would require, not only the support of the entire population there, but also outside interference, well trained insurgents and modern weaponry. All this requires finances, which do not exist even for the regular army, let alone tribal warriors. Briefly, with proper dialogue and economic development, the problems should be solved, and the north with its mineral and tourism potential developed.

9.0 ENVIRONMENTAL IMPACT REVIEW

The direct environmental impact of the projet could be felt at the site of production and at the site of consumption of the produce.

The indirect impact is at the site of coal mining and in the region in general through the effect the anticipated reduction of the use of firewood would have.

The direct impact is caused by the emission of side products from the carbonization plant. These are mainly gases. During the process, numerous gas analyses with Gastec tube technology were carried out both by analyzing the gases emitted by inserting analytical tube directly into the chimney and at some distance downwind from it.

The concentrations of acetone, acetic acid, ammonium, carbon dioxide and monoxide, hydrogen sulphide, nitrogen oxides (NO_x), phenol and sulphur dioxide were measured. Their values were found to be below limits of tolerance both for long- and short-term exposure set by American Conference of Government Industrial Hygienists (1988).

The same compounds were below the testing method's detection limits at a 100 metre distance downwind from the kiln.

The same compounds were measured at the user sites, i.e. in the kitchen were the produce was used. The result were similar in the normal kitchen conditions to those found at the plant site. The levels were below the accepted maxima and sometimes not detectable. In order to see if the compounds were even present in the gases, measurements were made by burning coal in a closed barrel and measuring the concentrated gases escaping from a small hole at the top of the barrel. In this case, higher concentrations were measured. However, to be exposed to these levels, the consumer would nigh well have to cover the stove with a hood to collect the fumes and remain under it for exposure - paramount to a deliberate suicide.

Analyses of ashes showed no high concentrations of any heavy metals allowing the ashes to be discarded even in a garden in the hopes of them adding some nutrient to the plants.

The indirect effect through the mining operation is not really part of the impact caused by the carbonization project and has been left in the realm of the mining operation

In order to give some thought to the overall environmental balance the use of carbonized coal and ensuing reduction of the use of firewood might have, the following scenario is presented as an argument for the coal:

(I) Case of firewood:

1. Trees assimilate CO_2 from the air thus keeping CO_2 balance normal. Cutting down trees for firewood directly increases the quantity of CO_2 in the atmosphere through reduced assimilation. The use of coal does not require cutting trees thus helping keep CO_2 levels down.

2. The parts of trees not used will remain on the ground and will be eventually broken down by natural biological organism which again produce CO_2. This is the second source of CO_2 increasing the greenhouse effect when using firewood.

3. Burning of wood produces CO_2, as does burning of coal. For the same amount of cooking, about 2.7 times more wood is needed than coal. Coal is burned in a well designed stove minimizing heat loss thus increasing the efficiency of the fire. Compared with the very ineffective way of cooking on three stones with firewood, it is

further obvious, that there is a lot of wasted energy lost into the surroundings. Another point to the account of wood in increasing the level of CO_2 in the atmosphere.

4. Cutting down trees for firewood has a number of other far-reaching environmental consequences:

-desertification,

-climatological impact,

-soil degradation,

-natural habitat destruction: fauna and flora,

-increased erosion,

-hydrological impact,

All these affect either directly or indirectly also the quality of human life through destruction and diminution of agricultural capacity of the land; a serious consequence in the arid regions where the conditions are precarious.

(II) Case of coal:

A. m Use of coal makes cutting trees unnecessary.

B. No biologically degradable waste material produced which could add CO_2 in the atmosphere.

C. Coal is used in an efficient manner in efficient stove reducing emissions.

D. Carbonization process produces CO_2 and other gases but they can be controlled and in a larger installation even used to produce much needed energy. It is possible to construct a zero emission plant if so required and if the economic balance is positive.

E. The use of coal causes no large-scale ecological impacts.

F. Finally, coal is an indigenous source of energy and its use would create employment and save the much needed foreign currency.

The environmental balance of the above listed points is:
coal: A+B+C+D+E+F less wood: 1+2+3+4 = positive balance for coal.

From this it appears that the use of coal not only increases the size of "CO_2 sink", but also improves the overall living conditions.

10.0 FUTURE OF CARBONIZATION IN NIGER

The project on the feasibility of producing carbonized coal and briquettes in Niger to substitute for firewood as a domestic and institutional fuel has proven to be feasible technically and economically. Furthermore, this substitution is environmentally friendly. Neither the production facility nor the fuel in use emit any appreciable concentrations of pollutant. Use of coal as a fuel

will save forest and trees in Niger, where the effect of advancing desert is felt very strongly. One of the reasons for the desertification is the overuse of forest resources. Use of coal decreases emissions of CO_2 into the atmosphere by saving forests which act as CO_2 sink, and thus reduces the greenhouse effect. A number of other indirect environmental effect swing the environmental balance to the side of coal as a beneficial substitute for wood as a source of energy.

Presently, the project is in a semi-commercial sate. Technically it is proven to be operational, but would require additional equipment to reach its full-fledged capacity from the pilot plant state. The market and clientele have been developed and won for the side of carbonized coal.

In order to upgrade and verify both technical and economic information concerning the viability of the endeavour, some additional investigations are required. They include some questions which were raise during the project, but to which no answers were obtained due to reluctance by the other parties.

The information needed concerns mainly economic aspects, such as investment costs and prices etc. in Niger.

To establish accurately the investment needs for upgrading the plant production from its pilot stage to an industrial operation

and to arrange all the logistics with Sonichar to assure a continued operation at the existing site, the following information is needed and to be collected in Niger:

1. On site assessment of the technical status of the plant to determine exactly materials end equipment needed to upgrade its production capacity.

2. On site discussions with Sonichar and the Ministry of Mines and Energy to determine the logistics of feedstock acquisition: future coal quality, quantities of coal available, delivery to the site, availability in case the mining is either reduced or increased, cost of coal and its dependence on the quantity and quality required, availability of coal in case the uranium mines in Arlit were closed etc.

3. Service arrangements with Sonichar: technical services, supply of electricity and water, laboratory services for quality control, use of existing buildings for the plant needs (offices etc,), continued expansion potential and space for stockpile at the existing site, site costs (rent?), site security, use of Sonichar banking facilities etc.

4. Any other technical arrangement,such as venting and incinerations of the emitted gases through Sonichar power station stacks.

Other information to be verified in Niger include:

1. Pricing of materials needed for plant structures and expansion (sheet metal, tools, cement etc.). These prices also are needed for investment calculations for expansion.

2. Transportation cost assessment: Transportation costs, modes of transportation, truck fleet sizes, truck capacities, pricing basis (backhaul, long-term contracts etc.). For the cost, quotation should be obtained.

3. Labour rates, product pricing, stove manufacturing and pricing, institutional interests, present markets and potential for expansion, established sales points, arrangements with SOCAREN investors to get them active on the marketing and further investment.

4. Position of the Niger government towards the enterprise. Government regulations, taxation duties, exemptions on imported as well as local materials.

5. Product promotion and its financing.

6. Status of coal exploration in the southern regions of Niger, and the long-term plans.

7. Environmental aspects.

8. "Association du Bois" and its position in regard to carbonized coal (lobbying for wood?)

9. Assessment of future markets: size and types.

10. Export potential to the adjacent countries with similar environmental (desertification) problems and the same lack of domestic fuel sources as in Niger.

The information to be collected in North America includes:

1. Freight quotations for equipment with a local expeditor.

2. Contact North American equipment suppliers and manufacturers to get equipment specifications, price quotations and availability data as well as delivery information.

3. Assess the availability, cost, technical capacity and operating cost of a large-scale (100,000 tpy) multi-hearth carbonization plant and the feasibility of its (their) transfer to Africa.

All this information is needed to assess accurately the investment needs, both for immediate upgrading of the plant and for the

future. Once all the information is on hand, a long-term future assessment can be accurately performed, and the long-term ecological and economical impact of using carbonized coal to replace firewood as source of energy can determined.